TECHNISCHE UNIVERSITÄT DRESDEN

Research Report 2021

Institut für Leichtbau und Kunststofftechnik

List of Abbreviations

TUD	Technische Universität Dresden
ILK	Institute of Lightweight Engineering and Polymer Technology at the TU Dresden

Online version
research report 2021
(Flipbook)

https://tud.link/dvqf

Content

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Introduction

It is amazing, how quickly people adapt to a new reality and feel at home in it. The second year of the pandemic has already brought a kind of routine to hitherto unfamiliar processes in both research and teaching. Quickly finding the new ordinary in the unusual is the essence of a robust, resilient structure these days and has also been a major feature of 2021.

We are particularly impressed by the fact that the research and development work in our more than 100 ongoing projects has remained almost unaffected by these special circumstances. Of course, priorities had to be redefined, but overall, 2021 can again clearly be recorded as a year of success for our institute. The acquisition of several basic-research-oriented DFG projects as well as application-oriented projects within the framework of numerous EU, BMBF, AiF and SAB research programs testifies to the undiminished performance of the entire ILK team. This has also been reflected in the continuous growth of our team by 18 new employees. Despite the additional challenges, we were also able to achieve the goals we had set ourselves with regard to doctorates as well as diploma and master's theses. Digital teaching was systematized and the new format of hybrid courses for students of lightweight engineering was successfully implemented. Finally, the internationalization activities of our institute were only slightly restricted, but continued in the new, partly digital formats with the usual intensity. We were even able to maintain our educational offerings aimed at children and young people.

In addition to all this, we were particularly touched by the groundbreaking ceremony for the realization of the National Lightweight Engineering Validation Centre (Nationales Leichtbau-Validierungszentrum LEIV), the construction of which is progressing according to plan despite the adversities so far and will culminate in the ceremonial opening in mid-2022. Another milestone and, to a certain extent, a living image of the pandemic era was set with the International Dresden Lightweight Engineering Symposium, which was fully digital for the first time. More than 1,000 participants and 82 lectures as well as a truly excellent virtual trade show environment contributed to an all-around successful symposium.

Overall, the symposium theme "RESOURCE NEUTRAL LIGHTWEIGHT DESIGN – adding value by saving resources", a guiding theme of ILK research as a whole, struck a chord. Innovative, holistic approaches that reconcile growth and progress on the one hand with environmental protection and resource conservation on the other offer answers to the pressing questions of our time. The socio-eco-technological essence of neutral lightweight design can also be found in numerous places in the coalition agreement of the new German government. In this respect, we expect a further boost for our research in the coming months and years and are pleased that the strategic realignment of our work is already bearing its first fruits so quickly.

We wish you a successful and healthy 2022 and hope that our 2021 Research Report inspires you and provides new ideas for your work.

Prof. Dr.-Ing. habil. Maik Gude

Prof. Dr. rer. nat. Hubert Jäger

Prof. Dr.-Ing. Niels Modler

Neutral lightweight engineering – An idea with impact

Lightweight engineering has long been an important driving force for a resource-saving and at the same time competitive economy. As early as 2010, the Dresden Lightweight Engineering Symposium was entitled: “Sustainability as an innovation driver in efficient lightweight system design”. The vision formulated at the time strikingly anticipates today's omnipresent demand for a balance between technology, economy and ecology. However, the application of lightweight design principles to overcome resource scarcity is not a new approach. Rather, its necessity becomes evident whenever the supply of raw materials is unstable or resources become scarce. Already in 1988, a publication from our institute postulated the necessity of an “economical use of resources and materials and the rational use of energy”, the “reuse” and “regeneration of the product or component” and explicitly emphasised the special “responsibility of the designer” (Knauer, 1988). In the following decade, Prof. Hufenbach's Dresden model “Functionally Integrative System Lightweight Engineering in Multi-Material Design” became a globally respected benchmark in lightweight design. An essential component of this design approach, formulated in 1995, is – in addition to classical technical and economic criteria such as safety, production, costs and quality – also the consideration of the environmental impact of technical structures. Resource conservation is thus a constituent element of Dresden's lightweight engineering and is firmly anchored both conceptually and methodologically.

While the three established design approaches in lightweight engineering (economy, efficiency and functional lightweight design) mainly address technical and economic product requirements, new holistic solutions are needed today to bring growth, environmental protection and resource preservation into balance. This is because environmentally relevant aspects are only indirectly taken into account in these classic three approaches, for example when cost savings offer ecological advantages en passant. In particular, thinking in terms of product cycles and the targeted cross-life-cycle design of the environmental impacts of lightweight structures and systems are not anchored there.

In order to actually achieve the goals of the international climate agreements and the European Green New Deal, it is crucial to move environmentally relevant aspects equally and consistently into the focus of research and development processes. What is required, therefore, is

a new (fourth) design approach for technical structures with the aim of avoiding harm to the environment or the remaining global resource potential. We call this goal “neutral lightweight design”. Although this approach is, by today's standards, an ideal that can only be partially realised with the technologies of our time, it must determine our thinking and actions in order to achieve a resource-neutral circular economy in the future.

The basic principle of neutral design is the consideration of sustainability criteria in all decision-making stages along the development chain of a product. In doing so, the entire life cycle of the product system from material procurement to end-of-life parts management must be anticipated for the respective production, use and recycling region. Neutral lightweight design thus goes further than pure life cycle assessment or the “cradle to cradle” principle. From today's point of view, this objective gives rise to four highlighted fields of action in research and development.

Firstly, a development process must be implemented that anticipates the entire life cycle of a product and already takes environmental impacts into account during product development. The responsibility of the developer no longer ends at the transition of the product into the use phase, but extends far beyond that. A specific product design must be worked out that enables a long product life and a recovery of the product-bound resources at the end of the life and at the same time fulfils the economic boundary conditions in all life phases. To realise this complex task, the 10 R strategies must be systematically taken into account.

Secondly, only recycled or fully recyclable as well as renewable bio-based materials may be used in the future. The use of materials that are not or only with difficulty recyclable, such as composite materials or their hybrids, must in future be appropriately well justified and also economically correctly taken into account in the overall life cycle balance.

The third field of action encompasses the technologies for manufacturing, repairing, reprocessing and dismantling lightweight products up to the disintegration of high-tech materials with low resource consumption and minimal environmental impact. Here, for example, it is necessary to find new methods of production based on regenerative sources or to develop approaches for the reuse of entire assemblies.

Finally, a lightweight engineering-specific assessment metric must be developed that predicts the effects of design, material and technology as well as their interactions along the entire life cycle of a product. The classic Life Cycle Assessment offers good starting points here in combination with other assessment methods. In this context, the availability and comparability of corresponding data are a decisive prerequisite for the success of neutral light engineering. National and ultimately international harmonisation of methods, technologies, materials and data must therefore accompany this process. Only through cooperation and communication can the complex challenges of a global circular economy be overcome.

Bicycle rack made from bio-based raw materials

The 24th International Dresden Lightweight Engineering Symposium: A mega success despite the pandemic!

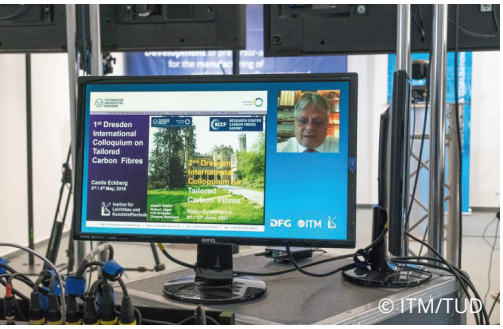
ILK board member Prof. Dr.-Ing. habil. Maik Gude in the lightweight engineering lounge.

On the 17/18 June 2021 one of the largest conferences of the year took place in Dresden under the motto “RESOURCE NEUTRAL LIGHTWEIGHT DESIGN – ADDING VALUE BY SAVING RESOURCES”. After the symposium, Prof. Maik Gude comments: “Unfortunately, due to the pandemic we were able to welcome our more than 1,000 participants only digitally. However, as we have seen, large digital events and interactive networking go well hand in hand together!” Even in the adapted format, the 24th International Dresden Lightweight Engineering Symposium, with more than its 82 top-class lectures in seven different sections, probed the guard rails of an entire future industry and gave it new trend-setting impulses. In addition to the topics “hydrogen”, “battery-electric drives” and “intelligent materials”, numerous experts discussed above all the recycling of products and materials as well as energy-autonomous processes this year. The entire atmosphere clearly showed that the chosen topic “RESOURCE NEUTRAL LIGHTWEIGHT DESIGN” is excellent suitable for our present time. Under the special aspects in the sense of neutral lightweight engineering, the digital symposium served as a forum for the cross-material and cross-product trend-setting brainstorming.

Since a long time, lightweight engineering in general and the Dresden Lightweight Engineering Symposium in particular are playing a key role for the ideas and innovations of a resource-efficient and at the same time competitive as well as socially balanced economy.The event provided solutions for a proactive contribution to reconciling growth and progress on the one hand with environmental protection and resource conservation on the other hand. In this sense, examples of successful "cradle-to-cradle" solutions were presented at the recent Lightweight Engineering Symposium and solutions for their sensible recycling were discussed. Furthermore, current developments in the life cycle assessment and its embedding in a continuous CAD-CAM workflow were introduced and visualised in the context of concrete product developments. “Adding value by saving resources” was the basic of all the technical as well as overview presentations to innovative ideas and specific approaches to neutral lightweight engineering.

The highlight of the first conference day was the intensive panel discussion on neutral lightweight engineering. “With its partners, the ILK is working on the approach of neutral lightweight consistently – 2019 seen as a purely ideal concept,” explains Prof. Gude: “The Symposium as an established discussion platform for the transfer of knowledge and experience between science, industry and politics was therefore particularly suitable for presenting this work to the critical eye of experts and the general public.” In order to do digital justice to the networking idea, that has accompanied the Dresden Lightweight Engineering Symposium from the very beginning, an interactive virtual trade fair was set up. Various exhibitors from industry and science presented their know-how and products at their exhibition stands. In addition, the well-attended Light Engineering Lounge offered another entertaining programme with short presentations on current projects. With this additional offer the first digital symposium of the ILK was well completed and could excellently keep up with past presence events.

International scientific exchange on tailored carbon fibres based on renewable raw materials



Impressions of the 2nd International Colloquium on Tailored Carbon Fibres: Prof. Dr. Hubert Jäger opening the conference (left), Dr. Iris Kruppke introducing the RCCF Saxony (centre) and Dr. Thomas Behnisch moderating the Young Scientist Session (right).

Carbon fibre research and in particular the development of carbon fibres from renewable raw materials is of major industrial relevance. At most composites and textile conferences, however, this field of research is only discussed in passing with a few individual lectures. To fill this gap, the ILK and the Institute of Textile Machinery and High Performance Material Technology (ITM) at the TU Dresden organised the *1st Dresden International Colloquium on Tailored Carbon Fibres* in 2018.

In 2021, the event format was taken up again and the second international colloquium was organised with a focus on the development and production of property-adapted carbon fibres. Due to the Covid-19-Sitution, the *2nd Dresden International Colloquium on Tailored Carbon Fibres* took place in June in the form of a two-day digital conference. This time, the focus was on the topics "Carbon fibres from renewable raw materials and process optimisation" and "Multifunctional carbon fibres". These were each dealt with in a session. The conference was rounded off with a third session for young scientists (Young Scientist Session), presenting numerous recently completed or advanced doctoral theses in the field of carbon fibre research. A total of 50 participants represented leading international research institutions such as Korea Institute of Science and Technology (KIST) – South Korea, Georgia Technical University (Georgia Tech) – USA, Carbon Nexus – Australia or Technological Center CANOE – France.

The production of carbon fibres from renewable, lignin- or cellulose-based precursors requires modified process control in stabilisation, carbonisation, graphitisation and surface functionalisation compared to the classic PAN-based starting materials. Not only the common interest in the development of sustainable carbon fibres, but specifically these interrelationships motivated three presented talks in particular: Dr. Celia Mercader (CANOE, France) discussed the production of low cost carbon fibres from cellulose (*Low cost carbon fibres from cellulosic precursors: spinning and carbonization at pilot scale*), Dr. Christoph Unterweger (Wood K+, Austria) discussed process optimisation of cellulose-based carbon fibres (*Cellulose-Based Carbon Fibres: Process Optimization and Fibre Properties*) and Dr. Nikals Garoff (Stora Enso, Sweden) spoke on the use of lignin from conifers for future carbon fibres (*Carbon Fibre – What a Tree Can Do*). At the conference, the highly complex mechanisms of structure formation during fibre production and the cross-scale process parameter-structure-property relationships were specifically addressed and discussed in an interdisciplinary manner.

The conclusion after two exciting conference days: Research approaches for (further) optimising and increasing the efficiency of the carbon fibre manufacturing process are being pursued with huge interest worldwide. The most important signal of the event: The common will to research for the development of multifunctional, but above all sustainable carbon fibres.

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Institute of Textile Machinery and High Performance Material Technology (ITM) and ILK of the TU Dresden

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TU Dresden: Flexible funding line in the "Internationalisation" funding programme

Awards and prizes

In 2021, the ILK looks back on a successful year with many highlights again. Among others the awards for the work and research at our institute reflect this fact.

AVK Innovation Award 2021: Convenient charging without cables through a highly integrated and ultra-thin vehicle module

Numerous technical challenges have to be solved before structurally integrated wireless charging systems for automotive applications are ready for the market. For example, the increased space requirements of currently commercially available charging modules prevent an efficient integration into the vehicle. Researchers from ILK at TU Dresden and Mercedes-Benz AG have tackled this problem. In close collaboration, an ultra-thin in-vehicle charging module was developed (see p. 59). With the design of this receiver module, a decisive milestone was reached in terms of the design, manufacture and especially the application of function-integrated lightweight structures in automotive applications, as well as cross-industry. For this achievement, the work was awarded one of the prestigious AVK Innovation Awards 2021. The AVK – Industrievereinigung Verstärkte Kunststoffe e. V. and AVK-TV GmbH awards the prestigious innovation prizes annually to companies, research institutes and their partners. The interdisciplinary development of the highly integrated inductive charging module for electric vehicles, which covered both the mechanical and electrical aspects, was awarded in the Research and Science category. The award ceremony honoring Prof. Dr. Niels Modler for the

AVK Innovation Award 2021 in the category Research and Science: f.l.t.r. Prof. Dr. Jens Ridzevski (AVK), Prof. Dr. Niels Modler (ILK), Steve Zimmer (Mercedes-Benz AG), Reinhard Lux (AVK).

ILK and Steve Zimmer for Mercedes-Benz AG took place on November 23, 2021 in Frankfurt/Main.

WAK Award 2021: A diploma thesis at the ILK with a special focus on sustainability in lightweight engineering

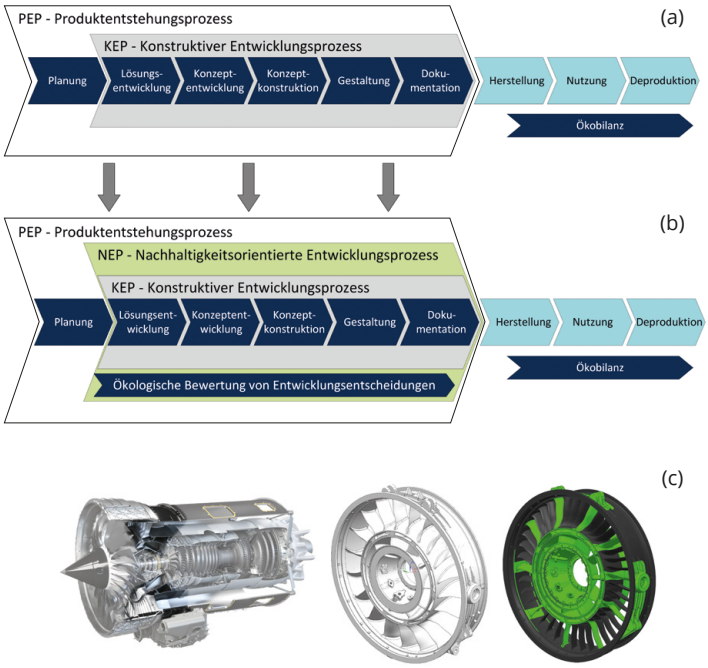
The handover of the certificate to Dipl.-Ing. Levin Schilling (in the middle) by the WAK member, Prof. Dr.-Ing. Volker Altstädt (right) and the representative of the donor company: Oechsler AG, Dipl.-Ing. Matthias Weißkopf (left).

The Scientific Alliance of University Professors of Polymer Technology (Wissenschaftlicher Arbeitskreis der Universitäts-Professoren der Kunststofftechnik, WAK) annually awards the best final thesis and dissertations in the field of polymer technology. This year, Dipl.-Ing. Levin Schilling was honoured with the Oechsler Prize for a work on methods and approaches for the development and design of components made of plastics. The award ceremony took place on 04.11.2021 in Aachen.

In his diploma thesis “Integration of the LCA into the development process of an engine intermediate case” Levin Schilling extended the classical development process to integrate the ecological product requirements. By demonstrating the undeveloped potential of ecological considerations early in the development phase of a product, the work makes a significant contribution in the field of neutral lightweight engineering. Furthermore, it can serve as a basis for further research in the area of sustainability-oriented development processes and thus contribute to the general improvement of environmental friendliness of products in the future.

The sustainability-oriented development process (SDP): The established design and development process according to VDI guideline 2221, which is limited to the implementation of classic technical and economic product requirements, was used as the basis for the research. Although a life cycle assessment also allows to quantify the ecological product properties and to derive recommended actions for the products, it is usually carried out on the existing product system due to the high level of system knowledge required. As a result, ecological potentials can only be tapped through costly system changes or within the framework of further development cycles. The SDP proposed by Levin Schilling, on the other hand, makes it possible to carry out the ecological decisions already while the product is being designed. Such an ecological assessment within the product development itself is more appropriate to the increasing demands in terms of development duration and costs as well as product complexity and quality than the subsequent life cycle assessment.

Sustainable development of a Rolls-Royce intermediate case (ICM): The developed SDP was applied as part of the LuFo project PEP4.0 (see p. 53) by Professor Dr. Maik Gude and Dr. Sebastian Spitzer. Together with the project partner Rolls-Royce Deutschland Ltd. & Co.KG, it was possible to investigate the ecological advantages of using fibre-reinforced plastic (FRP) composites in ICM compared to the commonly used lightweight metals. It was shown that the use of FRP within aviation is justified from an ecological point of view: the increased degree of lightweighting through the use of FRP significantly reduces the resulting emissions of the critical use phase of the highly active component and thus improves the sustainability of the engine structure across the entire life cycle.



(a) Product development in accordance with VDI Guideline 2221 with a subsequent ecological assessment by means of LCA. (b) Ecological assessment of development decisions within product development: SDP designed by L. Schilling. (c) Use of the SDP in the context of the development of an intermediate engine casing by Rolls-Royce

The award for this work is not only a tribute to the research of Levin Schilling in the field of methods and approaches for the development and design of polymers components, but can be interpreted in particular as recognition of the ILK's view for the sustainability in this field of research.

JEC Innovation Award 2021 for flying injection molding machine ROBIN

The Robotized Injection Moulding (ROBIN) technology has been awarded again this year. ANYBRID, together with the ILK of TU Dresden, won the JEC Composites Connect Innovation Award in the Equipment and Machinery category at this year's digital JEC Connect. Following last year's AVK Innovation Award, this is the second prestigious prize in the field of lightweight engineering for the latest ILK start-up.

Simple, but ingenious: "For us as a young start-up, this international award is the perfect boost at the right time to introduce our technology to the market," comments Dr. Michael Stegelmann, sales manager at ANYBRID GmbH: "We know that our technology has enormous potential. Anyway, this doesn't mean that the potential is directly recognized by all potential customers, too. Such a signet as the JEC Award helps enormously." The management of the ILK is also pleased with the award. "The idea of mobile injection molding is so simple and ingenious at the same time that it puts many conventional processing methods in the shade all at once.", emphasises Professor Niels Modler, Chair of Function-Integrative Lightweight Engineering, and continues: "As lightweight engineers, we teach our students from the very beginning to question conventional construction methods and thereby exploit the potential of novel materials and processes to the maximum. The ANYBRID team has succeeded excellently at this point."

[1] Schilling, L. Integration of the LCA into the development process of an engine intermediate case. diploma thesis 2021, unpublished.

Revolution of mobile injection molding: With ROBIN, the founding team has developed a revolutionary technology for the production of hybrid components, which is characterized by the fact that the machine technology has become a flyweight thanks to high-performance materials and efficient lightweight design. For example, the injection molding system, which weighs around 140 kg and has a clamping force of up to 12 tons, can be mounted on classic industrial robotics or gantry systems for the first time, and can thus be moved freely in space. In this way, one or more ROBIN systems can be ideally integrated into continuous production lines such as extrusion or pultrusion lines. Thus, all of a sudden, previous restrictions on the design of profiles are dissolved, and an innovative opportunity is created for a large number of manufacturing companies to stand out from the mass market.

In a number of following pilot projects, the ANYBRID team would now like to further demonstrate the versatile potentials in order to sell the first ROBIN systems as early as next year. Until then, the team can rely on the funding within the framework of an EXIST research transfer and the support of ILK.

Multiple beams at ILK: Outstanding internationalization work of our institute

Photo lighthouse Moritzburg: © Simone Wollmann. The guiding image of the TUD lighthouses: © geralt | pixabay.

TU Dresden honors selected partnerships, networks and programs with the status of a lighthouse for particularly excellent internationalization work. This appointment appreciates that these decentralized activities bring the university one step further on its way to a global university. As a start, the International Affairs Commission of TU Dresden announced 22 such shining examples of the internationalization in September 2021. Among them, the ILK was awarded three times at once.

UTC Dresden "Lightweight Structures and Materials and Robust Design": The Rolls-Royce partnership received this recognition in the category International Network with Outstanding TUD Participation. The UTC Dresden involves – besides the ILK with its three

professorships (Prof. Gude, Prof. Jäger, Prof. Modler) and the senior professorship (Prof. Hufenbach) – the Chair of Turbomachinery and Flight Propulsion (Prof. Mailach), the Chair of Thermal Power Machinery and Plants (Prof. Gampe), the Chair of Materials Technology (Prof. Leyens) and the Chair of Machine Elements (Prof. Schlecht) as well. The appointment acknowledges their work at the international level, in particular their long-standing collaborations with top-class British universities, such as the University of Oxford or the Imperial College London, as well as with Nanyang Technology University (NTU) Singapore.

National network with the Republic of Korea: In the category National Networks, the ILK was awarded with another lighthouse for its long-standing cooperation with Korea. The partnership network connects the TU Dresden with the leading research institutions of the Republic of Korea. These include in particular the Korea Institute of Materials Science (KIMS), the Korea Institute of Science and Technology (KIST) and Inha University Incheon. The cooperation is characterized by joint events, student and scientist exchange as well as a strongly transfer-oriented research collaboration in the fields of development of carbon fibers, hybrid composites, lightweight engineering methods and methods of calculation and validation.

Saxon delegation in Korea, 2017 for the opening of the Korean-German Material Center in Changwon.

Contract signed in 2014 at Tongji University.

Partnership with Tongji University: Already 2016, at the 20th International Dresden Lightweight Engineering Symposium with the Republic of China as a partnership country, the then rector of TU Dresden, Prof. Dr.-Ing. habil. Hans Müller-Steinhagen, described the ILK in his opening speech as a "lighthouse in the local research landscape" and emphasized the importance of the partnership with China for interdisciplinary science. Perhaps this was an omen that in 2021 the partnership with Tongji University would also be honored as a shining example of international networking in the category Partnerships. The cooperation between one of the oldest and most renowned universities in China and TU Dresden has been in place since 1998. Tongji University occupies the top positions in international rankings, particularly in the engineering sciences. In 2014, TU Dresden signed an agreement with Tongji University Shanghai and the associated Chinese-German University College (CDHK), and since 2015, the universities have maintained the double degree Master/Diplom "Post-Gradual Studies in Mechanical Engineering". In addition to the cooperation in teaching, many further activities have arisen in the past 23 years, joint research projects and publications, events and most recently, in November 2020, the DFG-funded "Sino-German Symposium on Smart Compliant Mechanisms".

Internationalisation

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2021, the ILK's internationalisation work was also influenced by the pandemic conditions. Numerous international activities remained in or had to be moved back into the digital space. Of course, stays abroad had to be postponed or even cancelled, but altogether the extent and intensity of our international activities was only slightly reduced. On the contrary, internationalisation was influenced in a positive sense, because we not only tested the new tools and methods of the digital world, but made also use of the hybrid formats to enrich our diverse collaborations.

Contact ILK-International@msx.tu-dresden.de

Australia	Deakin University, Melbourne/Geelong
Belgium	Ghent University
China	Tongji University, Shanghai University of Shanghai for Science and Technology (USST) Tianjin University
Greece	University of Patras (UoP) National and Kapodistrian University of Athens
Great Britain	University of Oxford University of Bristol University of Nottingham Queen's University Belfast Imperial College London
India	Indian Institute of Technology (IIT) Delhi, Neu Delhi
Poland	Akademia Górniczo-Hutnicza im. Stanisława Staszica, Krakau Politechnika Warszawska, Warschau Politechnika Śląska, Gleiwitz Politechnika Wrocławska, Breslau
Singapore	Nanyang Technological University (NTU)
South Korea	Inha University (IU), Incheon Korea Institute of Science and Technology (KIST), Jeonbuk Branch Korean Institute of Material Science (KIMS), Changwon

Scientist exchange and international partnerships

Due to travel restrictions, only limited mobility took place within the framework of the **ERASMUS and IASTE** exchange programmes. Nevertheless, thanks to IASTE, we were able to host six interns from Brazil, Ghana, Greece and Iran at the ILK. Furthermore, we sent an ERASMUS scientist to the University of Inha in South Korea for a three-month research stay. Other researcher exchange with the Chinese Tongji University and the Chinese-German University College (CDHK) had to be postponed until 2022.

The excellent results of internationalisation in 2021 included the successful completion of Dr. Valverde's doctorate in the Joint PhD-Programme with the University of Bristol. The results of his PhD thesis are reported on page 81.

In July 2021, the kick-off meeting of the **DAAD-project "Development of the innovative technology for the production of hybrid structures"** took place. In addition, further visits were realised within the framework of the ILK's cooperation project with the AGH Krakow (Poland): On the one hand, the ILK was welcoming Professors Selboda and Wojtaszek as well as the junior researcher Mr. Zygula in Dresden, on the other hand, Mr. Stanik and Dr. Langkamp from ILK visited the Polish partner in October.

2021, the country network with the Republic of Korea, awarded by the Lighthouse of TU Dresden, was extended to **Inha University (IU)**, Incheon. Although the ILK's partnership with the Inha Institute of Technology (IIT) from the Inha University is still very new, the first experiences have been extremely positive and both sides are strongly motivated. The focus of the cooperation is particularly on the expansion of interdisciplinary PhD supervision: **Joint PhD Programme TU Dresden/IU**. Despite the pandemic we organised a stay of ILK students at the IU. In addition to networking between the members of both institutes, the focus was on research in the field of hydrogen storage. The results will be published and the paper presented at the 20th European Conference on Composite Materials (ECCM20), in Lausanne (Switzerland) in June 2022. A return visit by ILK representatives to South Korea and the continuation of research work are planned for 2022.

Nanyang Technological University (NTU), Singapore is currently ranked eighth in the QS World Ranking for Engineering with an overall score of 91.8. This is making it one of the best technical universities in the world. A **Joint PhD programme with the School of Mechanical and Aerospace Engineering (MAE)** is currently being established. The deepened networking with NTU Singapore in the field of lightweight engineering that is being pursued in this way fits perfectly into the ILK's already robust internationalisation strategy. The further goal is to strengthen the international education of students and doctoral candidates, the implementation of research projects, the increase of the ILK's international recognition. With its stronger focus on the technical and natural sciences, the NTU can significantly complement the teaching and research at the TU Dresden. In return, the TU Dresden can bring the partnership its competence of high interdisciplinarity in the processing of research questions and expertise in the transfer of scientific solutions into practice. A partnership of both universities combines these diverse competences and allows the institutions to appear internationally as thought leaders of a sustainable and inclusive scientific society. The MAE at NTU is one of the largest mechanical engineering schools in the world, with more than 90 members. Faculty members are recruited from reputable universities worldwide and offer a lot of collective expertise in the traditional and upcoming disciplines of mechanical and aerospace engineering, as well as in the specialised fields of manufacturing, mechatronics, innovative design, nanotechnology or biomedical and computer-based applications. In the context of the industry and in the pursuit of sustainable habitats, MAE is also consistently developing other key skills to support the growth and competitiveness of the mechanical engineering sector in the global landscape. The collaborative research topics of the ILK and MAE are "Smart Structures", "Digital Twins", "Artificial Intelligence", "VTOL Systems", "Electrical Machines" and "Manufacturing Technologies". In addition, UTC Dresden contributes its outstanding qualifications in the areas of lightweight engineering systems, multi-material design and robust design. The prepared Joint PhD Programme will provide optimal conditions for the exchange of doctoral students. In this programme, doctoral students from Singapore and Dresden will be supervised and evaluated in their projects by a Supervision Management Committee (SMC) with equal number of representatives from both universities. The dual doctorate will also include a research stay of at least 6 months at the respective partner university. At the end of 2021, the conceptual work was completed and the agreement for the Joint PhD Programme was submitted for final approval.

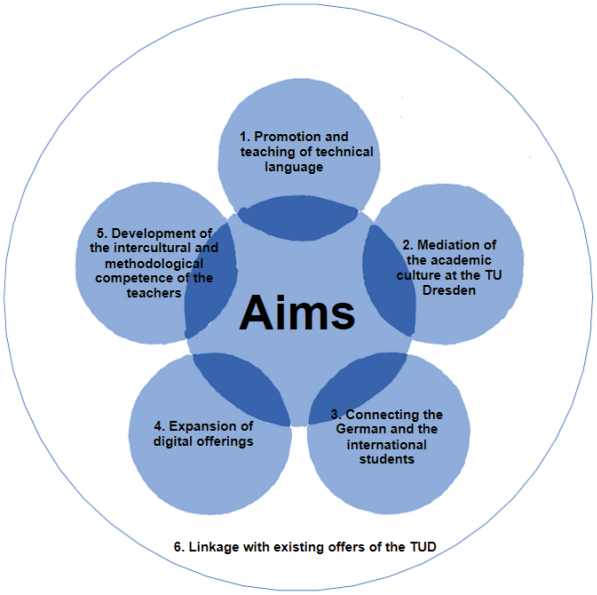
Model project EDI:TUD. Study success of international students of the ILK

1. Promotion and teaching of academic language: In cooperation with ILK teachers, the SZD, central institutions at the TU Dresden and external experts, coaching for the practical use of academic language has been designed and implemented since the winter semester 21/22. This creates a specific offer for language use and language didactics that not only sensitises teachers to the needs of international students, but at the same time provides tools for teaching academic language and supports the practice of a uniform grading concept that takes into account the (linguistic) challenges of international students.

2. Mediation of the academic culture at the TU Dresden: Since June 2021, a tandem programme has been implemented at the ILK. Each tandem consists of two students - the tutor supports, translates and advises his/her foreign tandem partner and mediates between students and teachers. In a further step, the tandems act as mediators or mentors for other german students interested in the tandem activity. Handouts and guidelines are also being developed with ILK teachers to achieve this goal. The website OPAL for students provides information and advice about studying, culture and everyday topics. New FAQs with the most important questions for international students have been created, as well as testimonial and explanatory videos that allows insights into life and studies at TU Dresden.

3. Connecting the German and the international students: The basic idea behind the third goal is to reduce segregation by origin through the formation of interest groups. To enable German and international students to interact with each other, peer-to-peer activities are implemented, with tutors functioning as intermediaries between international and German students. Moreover a matrix-based exchange platform is currently being organised to get to know each other easily before the start of the semester.

4. Expansion of digital offerings: The analogue and digital support services of the TU Dresden will be better linked to enable international students to learn independently. This should give international students easy access to (i.) necessary information (e.g. via forums, wikis and self-tests on OPAL), as well as to (ii.) interactive tools where their specific questions and needs can be specifically addressed (e.g. current set-up of an interactive Python notebook).



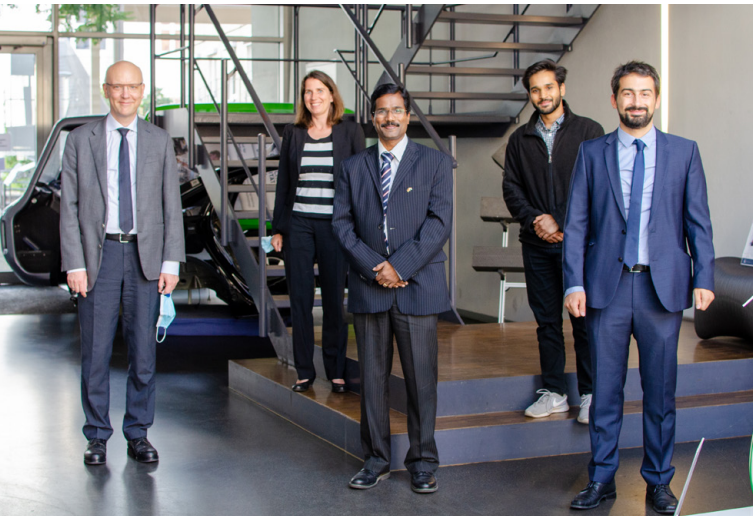
© TUD, Source: Schulze-Stocker et al., Successful, digital and integrated study - a project to increase the academic success of international students at the TU Dresden (in press)

5. Developing the intercultural and methodological competence of the teachers: A further effort is to update and systematise the already existing teaching materials (especially for e-learning) and to supplement them with newly recorded ones. The aspects of interculturality, internationalisation and e-learning didactics are given special consideration. In addition, the teachers take part in internal and external continuing education programmes. Besides intercultural training (together with SPRINT) was organised for sensitisation in dealing with Chinese students.

6. Linkage with existing offers of the TUD: The primary goal of EDI:TUD is to create synergies with existing offers at the TU Dresden, which will be implemented in the ILK as a model institute. Current networking activities are e.g. with the ZiLL, WBZ, TUD Certificate E-Teaching or the PASST?! programme. This also includes the prepared transfer of results for adaptation outside the model project at the ILK and the exchange of experience between the involved partners.

The achieved results will be published in: *Schulze-Stocker et. al., Erfolgreich, digital und integriert studieren – ein Projekt zur Steigerung des Studienerfolgs internationaler Studierender an der TU Dresden*.

Partnerschaft mit Indien: Counsellor Science & Technology der indischen Botschaft zu Gast am ILK



Tour of the ILK's experimental facilities: (from left to right) Prof. Niels Modler, Maike Heitkamp-Mai, Dr. Madhusudan Reddy Nandineni, Kaushik Ganesh Abhyankar and Dr. Angelos Filippatos.

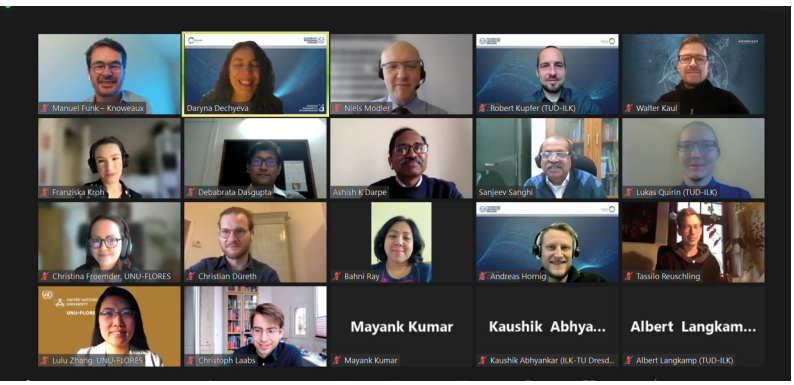
Dr. Angelos Filippatos in conversation with Dr. Madhusudan Reddy Nandineni.

India – with almost 1.4 billion people the second most populous country and largest democracy in the world - has developed rapidly in recent decades. Therefore, India plays a key role in the fight against climate change, among other things. Especially in the field of science and technology, there are long and intensive relations with Germany, and also with the TU Dresden. Students from India are among the largest groups of international students at TU Dresden. There are active interdisciplinary collaborations with several Indian universities and research institutions, and these cooperations shall be expanded in the future.

On 20 August 2021, the Counsellor for Science & Technology of the Indian Embassy in Germany: Dr. Madhusudan Reddy Nandineni, was a guest at TU Dresden in order to exchange views on current and future joint projects. In this context, he was also welcomed at the ILK. During his visit, Dr. Reddy was introduced to the current research as well as the international activities of the ILK and enjoyed a tour of our test facilities. Dr. Reddy's visit to the Institute summed up the results of the Indo-German cooperation in the COMPOLL project and opened up new perspectives for our cooperation with Indian universities, companies and public institutions.

In consideration of the constantly growing population, minimising the impact of human activity on the environment is becoming a crucial issue. In particular, noise, air and water pollution as well as waste management have become one of the greatest global challenges. Managing these tasks requires extensive transnational cooperation between societies with their different stages of development, linguistic diversity and cultural backgrounds, as well as their local problems and convictions. The DAAD project “Combating Enviromental Pollution throught Internalisation of Education” (COMPOLL) wants to achieve a better understanding of the challenges, deficits and possible solutions regarding environmental consciousness in Germany and India. The application and cooperation partners are the ILK and the Indian Institute of Technology Delhi (IIT Delhi). The project intends to increase the awareness of topics such as reducing plastic waste, recycling or sustainable design strategies and, against this background, strengthen the partnership between TU Dresden and India.

With IIT Delhi against environmental pollution. COMPOLL Mini-Conference 2021



On 30 November and 1 December 2021, a mini-conference on "Online Learning Curriculum Design" was held as part of the DAAD-funded project for Indo-German Partnerships (DIP) COMPOLL. The aim of this event, organised by the ILK together with the IIT Delhi, was the exchange of expert knowledge on environmental pollution, especially in the context of online teaching and curriculum design. About 30 guests attended the sessions, participated in workshops and discussed concrete ideas for the future realisation of the cooperation between the two institutes or universities and for strengthening the existing partnership between Germany and India. In the foreground – the COMPOLL topic: How can interdisciplinary and international cooperation overcome the problems of environmental pollution as well as waste management? The existing network between the leading Indian research institutions and the TU Dresden will be used here to increase environmental consciousness: How can we integrate environmental awareness into the curriculum? How can we realise joint study programmes of India and Germany? What does online teaching of the future look like? These and other questions were the focus of the COMPOLL mini-conference.

The two-day mini-conference opened with two keynote speeches. Dr. Madhusudan Reddy Nandineni from the Indian Embassy in Berlin spoke about the new Indian education policy (NEP-2020). With the aim of developing a new higher education system with quality education, fairness and inclusion, the NEP-2020 is particularly supportive of internationalisation activities. Shikha Sinha from the DAAD office in New Delhi presented cooperation projects between India and Germany and spoke about the role of the DAAD in future activities in the field of digitalisation. After these inspiring opening speeches, other invited speakers from India and Germany shared their expertise and experience. Dr. Patrícia Gallo (Centre for International Postgraduate Studies of Environmental Management, UNESCO CIPSEM) reported on organising online trainings for environmental decision makers - good communication and honesty are the roots of their successful implementation. Dr. Lulu Zhang and Dr. Christina Froemder (United Nations University Institute for Integrated Management of Material Fluxes and of Resources, UNU-FLORES) described the design of environmental education curricula. Then Prof. Dr. Kathrin Harre (HTW Dresden - University of Applied Sciences) spoke about microplastics and her goal to integrate current research results into her teaching concepts. In the afternoon, invited speakers from IIT Delhi shared their views: Prof. Dr. Mayank Kumar spoke about didactics in the context of air pollution, Prof. Dr. Bahni Ray focused on techniques to combat air pollution and finally Prof. Dr. Ashish Darpe discussed a concrete example, namely the IGI airport in New Delhi and the noise pollution that occurs there.

On the second day, the focus was on workshops and actual realisation of the COMPOLL cooperation between India and Germany. The first workshop dealt with the specifics of online learning formats compared to face-to-face teaching and suggested e-teaching formats for the joint programmes of IIT Delhi and ILK while discussing suitable tools and didactic approaches. In the second workshop, the participants discussed the possibility of integrating IIT Delhi's research activities on environmental pollution into the curricula, expanding the cooperation between IIT Delhi and ILK, and the possibility of a cooperatively organised event on air and noise pollution.

At the mini-conference, ideas on curriculum design, tools and didactics, topics for international education in environmentally conscious engineering as well as research on environmental protection in teaching formats and knowledge transfer were developed and will be included in the next steps of the COMPOLL project. The topics of environmental responsibility, recycling and waste management are to be added to the teaching profiles of both universities. Therefore, the preparation of academic staff for the implementation of teaching using new forms of teaching (e-learning) as well as openness to the internationalisation of academic life and work is essential. The COMPOLL mini-conference provided concrete approaches for the realisation.

The Greek-German Autumn School 2021

The DAAD-funded "1st Greek-German Autumn School on Lightweight Engineering and Composite Design" between the TU Dresden and the University of Patras (UoP) took place from November 8-12, 2021 in Patras. The aim of the Autumn School was to introduce the scientific location Dresden to the participants and to familiarize them with the teaching and research approaches at the TU Dresden in general and in engineering sciences in particular. A seven-member delegation from TU Dresden, led by Prof. Niels Modler (ILK, Chair of Function-Integrative Lightweight Engineering), joined Institute Director Prof. Vassilis Kostopoulos and his team for the Autumn School, which was attended by a total of 23 Masters and PhD students from the UoP. The intensive and busy week ended with an information event on studying in Germany and at the TU Dresden, organised together by the DAAD office in Athens and the Goethe Centre Patras.

In addition, the Autumn School brought together the complementary competences of the ILK and the Applied Mechanics Laboratory (AML) of UoP in the field of functionally integrative lightweight structures in order to further develop current research questions and to lay the foundation for further joint projects. Furthermore, the AML and the ILK signed a Memorandum of Understanding and the International Affairs Advisor of the School of Engineering Sciences and representatives of the ILK hold initial talks with the Rectorate of the UoP on the establishment of a Joint PhD Framework Program between the two universities.

Participants of the DAAD Autumn School 2021.

Signing of the Memorandum of Understanding between the AML and the ILK.

Expert Groups

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Lightweight Design

The realisation of new ideas, such as neutral lightweight construction, requires a strategy of holistic product development. Thus, modern lightweight construction solutions represent more than a material substitution on the individual part. The scientists in the Lightweight Construction Methods Group are therefore pursuing a methodical development approach that focuses on overall systems and functional spaces in order to demonstrate the entire lightweight construction potential.

On the basis of material-appropriate design and construction approaches and with the help of methodical concept analyses, lightweight components and systems are developed up to the prototype component for cross-sectoral applications in close international industrial cooperation, which go far beyond the state of the art. The development strategy is characterised above all by the material-oriented approach, which allows all construction materials and material combinations to be considered and thus forms the basis for highly efficient hybrid lightweight construction. To achieve demanding development tasks, a systematic development process is applied that actively considers the models, methods and data to be used and makes use of possibilities for digitalisation in order to increase the effectiveness and efficiency of individual process steps and the entire development process. In particular, numerical methods that accompany the engineering design process are used.

Calculation Methods and Simulation

The development of modern lightweight structures requires scientists to exhaust the whole potential a material has to offer while also enhancing the level of cost efficiency achieved. Computer-aided methods can make a decisive contribution to this and will become even more important in the development process and an more central element of the development process in the future. Therefore, linking the calculation methods along the entire value chain plays a key role.

The focus of the work in the scientific area CMS lies in the development and realization of practice-oriented methods combining multi-process, multi-material, multi-scale simulation techniques which facilitate the design of efficient lightweight materials, structures and systems in multi-material design. We benefit from the broad expertise of the ILK in the fields of experimental analysis, process engineering and design and incorporate this know-how directly into both the model development and the results evaluation processes. So, the design process, which is largely shaped by the complex interactions between material, production, joining and system behavior, can be made more robust, precise, and efficient.

Our goal is to synergistically exploit the currently insufficiently used high material-specific potential of new materials and construction methods, for example through digital twins. We combine in-house developed simulation and analysis methods with commercially available software solutions.

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Thermoplastic Processing

The manufacturing of promising lightweight structures demands the availability of efficient and networked process chains. With this in mind, the research carried out by the Expert Group on Thermoplastic Processes targets maximum efficiency throughout the entire value chain and the ambitious goal of a closed material cycle with simultaneous reduction of energy requirements.

To this end, the expert group manages a complex process network starting with the development, manufacturing and characterization of novel semi-finished thermoplastic goods with tailored characteristics, for example compounds, films, tapes and organosheets. Subsequently, new preforming technologies suitable for semi-finished products are developed, ranging from near-net-shape depositing of thermoplastic tapes to braiding of complex hollow structures. The process chain ends with the development of efficient manufacturing processes based on injection molding, compression molding, pultrusion, extrusion and generative techniques. The unique machine park available at ILK's Process Development Centre enables the group's scientists to set up and test fully automated networked, robust process chains under realistic serial manufacturing conditions. The activities draw on longstanding experience and extensive know-how gained in connection with the development of innovative tooling, automation and processing techniques for the efficient manufacturing of hybrid thermoplastic structures. The group's process development activities are supported by the use of continuous process simulation.

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Thermoset Processing and Preforming

The development of efficient manufacturing processes which factor in interaction between materials, processes and component properties has an increasingly significant role to play in the field of heavy-duty fibre-reinforced composite components based on thermosetting matrix systems. In addition to robust processing techniques compatible with serial manufacturing technologies and rapid-hardening matrix systems demand for realization of individualized lightweiht structures is particularly high.

Research at ILK's Expert Group on Thermosetting Processes and Preforming focuses on the characterisation, modelling and simulation of reactive processes, the engineering of systems and processes for innovative preforming concepts and the development and refinement of novel materials, semi-finished products and corresponding processing technologies. The manufacturing of active composite structures represents another area of research emphasis, which focuses on the targeted exploitation of the moderate process conditions that characterise the processing of thermosetting matrix systems. A comprehensive technological equipment enables the group's scientists to make use of both prototypical and serial processing technologies. Areas of focus include filament winding and braiding, injection and pressing techniques, additive manufacturing and pultrusion. Interdisciplinary cooperation with ILK's other expert groups is the basis for consistent research in the different subject areas.

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Joining Technologies

In the conception, design and dimensioning of lightweight structures, the provision of suitable joining systems has a decisive importance. The aim of our Expert Group is to identify the relevant problems in the field of joining technology at an early development stage especially with regard to multi material design. Based on this, application-oriented joining solutions are identified and investigated scientifically. For this purpose, both established technologies are considered and applied to specific joining tasks as well as novel material-adapted joining methods are developed. The Expert Group pursues a holistic, material-independent development approach. It includes the technological basics, the material-structural phenomena in joining zones and the modelling of both the joining process and the load-bearing behaviour.

One main research focus are intrinsic joining zones, which are formed in hybrid structures during component manufacturing: e.g. when overmoulding laser-structured or plasma-treated surfaces. Extrinsic joining zones, which enable the integration of hybrid structures into the system environment, are another focal point: e.g. the novel joining process Hotclinching. In addition, we develop novel methods for the analysis and description of the local composite material structure in joining zones for the design and dimensioning of joining systems: e.g. for inserts embedded by warm forming.

Testing Methods and Material Models

For the design of lightweight structures and systems, the knowledge and mathematical description of the process-specific material properties as well as the damage and failure processes is essential. Due to the testing equipment at the ILK, it is possible to comprehensively record the material and component characteristics. The characterization can be carried out starting with the determination of the thermomechanical properties of the materials, through the analysis of the stiffness and strength properties of the semi-finished products, to complex load tests on structures and systems. For the correct use and further development of the experimental methods and the implementation of the findings in material models and validation strategies, the experience and competences are bundled in the specialist group Testing Methods and Material Models. We thus see ourselves as an open forum for all issues relating to scientific experimentation and description – from the choice of methodology and statistical data evaluation to interpretation and mathematical description. In the area of material models, we therefore concentrate on the elucidation and description of the process-structure-property relationships.

In the area of materials and component testing, we devote ourselves to standardized and newly developed methods of destructive and non-destructive testing and meet the challenges of new materials and hybrid functional structures.

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Function Integration

Scientists at the ILK see function integration as a physical expression of their interdisciplinarity. Our well-coordinated, multidisciplinary team unites experts from a variety of disciplines including lightweight engineering, electrical engineering, mechatronics and computer science. By ensuring the targeted combination of mechanical, electronic and software-based R&D activities, ILK is able to develop products and solutions that go far beyond the state of the art.

The institute's approach not only combines functions and reduces the number of parts at component level, but also factors system-level interactions that arise from phenomena in the different scientific "worlds". This includes the identification and targeted application of cross-sector synergies between fields such as aviation, e-mobility, energy, mechanical and plant engineering, medical technology, consumer products, custom machine building and safety equipment. Through the successful cooperation of lightweight design, electronics and software experts and the associated "speaking a common language", the scientists meet the requirements placed on them. A special focus is the integration of mechanical, electronic, acoustic, haptic, actuatory and sensory functions into overall systems.

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Novel Materials and Special Processes

In order to pave the way to a climate-neutral circular economy in lightweight engineering, “Neutral lightweight engineering” is the upgrade of the previous ILK philosophy of “Function-integrative system lightweight engineering in multi-material design”. Under this aspect, the research group Novel Materials and Special Processes addresses the targeted development and research of climate-friendly hybrid technologies for the production of new types of recyclable mixed composites with application-oriented properties.

The high degree of customisability of additive manufacturing processes, the performance of fibre materials, the adaptability of bionic structures, the tolerant failure behaviour of metallic materials as well as the thermal resistance of ceramics can open up unexpected potential and new fields of application. This intended fusion of different technologies for the highest possible functionality and improvement of utility value is the key competence of the research group Novel Materials and Special Processes.

Our research focuses both metallic and ceramic fibre composites, the development of novel “hybrid casting” technologies for Aluminium/Magnesium thermoplastic composites as well as generative manufacturing processes (e.g. continuous fibre-reinforced 3D printing), the application of electron beam technology for energy-efficient cross-linking of plastics and the development and advanced processing of customised multifunctional carbon fibres based on renewable materials.

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Neutral Lightweight Engineering

The Neutral Lightweight Engineering group conducts research on interdisciplinary sustainability-oriented topics in the context of lightweight engineering. At the interface of engineering, economics, environmental science and society, we investigate product systems holistically and develop sustainable, application-oriented solutions. In particular, we address the following five topics: Sustainability-oriented development processes for lightweight systems, circularition of lightweight materials, resource-saving production technologies, lightweight design with materials from renewable resources, and life cycle analyses of lightweight products and technologies.

Guided by the ILK concept of Neutral Lightweight Engineering, we not only consider the technical and economic criteria in research and development, but explicitly include environmental aspects along the entire product or material life cycle. The positive vision of Neutral Lightweight Engineering is a resource-neutral circular economy. In line with the UN definition of sustainability, the anticipation of possible rebound effects as well as the analysis of process networks and supply chains with regard to societal criteria and environmental standards play a role in our research.

Key qualification

Non-destructive testing at ILK

“You've designed a beautiful and light part. And you are able to manufacture it too.” the potential customer is pleased to say. But the question often arises immediately: “But how do I know that it is flawless and will last for long?” This concern is all the more understandable because at the ILK we make highly stressed parts that are orders of magnitude lighter and the fibre composites that are often used for this purpose are not created until late in the production process.

The answer to such scepticism is provided by **non-destructive testing (NDT)**, which has a long tradition at the ILK. The origin of our current capabilities in this field lies in the 1990s. At that time, when the manufacturing processes for fibre composites were developing rapidly, a production-accompanying NDT was established at the ILK in order to expand the general confidence in the novel technologies and materials. Since that time, the NDT processes have been continuously developed. Nowadays, the discipline is also experiencing many new incentives, for example through technical progress in fully automated image recognition and evaluation. It has never been easier to apply even complex NDT procedures.

The ILK sees itself at the interface between the development and application of NDT. In addition to the consulting and services offered for the processes available at the ILK (Fig. 01), we are fundamentally researching

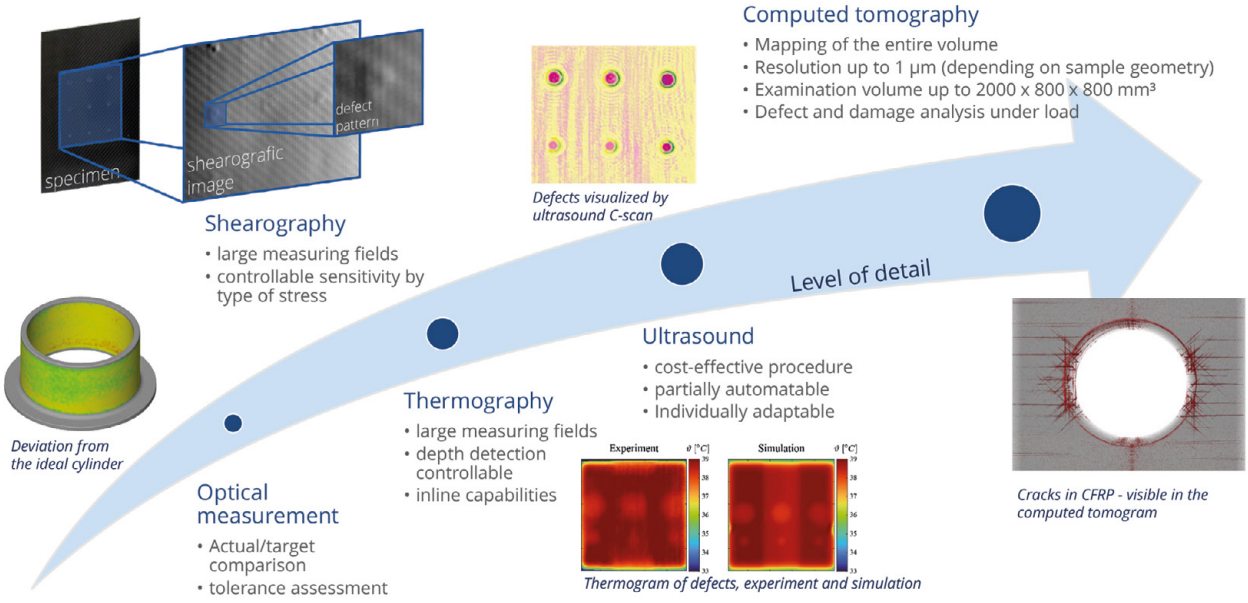

Fig. 01 Selected NDT processes and methods at ILK.

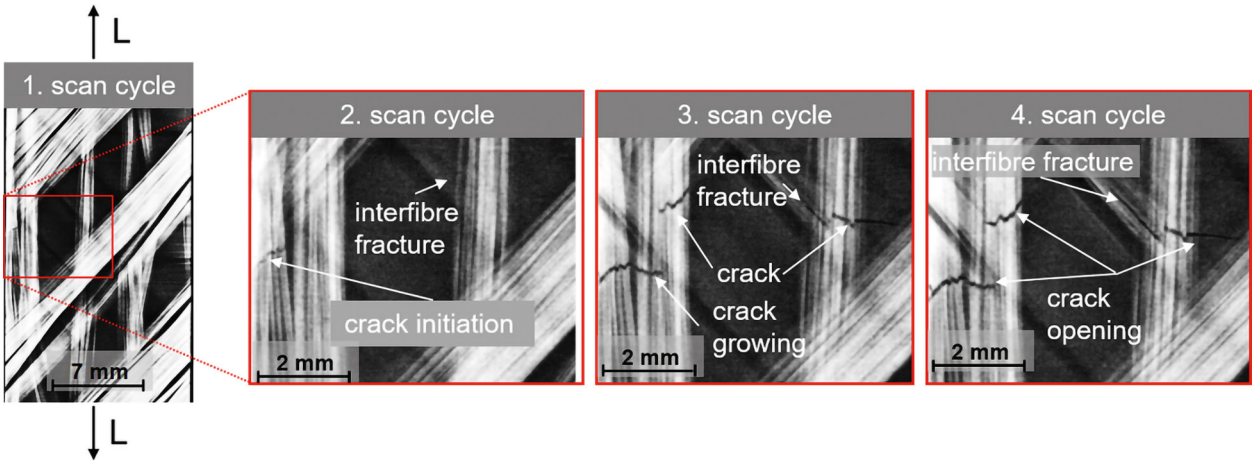

Fig. 02 In situ examination of different damage levels in a fibre composite.

new application possibilities and innovative processes in scientific projects. We are primarily interested in the clarification of the so-called process-structure-property relationships, which will enable data- and model-based material and process developments in the future. Structural analysis with imaging methods plays an essential role here in order to understand the essential mechanisms in the behaviour of the materials.

Basically, the aim of all NDT methods is to show the condition of the material or component. For this purpose, the interactions of the material with electromagnetic or mechanical waves are utilized. The NDT methods available at the ILK can be classified into the following groups:

NDT with electromagnetic waves
X-ray computer tomography
Shearography
Optical measurement and by eye inspection
Thermography

NDT with mechanical waves
Ultrasound: Impuls-Echo, transmission, water coupling, air coupling
Ultrasound microscopy
Acoustic emission
Vibration analysis

The ILK has particular expertise in the field of **X-ray computer tomography (xCT)**, which in principle can be used to detect all relevant defects in fibre composites. However, this method is limited in terms of spatial resolution, the ability to contrast defects and the analysis of large components. We therefore have three devices in use that complement each other's capabilities in this respect: We achieve the highest resolution of approx. 1 µm with the Nanotom, and we can examine particularly large or heavy components with the V|tome|x 450L. In order to contrast microcracks, which are often closed in the unstressed state, the ILK can use the in-situ computed tomograph, which was developed in-house. With this equipment, samples can be examined under mechanical loads such as tension, compression or torsion at resolutions from 5 µm voxel size. Load tests with accompanying xCT can be used to observe the initiation and evolution of cracks in discrete stages (Fig. 02). However, scan times of up to one hour have to be considered for high-contrast tomograms. Fast processes such as manufacturing, deformation and structure formation processes can nevertheless be explored by recording an "x-ray film" – but at the price of losing depth information.

Cost-effectiveness for xCT in series can be achieved, for example, by using fast xCT, which requires only a few minutes for a scan, in combination with group examinations. A considerable competitive advantage results from the higher information content due to the volume resolution compared to classical ultrasound examinations.

For further improving this xCT potential, the ILK is focusing on two priorities in its development: (1) reducing image artefacts during acquisition, for example through helical CT or the use of filters, and (2) improving image evaluation through the use of methods of 3D image correlation, correlative image analysis and the deeper integration of simulation results.

In contrast to xCT, **NDT with ultrasound** has a longer tradition and is widely established in materials testing. There are different variations of the method. The use of air-coupled ultrasound in a transmission arrangement is very efficient due to the low sample preparation effort, especially for the analysis of flat, small to medium size structures. Its spatial resolution is usually sufficient for the detection of all technically relevant defects such as delaminations, pore fields or dry spots. The disadvantage is that it usually cannot be used to inspect sandwich components and indicate the depth of the defect. In such cases, the pulse-echo method is clearly at an advantage, which can also be used with only one-sided accessibility. Its often lower efficiency can be compensated for by

phased array units, if necessary. The ILK also has an ultrasound microscope for special tasks that require an inspection with very high spatial resolution. Special test setups have already been developed at the ILK for specific industrial tests, for example to measure the residual wall thicknesses in coated pipes from the inside or to determine the stiffness tensor and its change as a result of material damage. The research goals we are currently pursuing with regard to ultrasonic methods include firstly the reliable determination of stiffness even in the case of strongly damping or viscoelastic materials, secondly the improvement of defect detectability and thirdly the coupling with simulation results.

Thermography is another exciting method available at the ILK. Lock-in and pulse-phase thermography are particularly suitable for non-destructive testing of fibre composites. Both process variants are also suitable for inline testing and test specimens with larger dimensions. The methods are suitable for detecting the same defect classes as can be detected with ultrasonic testing, although they can scan larger areas more efficiently. The ILK's research interest in the field of thermography is firstly focused on the improvement of defect detectability and secondly the automated selection of inspection parameters based on numerical simulations and through the use of machine learning.

A less common method of NDT is **shearography**. In this method, structures are illuminated by coherent laser light, creating a characteristic speckle pattern on the component surface. Excitation of the structure, for example with ultrasound, infrared radiation, local pressure or mechanical stress, induces a deformation that can be measured and displayed by comparing the interference pattern to the reference state. The inhomogeneities that become visible in the process can indicate defects. Shearography offers three major advantages: Firstly, it can achieve a high measurement resolution even for large components. Secondly, it is independent of material properties, and thirdly, it is relatively insensitive to environmental influences. The fact that the method targets deformation differences, i.e. ultimately stiffness changes in the tested structure, means that defects that endanger component integrity can be reliably detected. At the ILK, application-oriented methods for automated parameter setting and defect detection have recently been developed in particular, which are now available with a transportable measuring system (laser class 1) that can be used in the field.

To round off the ILK's expertise in the field of dimensional, positional and shape deviations, but also surface topology, a variety of **optical measurement systems** are used that cover different measurement volumes. Other methods such as **vibration analysis**, **strain measurement with fibre sensors** and **acoustic emission analysis** open up the ILK's competences in the field of NDT in the direction of structural health monitoring (SHM).

With the equipment available, the methods and concepts developed, the ILK has built up a wide-ranging field of expertise in quality assurance for diverse lightweight structures and the associated manufacturing processes. So if you are asking yourself “Can this also be tested?” then please feel free to contact us – **testing is our area of expertise**.

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Expert group:
Testing methods and material models

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Selected Projects

FATIIGUE

Experimental and numerical modeling of micro crack induced delaminations under reversed cyclic loading

The project FATIIGUE aims on establishing a deep understanding of the damaging process by micro crack induced delamination growth in fiber reinforced plastics. In case of static and cyclic loading extensive experiments in terms of fracture mechanics as well as laminate coupon test are conducted.

Therefore exisiting experimental methods are customized and algorithms for the evaluation of crack length and delamination area by use of optical methods will be developed (Fig. 01).

Based on the experimental results, numerical simulations are established by the Institute of Structural Analysis (ISD, Fig. 02). The delamination process will be described in terms of adjusted cohesive zone models, which are calibrated by the results of the fracture mechanical tests. To transfer the calibrated cohesive models to laminates, they will be extended specifically for reversed loading conditions.

Finally, it will be verified either micro crack induced delaminations in composite cross-ply laminates can be modeled directly from fracture mechanics results or new testing methods, which satisfy the requirements of the loading conditions in laminates, have to be developed.

Period

01.09.2021 – 31.08.2023

Project management

Prof. Dr.-Ing. habil. Maik Gude

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Gordon Just

Project partners

Institute of Structural Analysis (ISD)
at Leibniz Universität Hannover (LUH)

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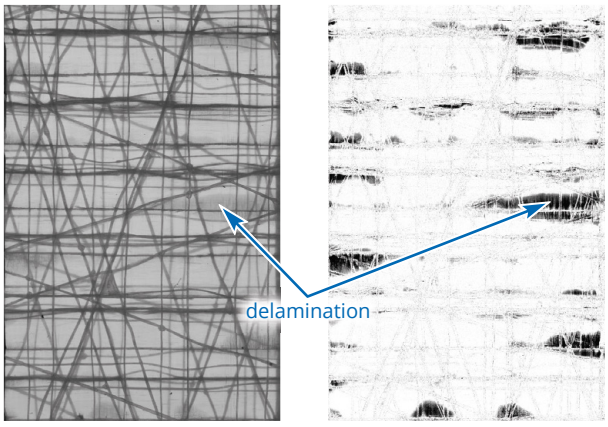


Fig. 01 Transmitted white light image of a delaminated specimen (left) and increased delamination detectability by image normalization (right).

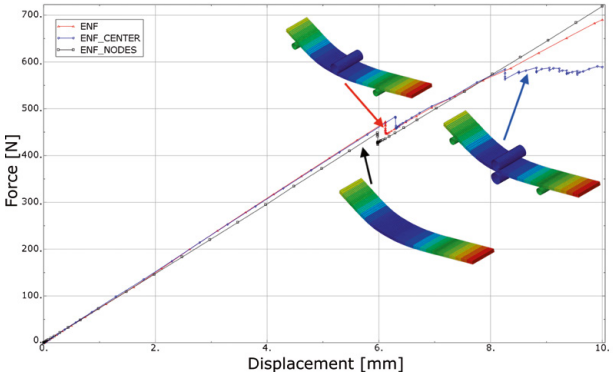


Fig. 02 Numerical study on the influence of loading conditions for ENF tests.

Hybsch

Design development and technology synthesis for the production of cellular hybrid plastic structures for application in acoustic resonators

In the course of the Hybsch project, the Institute of Lightweight Structures and Polymer Technology at the TU Dresden is striving to develop novel cellular core structures. For this purpose, the integration of flexible walls enables the targeted application of the core in acoustic liners for the reduction of sound emissions. Furthermore, the integration of fiber-reinforced tapes increases the compressive strength compared to similar core structures.

In this context, the manufacturing realization of the hybrid core structure within a continuous process is investigated, taking into account the structural-mechanical as well as acoustic specifications. Thereby, the sub-process steps of the tape application, the partial cutting as well as the forming are examined in detail. The work done so far focused on the development and description of cellular curved core structures suitable for continuous manufacturing. In addition, a structural mechanics analysis of cell configurations with varying characteristics of the reinforcing structure has been carried out. In experimental analyses, the process steps "tape application" and "forming" were investigated and suitable process parameters were defined.

Period

01.04.2021 – 31.03.2023

Project management

Prof. Dr.-Ing. Niels Modler

Contact

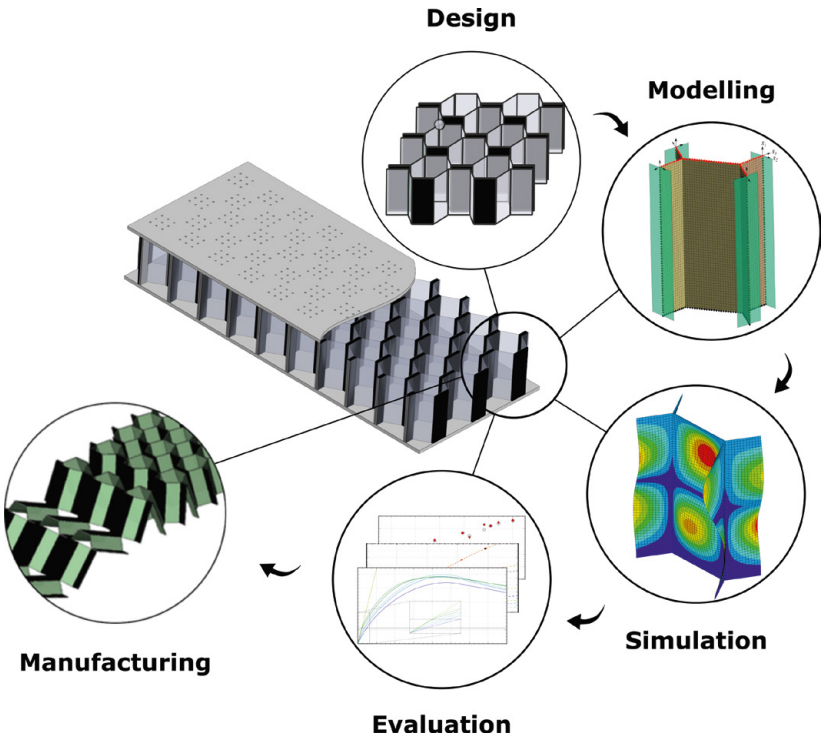
Moritz Neubauer

Funding

Funded by

Deutsche Forschungsgemeinschaft
German Research Foundation

German Research Foundation (DFG)
Project number: 416814415



Analysis steps of the studies on cellular core structures.

SFB/TRR 285 - C04

Local and integral in-situ analysis of process- and operation-related damage effects of joints

The deformation and damage phenomena during the manufacture and testing of mechanical joints cannot yet be directly observed and characterized in detail due to the limited accessibility of the joint. Instead, a joint must first be unloaded, specimen must be prepared destructively e.g. for micrographs and are then analyzed to evaluate the consequences of a load. In this ex-situ analysis, elastic deformations reset as a result of unloading, whereby cracks that have been introduced potentially close and thus can only be detected to a limited extent.

The aim of the ILK in the TRR285 subproject is the development of a non-destructive in-situ testing method for mechanical joints. For a high-resolution analysis, a novel experimental method using X-ray computed tomography (in-situ CT) is being developed. This method allows the three-dimensional observation of the joining zone during the joining process or loading. For this purpose, in-situ joining and testing devices were developed and successfully put into operation on the basis of preliminary experimental investigations. Initial in-situ clinch and tensile shear tests have already demonstrated the potential of the new testing method; see Fig. 01 and Fig. 02.

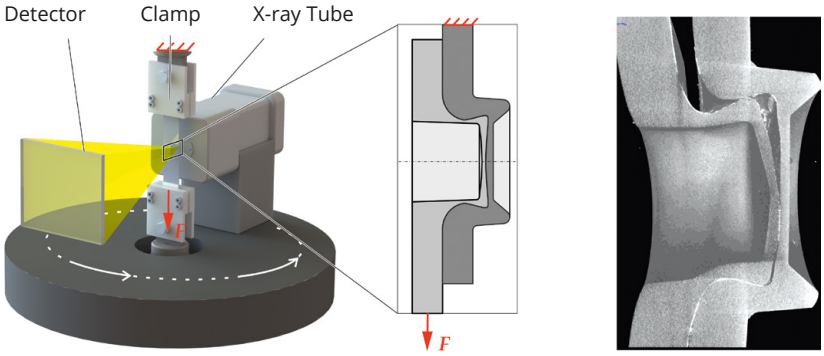


Fig. 01 In-situ test setup (left) and reconstructed 3D image of an aluminum clinch joint under shear loading (right).

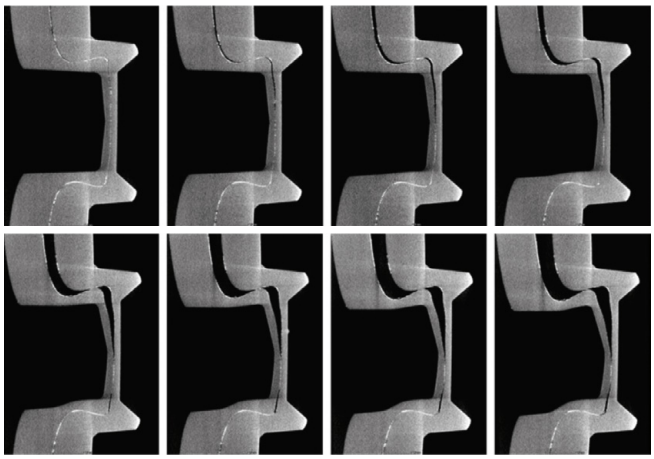


Fig. 02 Series image of an aluminum clinch joint under increasing load.

Period

01.07.2019 – 30.06.2023

Project management

Dr.-Ing. Robert Kupfer

Contact

Daniel Köhler
Juliane Troschitz

Project partners

Chair of Forming Processes (FF) at the Institute of Manufacturing Science and Engineering (IF) at the TU Dresden

Funding

Funded by

DFG Deutsche Forschungsgemeinschaft
German Research Foundation

German Research Foundation (DFG)
Project number: 418701707 – TRR 285

SFB/TRR 285 - A03

Calculation and evaluation of process-induced material structure phenomena in FRP-metal connections

The connection of lightweight structures made of fibre-reinforced plastic (FRP) with thermoplastic matrix in complex assemblies with dissimilar materials is a challenging task. However, the specific material properties of the FRP enable the development of novel joining technologies with dissimilar joining partners. The joining processes are accompanied by local changes in the material structure of the FRP. Within the framework of the sub-project, the change of the local material structure during joining are investigated both experimentally and numerically. A simulation chain from the joining process to the evaluation of these FRP-metal joints is being developed. For this purpose, a technology map of all continuous fibre-reinforced FRP clinching processes was created. A phenomenological investigation was carried out on a hotclinch joint by means of computer tomography images. The numerical description of such forming phenomena was tested and verified on moulding processes of FRP into a contoured mould. Hereby, the combination of the Euler-Lagrange approach with microscopic modelling could already show the potential to predict the resulting material structure. In the further course of the project, the obtained numerical elaborated modelling approaches are to be validated with newly developed test environments.

Period

01.07.2019 – 30.06.2023

Project management

Prof. Dr.-Ing. habil. Maik Gude

Contact

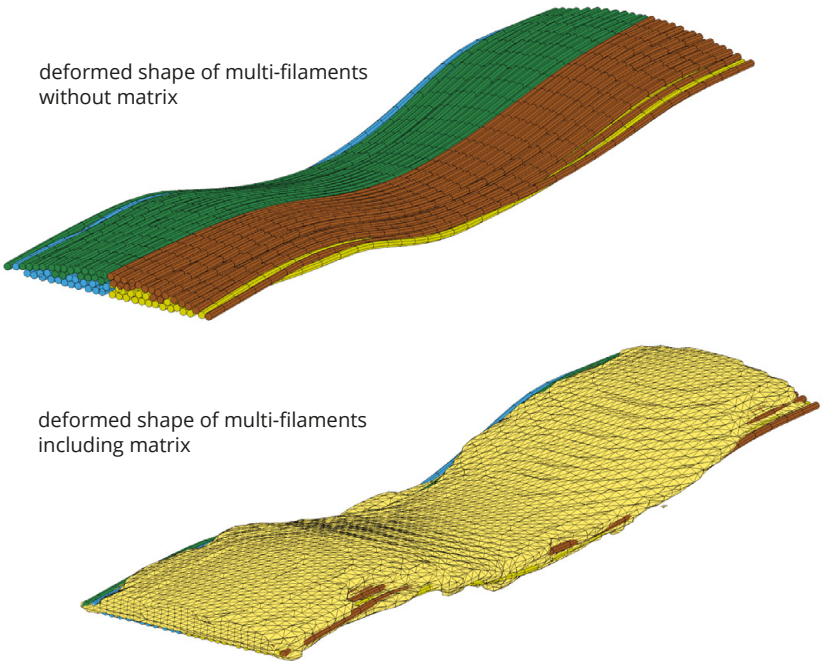
Dr.-Ing. Andreas Hornig
Benjamin Gröger

Funding

Funded by

DFG Deutsche Forschungsgemeinschaft
German Research Foundation

German Research Foundation (DFG)
Project number: 418701707 – TRR 285



Source: [1]

Numerical forming by using an Eulerian-Lagrangian-Approach on microscale.

[1] Gröger, B.; Würfel, V.; Hornig, A.; Gude, M. Forming process induced material structure of fibre-reinforced thermoplastics – Experimental and numerical investigation of a bladder-assisted moulding process. Journal of Advanced Joining Processes, Volume 5, 2022, 100100. https://doi.org/10.1016/j.jajp.2022.100100.

Insert

Simulation-assisted development of material-, load- and process-specific inserts for thermoplastic composites

The application of metallic load introduction elements as a reliable and efficient joining technique for composites is widely accepted in most areas of lightweight design. To date, such inserts either have to be embedded with high effort during component manufacturing or need an additional process step for integration. By means of a novel automated process inserts now can be integrated into thermoplastic composite during component manufacturing using warm forming technology.

Throughout this process, the reinforcing fibres are reoriented by a tapered pin, resulting in a complex material structure with locally varying fibre orientations and fibre volume content. In the design process of such joints, the material structure in the load introduction zone has to be considered to enable a reliable description of the load-bearing behaviour. Hence, within this project an experimentally-assisted numerical characterisation method for warm formed joining zones is developed. For this purpose, the local fibre orientations and fibre volume contents in the load introduction zone are determined using computed tomography. Subsequently, the local mechanical properties of the material can be calculated and transferred into a finite element model. This provides the possibility for realistic depiction of the deformation and damage behavior of the load introduction zone.

Period

01.07.2019 – 31.03.2022

Project management

Prof. Dr.-Ing. habil. Maik Gude

Contact

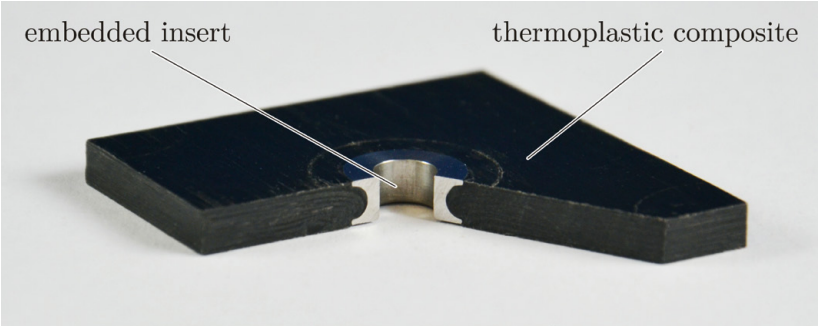
Juliane Troschitz
Dr.-Ing. Robert Kupfer

Funding

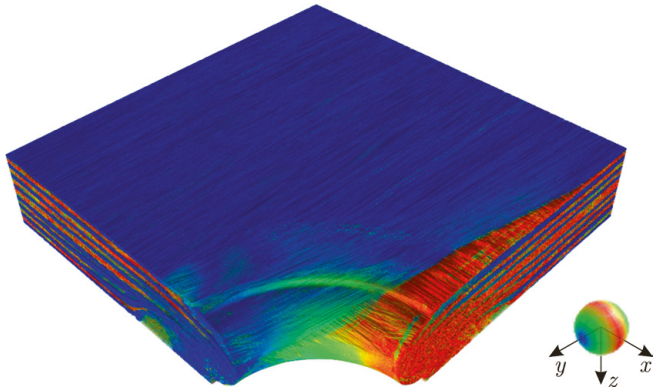
Funded by

DFG Deutsche Forschungsgemeinschaft
German Research Foundation

German Research Foundation (DFG)
Project number: 408132410



Thermoplastic composite with embedded insert.



Analysis of local fibre orientations for transfer to simulation models.

InSituRotor

Investigation of damaged fibre-reinforced high-speed rotors using in-situ measurement systems

The relationship between damage state and dynamic behaviour of fast rotating composite rotors was investigated within this collaborative project. This required the development of novel measurement systems that allow the simultaneous in-situ measurement of damage state and vibration behaviour during rotation. The in-plane strain field and the out-of-plane vibration were measured by optically reading out diffraction grating sensors on the rotor surface (see Fig. 1). The measurement of strain fluctuations on the rotating composite disc demonstrated that the crack propagation can be tracked spatially resolved and as a function of the rotational velocity, which allowed an in-situ quantification of the damage state of the rotor. Using optical coherence tomography (OCT), high-resolution three-dimensional images were taken in order to investigate the cracks, their propagation as well as the opening and closing process in composite samples. Furthermore, the OCT system allowed the visualization of the composite rotor and its textile architecture under rotational load (see Fig. 2). These experimental results were used to validate numerical models that describe the velocity-dependent damage state and the resulting change in vibration behaviour.

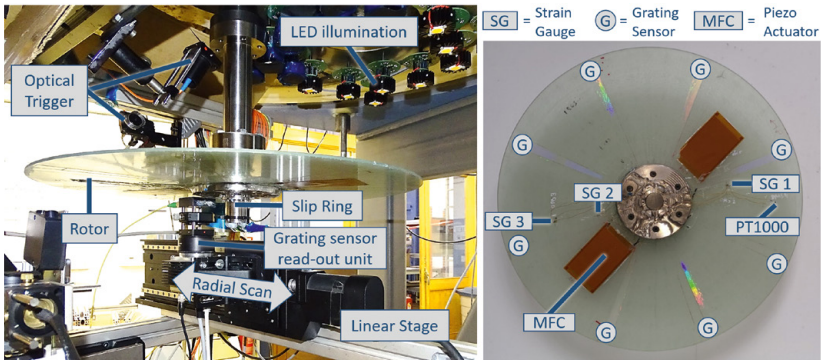


Fig. 01 Test setup for measurements using a diffraction grating sensor (left) and composite rotor with applied sensors and excitation system (right).

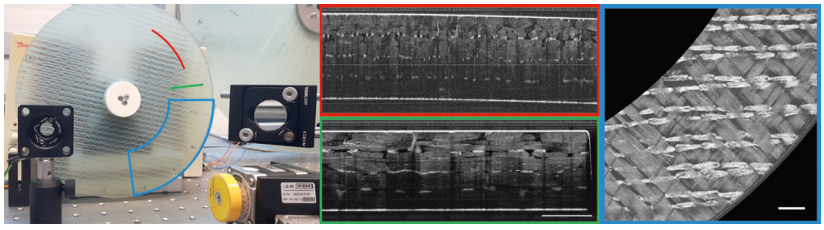


Fig. 02 Sections from the three-dimensional acquisition of the composite disc using OCT.

Period

01.06.2017 – 31.07.2021

Project management

Prof. Dr.-Ing. habil. Maik Gude

Contact

Tino Wollmann
Dr.-Ing. Angelos Filippatos

Project partners

- Laboratory for Measurement and Sensor System Technique (MST) at the Institut of Principles of Electrical and Electronic Engineering at the TU Dresden
- Clinical Sensoring and Monitoring (KSM) at the Faculty of Medicine Carl Gustav Carus at the TU Dresden

Funding

Funded by

DFG Deutsche Forschungsgemeinschaft
German Research Foundation

German Research Foundation (DFG)
Project number: GU 614/14-1

MALAGA

Tailored metal-polymer-metal laminates for improved energy absorption characteristics of crash structures

Metal-polymer-metal (MPM) composites combine the advantages of their individual components and thus achieve a better mechanical property profile than conventional metal sheets, such as higher specific stiffness and strength. This predestines MPM composites for use in crash-relevant components. However, consistent modelling and computation of the deformation and failure behaviour of hybrid components is currently still a major challenge.

Therefore, a scale-spanning modelling and characterisation strategy for MPM composites was developed within the MALAGA project, which enables the targeted adjustment of the failure behaviour of highly dynamical loaded MPM structures.[1] On the one hand, the influence of the trigger concept on the axial crash behaviour[2] and, on the other hand, the influence of the adhesive strength between metal and polymer on the energy absorption capacity were investigated experimentally and numerically[3]. Furthermore, the developed approach could be successfully transferred to bending-loaded hat profiles.[4]

Period

01.10.2018 – 31.12.2020

Project management

Prof. Dr.-Ing. habil. Maik Gude

Contact

Moritz Kuhtz
Jonas Richter

Project partners

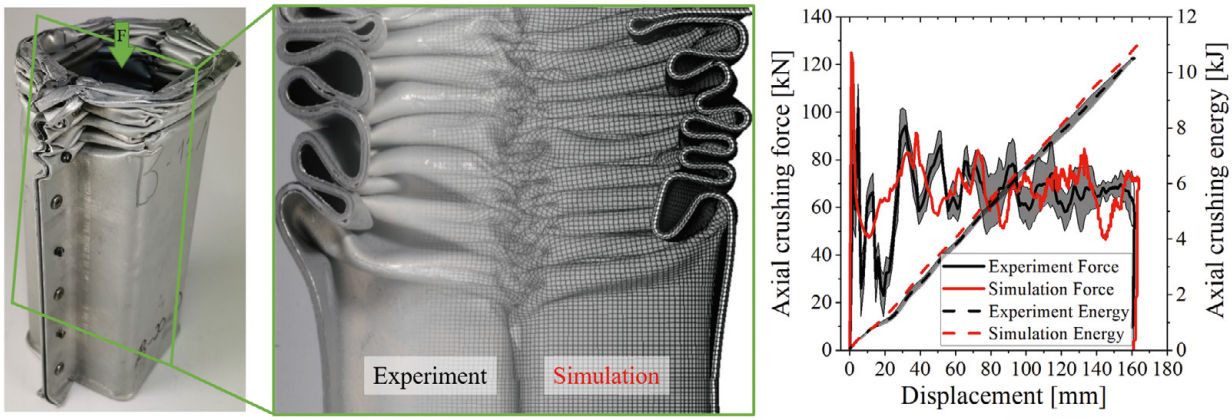
Institute of Metallurgy (IMET)
at the TU Clausthal (TUC)

Funding

Funded by

DFG Deutsche Forschungsgemeinschaft
German Research Foundation

German Research Foundation (DFG)
Project number: 407352905



Source: [2] modified

Experimental and simulative investigation of the failure behaviour of highly-dynamical loaded MPM-composites.

[1] Richter, J.; Kuhtz, M.; Hornig, A.; Harhash, M.; Palkowski, H.; Gude, M. A Mixed Numerical-Experimental Method to Characterize Metal-Polymer Interfaces for Crash Applications. Metals 2021, 11, 818. https://doi.org/10.3390/met11050818.

[2] Harhash, M.; Kuhtz, M.; Richter, J.; Hornig, A.; Gude, M.; Palkowski, H. Trigger geometry influencing the failure modes in steel/polymer/steel sandwich crashboxes: Experimental and numerical evaluation. Composite Structures, Volume 262, 2021, 113619. https://doi.org/10.1016/j.compstruct.2021.113619.

[3] Harhash, M.; Kuhtz, M.; Richter, J.; Hornig, A.; Gude, M.; Palkowski, H. Influence of Adhesion Properties on the Crash Behavior of Steel/Polymer/Steel Sandwich Crashboxes: An Experimental Study. Metals 2021, 11, 1400. https://doi.org/10.3390/met11091400.

[4] Harhash, M.; Fischer, T.; Grubenmann, M.; Hua, W.; Heingärtner, J.; Kuhtz, M.; Gude, M.; Hora, P.; Ziegmann, G.; Palkowski, H. Top-hat crashboxes of thermoplastic fibre-metal-laminates processed in one-step thermoforming: Experimental and numerical study. Composites Part B: Engineering, Volume 226, 2021,109367. https://doi.org/10.1016/j.compositesb.2021.109367.

LignoBraid

Biobased lightweigth hollow profiles with braided wood tapes

With its distinctive anisotropy and high specific stiffnesses, wood offers great application potential for resource-saving lightweight design. In contrast to classic fiber composites such as glass-fiber reinforced plastics, however, it has so far only been possible to a limited extent to produce geometrically complex wooden lightweight hollow profiles with a load path-adapted fiber orientation. The aim of the FNR project LignoBraid is to overcome this deficit by establishing a closed process chain from the production of continuous wood tapes, through their processing into preforms with defined fiber orientation using the braiding process, to the manufacture of lightweight hollow profiles.

For this purpose, veneer sheets are first joined into continuous bands, cut to a defined width and made available for the braiding process. This has to be adapted to the specific requirements of the wood tapes and a parameter set identified for high-quality and efficient processing. The preforms produced in this way are then infiltrated with bio-based plastics, with the aim of reducing the amount of plastic used to a minimum. Thus, the inherent light properties of the wood can be used to advantage. The developed process chain will finally be evaluated in collaboration with a consortium from industry with regard to its ecological and economic advantages.

Process chain: From the production of the wood tapes to the finished hollow profile.

Period

01.03.2021 – 31.08.2023

Project management

Prof. Dr.-Ing. habil. Maik Gude

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Dr.-Ing. Robert Kupfer
Alexander Liebsch

Project partners

Chair of Wood and Fibre Material Technology (HFT) at the Institute of Natural Materials Technology at the TU Dresden

Funding

Supported by:

Federal Ministry of Food and Agriculture

on the basis of a decision by the German Bundestag

Federal Ministry of Food an Agriculture (BMEL)

Funding code: 2220HV059B

Managed by:

FNR
Fachagentur Nachwachsende Rohstoffe e.V.

Agency for Renewable Resources (FNR)

FAVILEIT

Development of a test stand for the simultaneous characterization of fibers and yarns, regarding their electrical and mechanical properties

The rapid development of the smart textiles sector enables a new dimension of functional integration and creates the preconditions of an innovative design for the future. In addition to the use in consumer goods such as heated clothing, also technical e-textiles with integrated electronic and sensory functions can be developed and have a broad range of applications. An enhanced fibre composite component with sensory functions enables monitoring the conditions of critical structural components (SHM) and damage detection in an early stage. For the selection and development of suitable fibre materials, the electrical and mechanical properties of the fibres have to be known. Currently, there is no standardised or commercially available testing machine for the combined determination of these properties. The project FAVILEIT wants to close this gap within a two year ZIM-Project in cooperation with the Textechno Herbert Stein GmbH & Co. KG. Thereby, a suitable test method for the simultaneous characterisation of the mechanical and electrical properties of electrically conductive fibres in a single device is developed and implemented in the world's leading fibre testing device FAVIMAT+. In the second project phase, the developed technology will also be implemented in an automatic tensile tester for yarns of the STATIMAT series.

Single fiber tester FAVIMAT+ with automation unit AIROBOT2 (right) and enlarged illustration of the measuring field (left).

Period

01.04.2021 – 31.03.2023

Project management

Prof. Dr.-Ing. Niels Modler

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Christoph Hildebrand
Tom Ehrig

Project partners

Textechno Herbert Stein GmbH & Co. KG

Funding

Supported by:

Federal Ministry for Economic Affairs and Climate Action

ZIM Zentrales Innovationsprogramm Mittelstand

on the basis of a decision by the German Bundestag

Federal Ministry for Economic Affairs and Climate Action (BMWK): Central Innovation Programme for SMEs (ZIM)

Funding code: KK5047604DF0

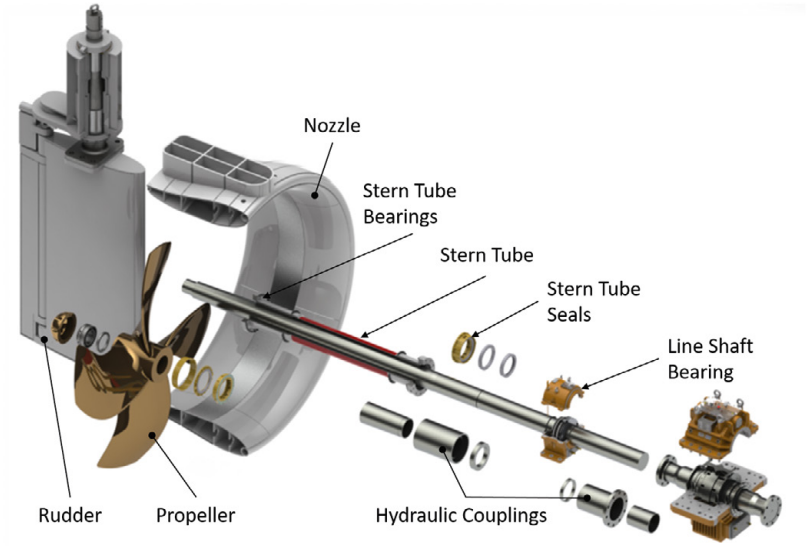
Managed by:

AiF Projekt GmbH, Subsidiary of the German Federation of Industrial Research Associations “Otto von Guericke” e. V. (AiF)

PRILLIAND

Development of an additive production technology for manufacturing plastic-based components for maritime applications

Maritime sealing systems are subject to high mechanical and media stresses and are essential for the safe and economical operation of ships. The "sterntube system" is defined as the components of the ship's shaft system that support the drive shaft in the boat's hull and at the same time prevent seawater from penetrating through the drive shaft channel. Due to the varying sizes of the individual components of the sterntube system and their small quantities per ship, they have been produced as large-scale constructions in metallic cast alloys in a time-consuming and cost-intensive reworking process. The joint project PRILLIAND therefore aims to make the conventional production of the highly customized product solutions for the sterntube system components available on the market more efficient in both economic and ecological terms. Through the use of innovative additive manufacturing technologies in combination with modern lightweight materials, selected components of the sterntube system will be rethought and designed in a way that is both material- and production-oriented. This significantly increases the weight-specific mechanical properties of the previously metallic components. The high degree of customizability that can be achieved at the same time also enables fast and cost-effective adaptation to customer requirements. PRILLIAND consequently provides the basis for efficient low-volume production of rotationally symmetrical large structures for maritime applications.



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Exploded view of a vessel shafting with the main components of the stern tube system.

Period

01.04.2021 – 31.03.2024

Project management

Prof. Dr.-Ing. habil. Maik Gude

Contact

Johanna Maier
Tobias Kastner

Project partners

Wärtsilä Deutschland GmbH

Funding

Supported by:

Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag

Federal Ministry for Economic Affairs and Climate Action (BMWK): Maritime Research Programme of the Federal Government

Funding code: 03SX544B

Managed by:

Projektträger Jülich Forschungszentrum Jülich

Projektträger Jülich (PTJ)

KORESIL

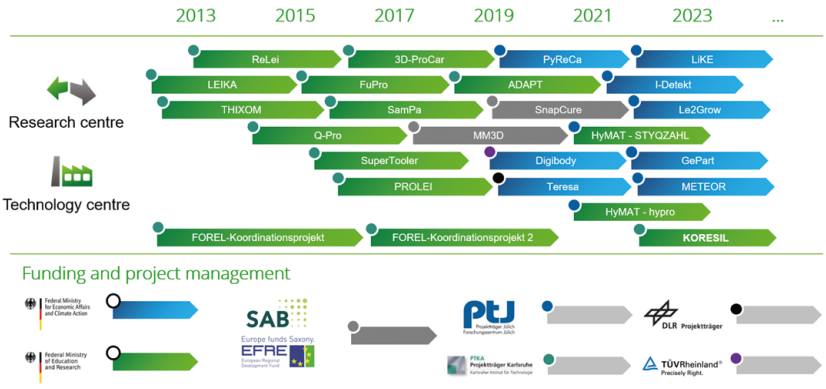
Concepts for the resource-efficient and reliable fabrication of lightweight structures

The project KORESIL strives for technological and social innovations. The project partners realise a process chain including five sub-technologies and a closed material-loop. In parallel, a virtual copy of this process chain is modelled. The coupling of these two dimensions by adapted interfaces enables an in-depth analysis and optimization of the whole process chain. By this, an improved resource efficiency as well as novel concepts and tools for work space design and staff training become possible.

At ILK, we analyse socio-technical interactions using the example of a manufacturing cell for the robot-assisted injection moulding onto profiles, under due consideration of digitalisation, automatisation and humans. The results are used to derive instructions for the optimised design of working places and training measures. This provides the basis for the development and testing of adapted VR/AR-tools for the efficient transfer of information in real and digital production environments.

Fields of activity and closed material-loop within the project KORESIL.

The acquired solutions support the activities in the research and transfer projects of the Plattform FOREL, Germany's biggest R&D-network in lightweight engineering. Within this network, ongoing systematic research and cross-project exchange fosters the closing of existing knowledge gaps in the genesis of resource-efficient lightweight structures.



FOREL project portfolio 2013–2021.

Period

15.02.2021 – 31.01.2024

Project management

Prof. Dr.-Ing. habil. Maik Gude

Contact

Dr.-Ing. Daniel Weck
Michael Müller-Pabel

Project partners

- Laboratory for material and joining technology (LWF) at the Paderborn University (UPB)
- Institute for Machine Tools and Industrial Management (*iwb*) at the TU Munich (TUM)
- Institute of Mineral Processing Machines and Recycling Systems Technology (IART) at the TU Bergakademie Freiberg
- Institute of Forming Technology and Lightweight Components (IUL) at the TU Dortmund

Funding

Supported by:

Federal Ministry of Education and Research

on the basis of a decision by the German Bundestag

Federal Ministry of Education and Research (BMBF): Programme „Innovationen für die Produktion, Dienstleistung und Arbeit von morgen“

Funding code: 02P20Z000 to 02P20Z004

Managed by:

PTKA Projektträger Karlsruhe im Karlsruher Institut für Technologie

Projektträger Karlsruhe (PTKA)

MonStrain

Development of a novel spatially resolved carbon fiber-based strain measurement system for real-time structural health monitoring and validation of load assumptions

Vision of the novel carbon fiber-based spatially resolved strain sensor in the targeted generic wing demonstrator.

Within the MonStrain project, the ILK is striving to research a novel carbon fiber sensor for strain measurement and its integration into a generic airfoil demonstrator. The aim is to provide sensors of several meters in length with a spatial resolution in the single-digit millimeter range, which can be successfully used in small aircrafts.

The measurement principle of the sensor is based on spatially resolved resistivity determination of a pre-damaged carbon fiber roving by electrical time domain reflectometry. Until now, the length of these sensors has been limited to 15 cm due to the high base resistance of the carbon fibers, which is why the project is particularly aimed at scaling up to longer measurement lengths.

Initial results show that the base resistance is massively reduced by using metal-coated carbon fibers. This allows the possible measurement length to be increased while retaining the fiber character and the associated sensor properties.

In order to be able to realize a realistic demonstration at the end of the project, real loads from gliders were analyzed together with Akaflieg Dresden and the data was adopted as boundary conditions for the generic airfoil demonstrator.

Period

01.01.2021 – 30.06.2024

Project management

Prof. Dr.-Ing. Niels Modler

Contact

Jan Condé-Wolter
Philip Steinbild

Project partners

Akaflieg Dresden e. V.

Funding

Supported by:

Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag

Federal Ministry for Economic Affairs and Climate Action (BMWK): Federal Aviation Research Programme LuFo VI-1, Funding line “Eco-efficient aviation and disruptive technologies”

Funding code: 20E1904

Managed by:

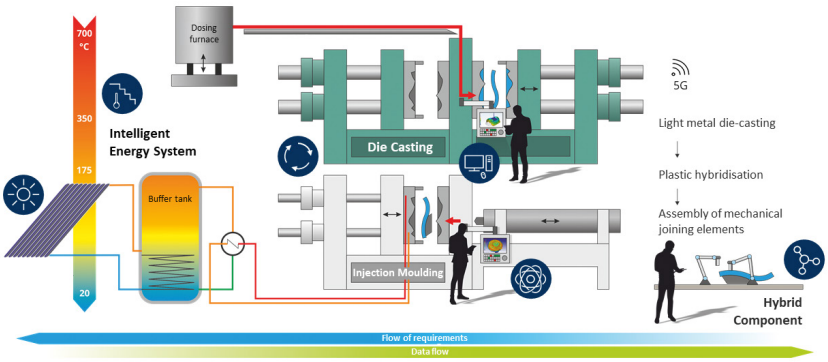
DLR Projektträger

German Aerospace Center (DLR)

METEOR

Methods and technologies for validating and optimizing the ressource efficiency of process networks in the production of hybrid lightweight structures

In order to demonstrate the CO_2 savings potential of combined casting processes that can already be realised today, the development and setup of a novel solar thermal tool heating and cooling system is part of the METEOR project. For this purpose, an innovative temperature control cascade is being established for the particularly relevant production chain of a hybrid casting process consisting of light metal die-casting and plastic injection moulding with subsequent mechanical joining. The project requires a real-time inline filling simulation to control the pressure and injection moulding processes actively. The simulation builds the basis to create a continuous virtualised model of the manufacturing processes from the starting material or semi-finished product to the finished hybrid lightweight structure. On the one hand, the effects of process parameter changes are identified and correlated with the properties of the lightweight structures. These lightweight structure properties are in turn subsequently used for the software-supported predefinition of the product properties. On the other hand, this approach opens up the possibility of being able to better assess and control both resource efficiency and CO_2 savings during production in the sense of a life cycle assessment (LCA).



METEOR process network for the production of a hybrid structure.

Period

01.12.2020 – 30.11.2023

Project management

Prof. Dr.-Ing. habil. Maik Gude

Contact

Rebecca Bräuer
Moritz Kuhtz
Tino Mrotzek

Project partners

- Böllhoff Verbindungstechnik GmbH
- KraussMaffei Technologies GmbH
- technotrans-solutions GmbH
- Institute of Product Engineering (IPE) at the Universität Duisburg-Essen (UDE)
- Laboratory for material and joining technology (LWF) at the Paderborn University (UPB)

Funding

Supported by:

Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag

Federal Ministry for Economic Affairs and Climate Action (BMWK): Technology Transfer Programme Lightweight Construction (TTP LB), FL2: CO_2 savings and CO_2 capture through the use of new construction techniques and materials, FL4: Demonstration plan

Funding code: 03LB2010A

Managed by:

Projektträger Jülich
Forschungszentrum Jülich

Projektträger Jülich (PTJ)

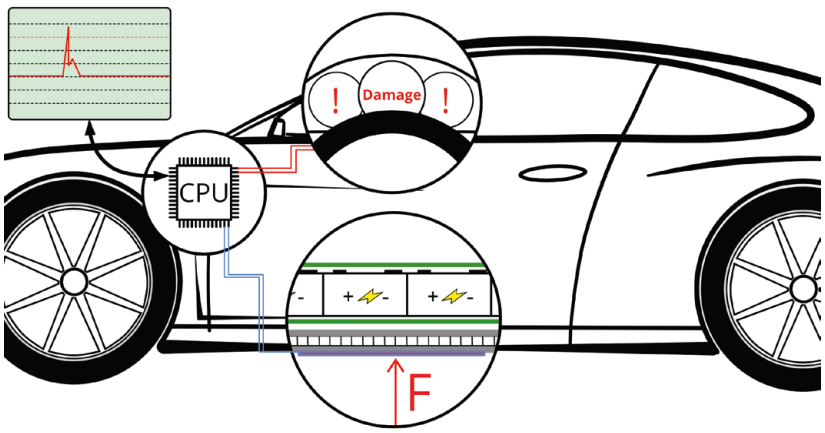
I-Detekt

Intelligent battery protection system for electric vehicles for detection of undesired mechanical damage

In the I-Detekt project, an intelligent battery protection structure for electric vehicles made of glass-fibre reinforced plastic is being developed. This can be used to automatically detect and classify relevant damage to the overlying battery module. Thanks to a structure-integrated sensor system, it is also possible to determine the exact extent of the damage by applying a mechanical load. This type of diagnosis will make it possible in future to carry out service activities and component changes no longer according to fixed time intervals, but only when it is demonstrably necessary.

For the technological implementation of the sensor-based battery protection structure, it is first necessary to consider potential manufacturing technologies for the fibre-composite-compatible integration of electronic components. In addition to the integration technology, the electrical contacting of the components using printed conductors needs to be investigated. Another focus is the description of occurring damage events, which includes the acquisition of suitable measurement signals, their processing and evaluation, as well as the correlation to the actual event.

The aim of the project is the automated production of a generic product demonstrator in the form of a fibre composite structure with specifically selected and integrated sensors on which suitable production technologies can be demonstrated and a validation or iterative adaptation of evaluation algorithms for damage analysis can be shown.



Principle illustration of an intelligent electric vehicle battery protection system for the detection of undesired mechanical damage.

Period

01.12.2020 – 30.11.2023

Project management

Prof. Dr.-Ing. Niels Modler

Contact

Florian Lehmann
Dr.-Ing. Anja Winkler

Project partners

- Dr. Ing. h.c. F. Porsche AG
- Audi AG
- Wirthwein AG
- XENON Automatisierungstechnik GmbH
- PRODAT Informatik GmbH
- IZP Dresden mbH
- SPEKTRA Schwingungstechnik und Akustik GmbH Dresden
- Kube GmbH Ingenieurbüro

Funding

Supported by:

Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag

Federal Ministry for Economic Affairs and Climate Action (BMWK): Technology Transfer Programme Lightweight Construction (TTP LB)

Funding code: 03LB2001I

Managed by:

Projektträger Jülich Forschungszentrum Jülich

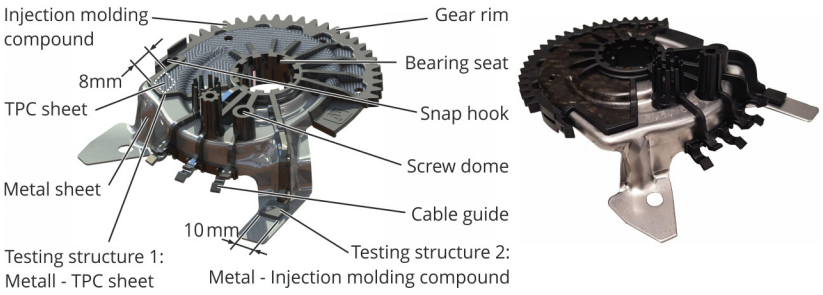
Projektträger Jülich (PTJ)

hypro

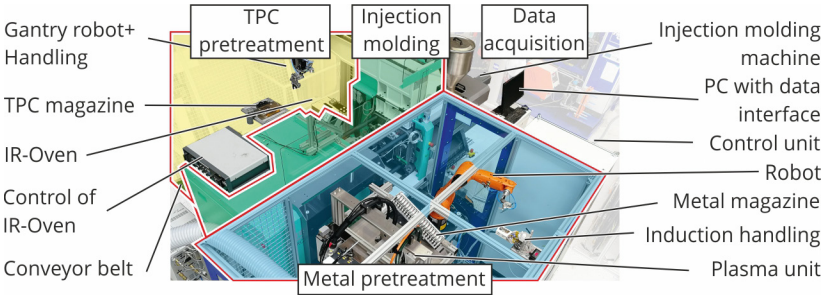
Holistic implementation of hybrid design in series production

Adhesively bonded thermoplastic composite metal structures offer a high potential for weight reduction, especially for geometrically complex and highly loaded lightweight structures. However, to ensure a resistant adhesion between the metal insert, thermoplastic composites (TPC) and injection moulding compound, the metal surface must be carefully pre-treated. Therefore, the production technology for these hybrid structures is currently not competitive and is not yet implemented on an industrial scale.

The BMBF project hypro aims to close this gap and to build up a comprehensive understanding of thermoplastic composite metal structures. For this purpose, a combined physical and virtual process chain is developed. The core of this process chain is an injection molding technology in which deep-drawn metal inserts are combined with prefabricated TPC patches and overmolded with fibre-reinforced plastic. To ensure a highly resilient bond between the plastic components and the metal insert, the metal surface is cleaned and coated inline using plasma technology. During the whole process chain, the component-specific process data are recorded and processed for comprehensive process studies. The combination of physical and simulation data enables computationally based non-destructive inline quality assurance and the prediction of component properties.



Generic hypro hybrid part: concept (left) and manufactured hybrid part (right).



Automated hypro manufacturing cell.

Period

01.05.2020 – 31.10.2022

Project management

Prof. Dr.-Ing. habil. Maik Gude

Contact

Dr.-Ing. Robert Kupfer
Alexander Liebsch

Project partners

- Consortium leadership: Brose Fahrzeugteile SE & Co. KG
- AUMO GmbH
- COBES GmbH
- FEP Fahrzeugelektrik Pirna GmbH & Co. KG
- GK Concept GmbH
- inpro Innovationsgesellschaft für fortgeschrittene Produktionssysteme in der Fahrzeugindustrie mbH
- Plasmatreat GmbH
- Symate GmbH
- Laboratory for material and joining technology (LWF) at the Paderborn University (UPB)

Funding

Supported by:

Federal Ministry of Education and Research

on the basis of a decision by the German Bundestag

Federal Ministry of Education and Research (BMBF)

Funding code: 03XP0284J

Managed by:

Projektträger Jülich Forschungszentrum Jülich

Projektträger Jülich (PTJ)

ReCar

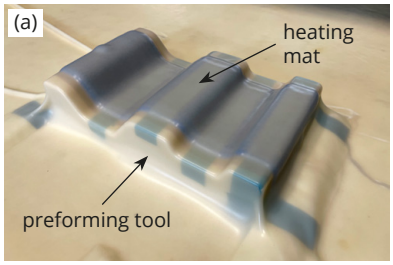
Development of a modular heating system made of recycled carbon fiber nonwovens for use in forming and preforming tools

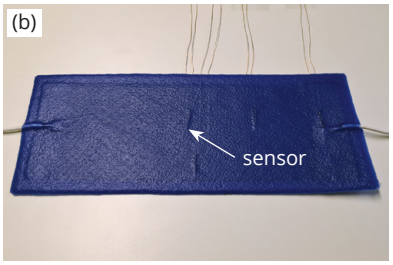
In order to open up new applications of recycled carbon fibers (rCF), the project ReCar aims at the development of a novel heating system made of rCF nonwovens. Therefore, a comprehensive characterization of the electrical properties of rCF nonwovens, among other things, was performed at the beginning of the project.

Based on the preliminary investigations a prototypical heating element in form of a flexible mat was developed along with the corresponding manufacturing process. During this multistage method rCF nonwoven cuttings are electrically contacted and embedded in silicone. The resulting heating mat shows both high flexibility and high surface quality.

Semi-finished products can be heated and formed simultaneously by applying the flexible heating mat. One-sided forming and preforming tools were developed based on this method followed by the conduction of forming experiments of thermoplastic sheet material as well as fixation of textile preforms by binder activation. The required shaping took place in a membrane press. Integration of sensors into the heating mat and a costum-made control interface with temperature regulation enable control of the process temperature.

As the project continues, a modular combinability of the rCF heating elements as well as another preforming tool with permanently integrated rCF nonwovens will be developed and validated.





Preforming tool with applied heating mat inside of a membrane press (a) and flexible rCF nonwoven heating mat with embedded temperature sensors (b). Preform – unidirectional carbon fiber non-crimp fabric – manufactured by heating mat and preforming tool (c).

Period

01.01.2020 – 30.06.2022

Project management

Prof. Dr.-Ing. Niels Modler

Contact

Ron Luft
Tom Dziewiencki

Project partners

- eco2heat GmbH
- Plasta Kunststofftechnik Oederan GmbH

Funding

Supported by:

Federal Ministry for Economic Affairs and Climate Action

ZIM Zentrales Innovationsprogramm Mittelstand

on the basis of a decision by the German Bundestag

Federal Ministry for Economic Affairs and Climate Action (BMWK): Central Innovation Programme for SMEs (ZIM)

Funding code: ZF4024716DF9

Managed by:

AiF Projekt GmbH, Subsidiary of the German Federation of Industrial Research Associations "Otto von Guericke" e. V. (AiF)

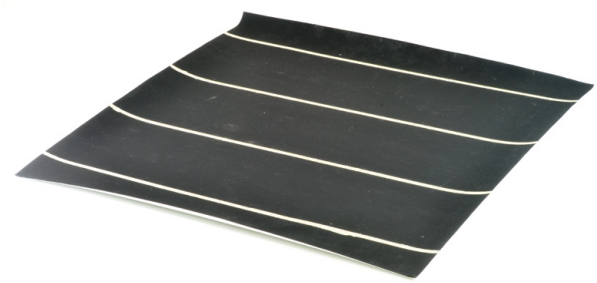
SmartMembrane

Smart membrane pressing technology for manufacturing of high performance composite components of high diversification

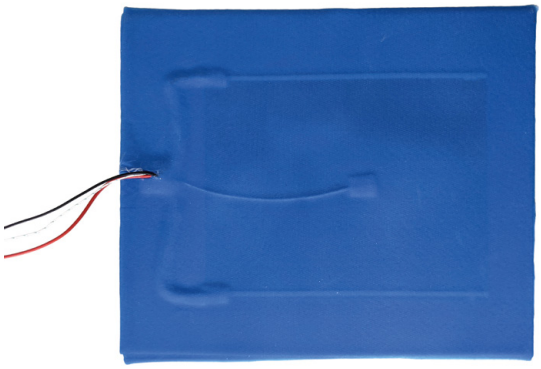
The implementation of FRP products with a high degree of individualisation requires cost-effective manufacturing processes. One main driver for the resulting costs is the tool development and manufacturing.

Within the framework of the German-Polish CORNET project SmartMembrane, a new membrane is being developed for the efficient production of high-performance FRP. The key element is the intelligent and elastic heating membrane, consisting of an elastomer modified with nanomaterials and sensory elements for process monitoring and control. The CNT-modified heating element with adapted electrical and thermal properties, produced in a calendering process, is embedded in the silicone material together with temperature and pressure sensors. These electrical components are additionally contacted with a conductive silicone-based paste. In addition, extensive experimental tests are carried out to characterise the thermal, electrical and mechanical properties of the SmartMembrane. To demonstrate its technological as well as economic potential, the implementation of the membrane in an adaptive tool is an essential part of the project.

The developed membrane enables the production of FRP components with customised properties and reproducible material quality in small series at comparatively low investment costs.



CNT-modified heating element with adapted electrical and thermal properties.



Developed SmartMembrane with integrated heating structure and sensor elements.

Period

01.01.2020 – 30.03.2022

Project management

Prof. Dr.-Ing. habil. Maik Gude

Contact

Rafal Stanik
Tom Dziewiencki

Project partners

- FILK Freiberg Institute gGmbH
- Cluster of Innovative Manufacturing Technologies Association (CINNOMATECH)
- Faculty of Materials Science and Engineering at the Warsaw University of Technology
- Instytut Badawczo Rozwojowy Inotec Sp. z o.o.

Funding

Supported by:

Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag

Federal Ministry for Economic Affairs and Climate Action (BMWK): Programme “Collective Research Networking (CORNET) / Industrial Collective Research (IGF) international“

Funding code: 266 EBR/2

Managed by:

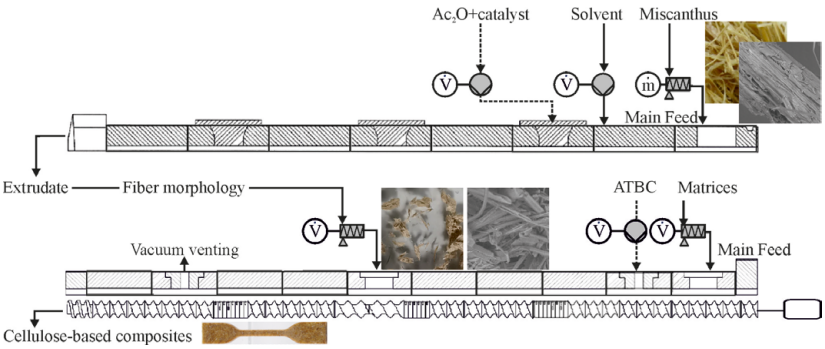
German Federation of Industrial Research Associations “Otto von Guericke” e. V. (AiF)

CeCo

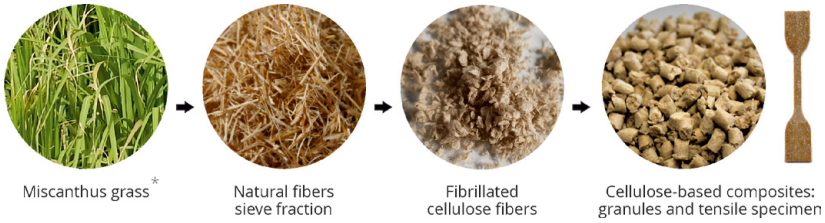
Development of a manufacturing process for novel cellulose-based composites in injection molding

In the project, a two-stage extrusion process for cellulose-based thermoplastic composites is being developed together with the Papiertechnische Stiftung PTS. For this purpose, bio-based polymers are used as matrix and regional miscanthus grass as fiber reinforcement. In the first step, cellulose fibers from the miscanthus grass are fibrillated into micrometer scale and simultaneously chemically modified to improve fiber-matrix compatibility through reactive extrusion. The resulting fiber morphology and degree of chemical modification are analysed and adjusted in the process. In the second extrusion step, the fibrillated cellulose fibers are further processed with cellulose-based matrices such as cellulose acetate (CA) and cellulose acetate butyrate (CAB) to form injection moldable cellulose-based compounds.

Compounds with drop-in biopolymers such as Bio-PP/Bio-PE are used for comparison. The manufactured materials are characterized regarding their mechanical and physical as well as rheological properties. It could already been shown that the all-cellulose composites from biomass achieve comparable mechanical properties to glass fiber-reinforced polypropylene (GF-PP) with similar fiber contents (20-30 weight %).



Two-stage extrusion for the production of all-cellulose compounds.



Material transformation from raw material to composite.
*© Katrin Schneider, korina.info – CC-BY-SA-4.0 / Image detail

Period

01.08.2019 – 30.04.2022

Project management

Dr.-Ing. Robert Kupfer

Contact

Dr.-Ing. Robert Kupfer
Yuanxi Liu

Project partners

Institut für Zellstoff und Papier (IZP)
of the Papiertechnische Stiftung (PTS)

Funding

Supported by:

Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag

Federal Ministry for Economic Affairs and Climate Action (BMWK): Programme "Industrial Collective Research" (IGF)

Funding code: 20338 BR/1

Managed by:

German Federation of Industrial Research Associations "Otto von Guericke" e. V. (AiF)

DECHEMA

Gesellschaft für Chemische Technik und Biotechnologie e. V. (DECHEMA)

ABSOLUT

Automatic bus shuttle – self-organizing between Leipzig and the BMW terminal

© ABSOLUT

Structurally and sensorically enhanced electric vehicles for autonomous driving.

The ABSOLUT project is concerned with the development and approval of two autonomously driving, electrically powered vehicles for a Leipzig test route with driving speeds of up to 70 km/h: a 2nd generation Peoplemover EasyMile EZ10 and a VW eCrafter minibus. Both will be equipped with sensor networks and associated computer technology to record and evaluate traffic and environmental conditions. In addition to cameras, various lidars and radars will be used. Special adapters were designed to integrate these into the supporting structure in a functionally appropriate way. Due to the higher driving dynamic stresses in the EZ10 vehicle structure, new chassis with an increased track width were developed and integrated. This was based on simulation calculations of both the operating loads and the registration-relevant tipping load case. The field of vision problem resulting from the very wide A-pillars led to the concept of a standing fixed driver in the design of the safety driver's workplace. In addition, the vehicle is equipped with a camera/monitor system that reduces the concealed field of vision in compliance with the approval. Further work deals with the Continous Technical Inspection – especially for the EasyMile. For this purpose, risk analyses are carried out to identify failure-critical components and their effect on system behaviour, and concepts for condition recording and assessment are derived from this.

Period

01.01.2019 – 30.09.2022

Project management

Prof. Dr. rer. nat. Hubert Jäger

Contact

Dr.-Ing. Frank Adam

Project partners

- Dresden Institute of Automobile Engineering (IAD) at the TU Dresden
- Institute of Traffic Telematics at the TU Dresden
- Stadt Leipzig
- BitCtrl Systems GmbH
- Ingenieurgesellschaft Auto und Verkehr GmbH (IAV)
- Fahrzeugsystemdaten GmbH (FSD)
- Sedenius Engineering GmbH
- Virtence GmbH
- glts cotech GmbH
- INAVET GmbH
- ApiOmat GmbH

Funding

Supported by:

Federal Ministry for Economic Affairs and Climate Action

IKT FÜR ELEKTROMOBILITÄT

on the basis of a decision by the German Bundestag

Federal Ministry for Economic Affairs and Climate Action (BMWK): Technology programme „ICT for Electric Mobility III“

Funding code: 01ME18001H

Managed by:

DLR Projektträger

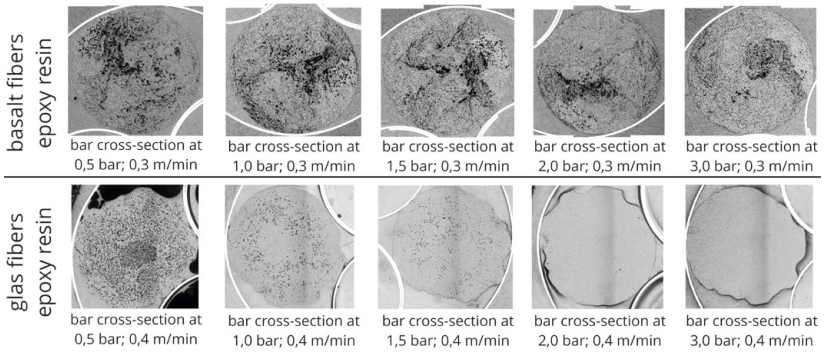
German Aerospace Center (DLR)

Pultix

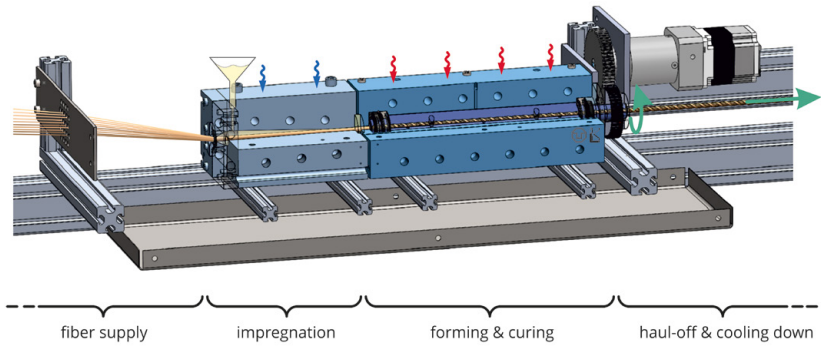
Innovative pultrusion process for the continuous production of thermoset reinforcing bars with helix profiles

Reinforced concrete as a flexibly adaptable material enables versatile applications in civil engineering. Among many advantages, the necessary encapsulation due to the susceptibility of steel reinforcement to corrosion leads to a greater use of concrete than it is necessary for optimal load-bearing behavior. For the most part, concrete consists of resource-intensively produced cement. In contrast, rebars made of fiber composite materials can provide sufficiently high load-bearing properties without corrosion problems.

The main objective was the development of an efficient pultrusion process for manufacturing thermoset composite rebars with a surface topology. Various processes have been considered and evaluated and, finally, the novel primary forming process of helix pultrusion proved to be predestined. For its implementation, methods for impregnating different fibers with different matrix systems were elaborated and experimentally tested, followed by fundamental studies on the curing behavior of resin systems and the forming possibilities of pure resin and fiber composite samples at different degrees of curing and forming temperatures. Based on these results, a combined forming and curing tool for process-integrated realization of the helix-structure has been developed and successfully launched. Finally, the novel process line enabling single-stage pultrusion of profiled thermoset composite rebars has been tested and validated within processing studies.



Comparison of bar cross-sections using microscopy to evaluate the impregnation quality of different fiber systems with different process parameters.



Complex tool for shaping in the helix pultrusion as a detail of the process chain in a partial sectional view.

Period

01.10.2019 – 31.01.2022

Project management

Prof. Dr.-Ing. habil. Maik Gude

Contact

Daniel Wohlfahrt
Sirko Geller

Funding

Supported by:

Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag

Federal Ministry for Economic Affairs and Climate Action (BMWK): Programme "Industrial Collective Research" (IGF)

Funding code: 20853 BR/1

Managed by:

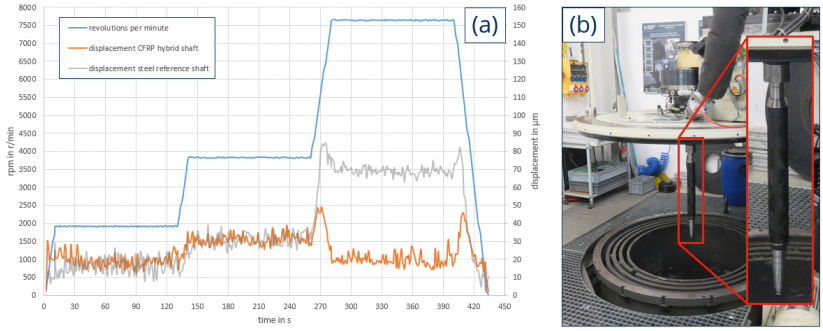
German Federation of Industrial Research Associations "Otto von Guericke" e. V. (AiF)

Composites United Leichtbau-Forschung gGmbH (CU-LF)

LiWeKo

Weight-reduced lightweight clamping devices, tools and components for efficient, highly dynamic machining processes

Machining machines are among the largest energy consumers in industry. Increasing the energy efficiency of machining processes is therefore of the highest relevance. In precision grinding, for example, the energy demand of conventional standard grinding machines can be significantly reduced simply by increasing the machining speed. At present, however, undesirable vibrations occur at high speeds due to the large rotational mass and low damping capacity of the materials used up to now. As a result, the machine components are heavily stressed and the required surface quality or dimensional accuracy on the workpiece cannot be guaranteed. The objevtive of the LiWeKo joint project is therefore to reduce the total rotational mass by means of weight-reduced clamping devices, tools and peripheral parts based on modern lightweight materials and manufacturing methods. This should make it possible to increase the circumferential speed and thus achieve a significant reduction in the energy required for precision grinding processes (up to 30 %). The tool system of a standard grinding machine is used as a demonstrator to prove the applicability of the developed tool system (consisting of grinding wheel, holder for clamping the grinding wheel and tool spindle) as well as the reduced energy requirement.



(a) Comparison of the vibration displacement of a steel reference shaft and the CFRP hybrid shaft, (b) Clamped CFRP hybrid shaft in the rotational test environment.

Period

01.10.2019 – 30.09.2022

Project management

Prof. Dr.-Ing. habil. Maik Gude

Contact

Dr.-Ing. Thomas Behnisch
Andreas Borowski

Project partners

- QSIL Ingenieurkeramik GmbH
- CONNOVA Deutschland GmbH
- LIGHTWAY GmbH & Co. KG

Funding

Supported by:

Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag

Federal Ministry for Economic Affairs and Climate Action (BMWK): 7th Energy Research Programme of the Federal Government “Innovations for the Energy Transition”

Funding code: 03EN2015D

Managed by:

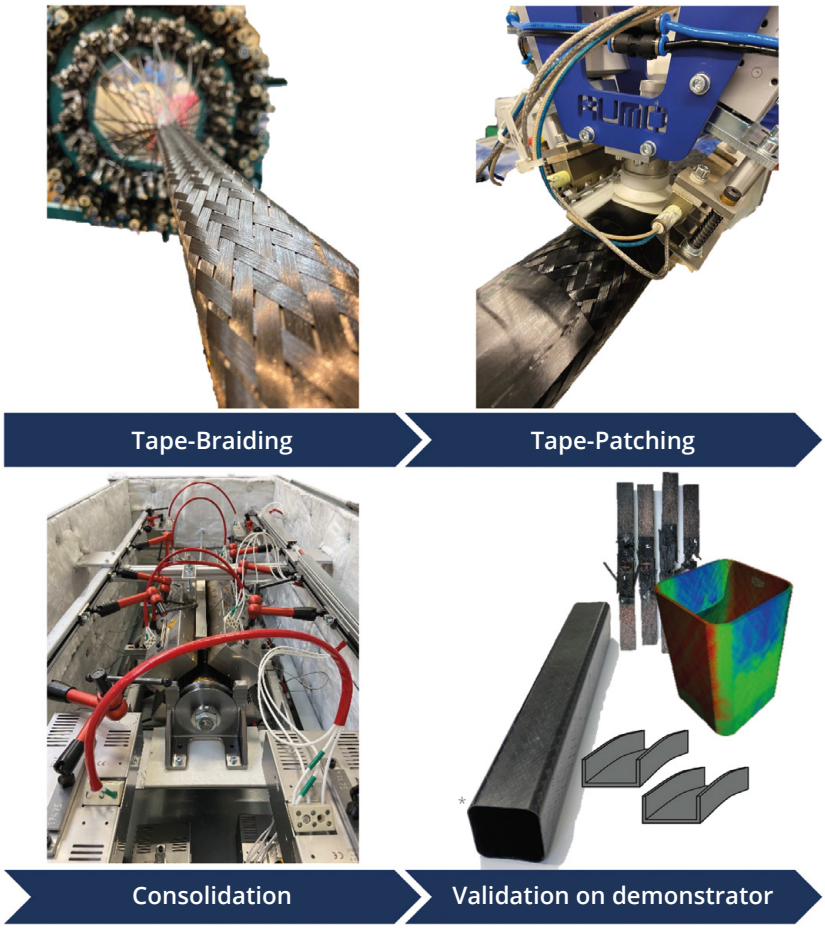
Projektträger Jülich Forschungszentrum Jülich

Projektträger Jülich (PTJ)

FeLiSa

Automated production of fibre-thermoplastic composite profiles for open and closed aerospace structures in series application

The primary objective of the application-oriented research project FeLiSa is the development of a novel process chain for the production of complex shaped fibre-thermoplastic composite structural profiles. This is an automated, reproducible and, above all, energy-optimised "out of autoclave" process for the aerospace industry. The focus is on the primary structures that recur in large numbers in the aircraft, such as C-spars. The preforms are innovatively manufactured in the combined tape-braid-patch (TBP) process and afterwards consolidated in a tooling system with energy-efficient, variothermal temperature control by means of an active heating-cooling system. The reduction in cycle time compared to the established thermoset prepreg technology enables a twenty-fold increase in productivity. In addition, production costs are to be reduced by means of continuous process automation and the resulting improved reproducible component quality, and the "buy-to-fly" ratio of the carbon fibre-reinforced PEKK material is to be increased to 95 %, thus significantly reducing rework and scrap. At the end of the project, a prototypical implementation of the TBP process and the consolidation of the profiles in the developed tool system for the proof of functionality in a near-series environment for curved structures is aimed for.



The FeLiSa process chain for the automated production of complex shaped structural profiles and its validation on the demonstrator.
* © Photo (Square pipe profile): herone GmbH

Period

01.04.2019 – 30.09.2022

Project management

Prof. Dr.-Ing. habil. Maik Gude

Contact

Veit Würfel
Jan Condé-Wolter

Project partners

- Boeing Deutschland GmbH
- Siegfried Hofmann GmbH
- AUMO GmbH
- herone GmbH

Funding

Supported by:

Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag

Federal Ministry for Economic Affairs and Climate Action (BMWK): Federal Aviation Research Programme LuFo V-3, Funding line "Technology"

Funding code: 20W1727A

Managed by:

DLR Projektträger

German Aerospace Center (DLR)

XeroPul

Development of a technology for selective powder binder application by xerography

Binder technologies play a central role in preforming to improve the automation level and cost-efficiency, as well as to ensure reproducible component quality in manufacturing fiber-reinforced composite structures. To date, binder systems have almost exclusively been applied to the full surface, which can affect permeability and formability. These effects can be significantly reduced by selective binder application, but suitable application technologies have been missing so far.

In the Xeropul project, an efficient and flexible binder application technology based on the xerography principle was developed, which is particularly suitable for selective but also for full-surface application. The CNC-controlled xerography module transfers powder binders by means of electrostatic forces and was developed in cooperation with the project partner AUMO GmbH.

In addition to the elaboration of the process fundamentals and the process-specific characterization of the powder binders, the production of the xerography module and its integration into a prototypic preforming process represented key activities. It was possible to transfer binder patterns with high homogeneity and resolution above the requirements, while process times were significantly reduced. The novel technology was finally validated by manufacturing demonstrator preforms.

Period

01.03.2019 – 31.08.2021

Project management

Prof. Dr.-Ing. habil. Maik Gude

Contact

Karsten Tittmann

Project partners

AUMO GmbH

Funding

Supported by:

Federal Ministry for Economic Affairs and Climate Action

ZIM Zentrales Innovationsprogramm Mittelstand

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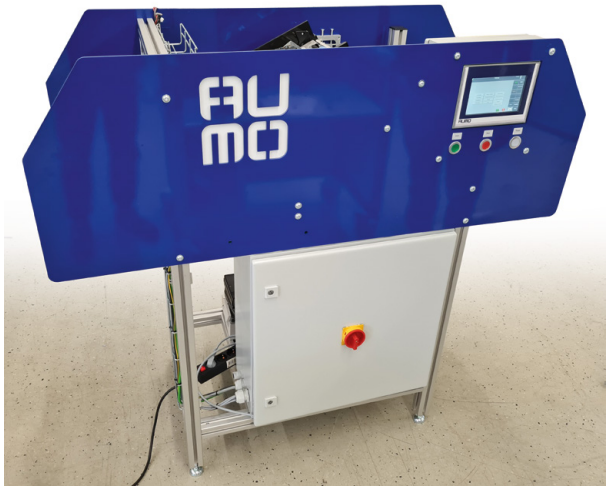
Federal Ministry for Economic Affairs and Climate Action (BMWK): Central Innovation Programme for SMEs (ZIM)

Funding code: ZF4024711WO8

Managed by:

AiF Projekt GmbH, Subsidiary of the German Federation of Industrial Research Associations “Otto von Guericke” e. V. (AiF)



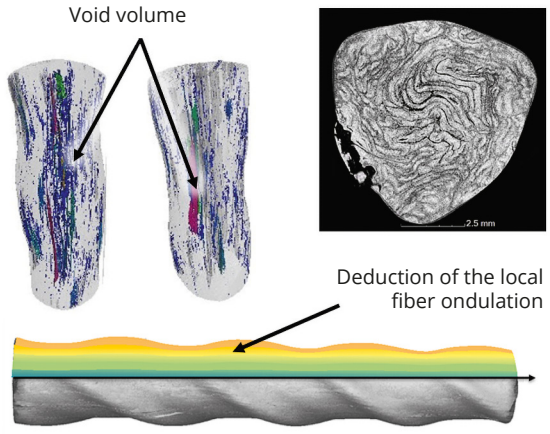
Developed test rig for xerographic powder binder application.

Selective test pattern for resolution verification.

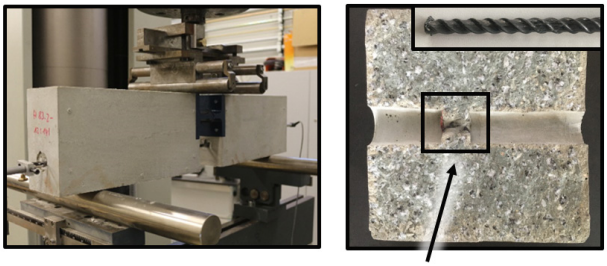
C³-V2.5A

Carbon Concrete Composite C³ – Load adapted carbon rebars for an economical use in the construction industry

The aim of the project C³-V2.5A was the further geometric development and experimental validation of novel carbon reinforcing bars and the development of adapted economic manufacturing technologies for a large-scale use in the construction industry. The focus was on the targeted exploitation of the high load-bearing potential of carbon fibers to achieve the required tensile and bonding property values in civil engineering, irrespective of the matrix material used. For this objective, a reinforcing rebar profile adapted to this new carbon concrete construction method was developed and implemented as an industrial example within the scope of the collaborative project. In addition to the high structural properties of the individual bars, the investigations also focused for the first time on the design of an optimized rebar profiling for a sufficient positive and frictional connection to ensure the necessary bonding effect. By developing production technologies adapted to these requirements, load adapted carbon rebars with an extensive range of properties are now available for an economical use in the construction industry.



Computed tomography analysis for the evaluation of the inner fiber structure of the novel carbon Helix-rods.



© IfB

Analysis of the bonding effect between the carbon Helix-rod and the C³-concrete.

Period

01.01.2019 – 28.02.2021

Project management

Prof. Dr. rer. nat. Hubert Jäger

Contact

Dr.-Ing. Mike Thieme

Project partners

- Institute of Concrete Structures (IMB) at the TU Dresden
- Institute of Construction Materials (IfB) at the TU Dresden
- Action Composites Hightech GmbH; formerly: thyssenkrupp Carbon Components GmbH (tkCC)

Funding

Supported by:

Federal Ministry of Education and Research

zwanzig20 PARTNERSCHAFT FÜR INNOVATION

on the basis of a decision by the German Bundestag

Federal Ministry of Education and Research (BMBF): Programme „Zwanzig20 – Partnerschaft für Innovationen“

Funding code: 03ZZ0325A

Managed by:

PTJ Projektträger Jülich Forschungszentrum Jülich

Projektträger Jülich (PTJ)

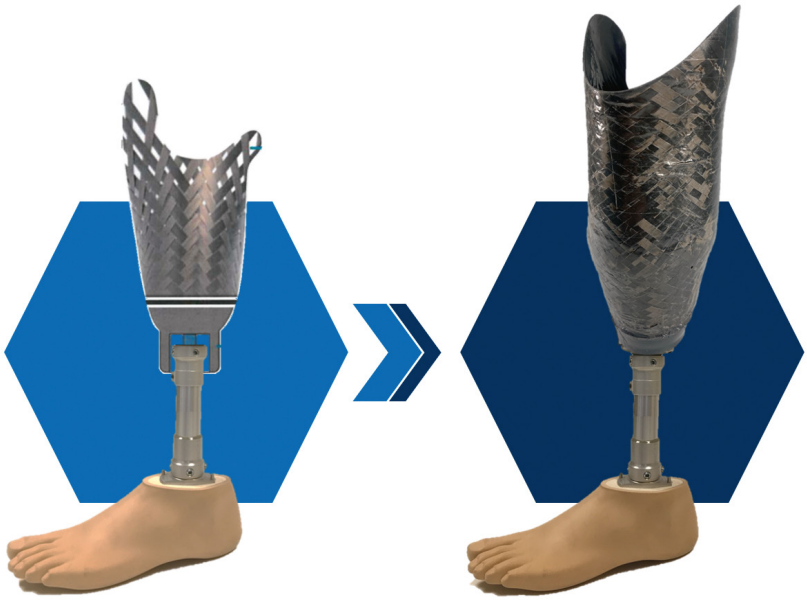
TapeProthese

Development of a technology for the production of sockets for transtibial prostheses on the basis of prefabricated blanks made out of tape braid for rapid individual fitting to the patient

As a replacement for the loss of extremities due to an accident or illness, prostheses are a widespread aid for those affected to regain mobility and participate as good as possible in everyday life. Although a wide variety of prostheses are commercially available, their manufacture is currently enormously complex and costly. The research and technology development project TapeProthese aims to provide an alternative by efficiently and reproducibly manufacturing of shafts for transtibial prostheses on the basis of industrially prefabricated blanks.

The prosthesis sockets are manufactured from carbon fiber-reinforced thermoplastic tapes in a braiding process. Due to the textile draping behavior of the braided preforms, they enable the manufacturing of individually shaped structural components. In addition, finished prosthetic shafts can be subsequently reshaped or adapted. As a central element of the manufacturing process chain for the shaft components, a new technology for the overmoulding of braided hollow structures in preform condition has been developed. Thanks to this technology, a large part of the prosthesis manufacturing process can be automated. Using this process chain, a demonstrator of a transtibial prosthesis was finally conceptualized, designed, manufactured and successfully tested.

To accomplish the project, partners from industry and research worked closely together within the interdisciplinary project consortium and realized the specific work packages.



Tape prosthesis concept (left) and Tape prosthesis technology demonstrator (right).

Period

01.05.2019 – 31.07.2021

Project management

Prof. Dr.-Ing. Niels Modler

Contact

Simon Eckardt
Antonio Becke

Project partners

- Augst Kunststoffprodukte GmbH
- B+S Werkzeug- u. Formenbau GmbH
- EBB Beschlagtechnik GmbH
- FGMD GmbH
- herone GmbH
- Kajamed GmbH

Funding

Supported by:

Federal Ministry for Economic Affairs and Climate Action

ZIM Zentrales Innovationsprogramm Mittelstand

on the basis of a decision by the German Bundestag

Federal Ministry for Economic Affairs and Climate Action (BMWK): Central Innovation Programme for SMEs (ZIM)

Funding code: 16KN067353

Managed by:

VDI|VDE|IT

VDI/VDE Innovation + Technology GmbH

PEP4.0

Development of a highly efficient linked product development process (PEP) for hybrid lightweight structures in the context of industry 4.0

In the project PEP4.0, the ILK is collaborating with Rolls-Royce Germany to research efficient methods for the development of an intermediate engine casing (IMC) in metal-fibre reinforced composite design (cf. Fig. 01). The basis for this is a digitally linked product development process that combines the methods, models and data of the individual disciplines of design, dimensioning and manufacturing into a linked development structure from the specification of requirements through to production (cf. Fig. 02).

Using this interlinked approach, it was possible to successfully develop a hybrid design of the IMC in which structural loads are transferred from the inside of the engine to the outside via aerodynamic guide vanes made of fibre-plastic composite. There, a fibre composite ring with a diameter of about 1.20 m takes the loads, merges them at one point, where they are then transferred to the aircraft fuselage. Via this load path, the thrust generated inside the engine can be used to propulsion the aircraft.

The guide vanes consist of variable-axis arranged fibres that are suitable for the load path and are positioned using the Tailored Fiber Placement method. The engineering design process set up to realise such a structure is a world first and could only be achieved through digital linking and the close cooperation of the project partners with Leibniz-Institut für Polymerforschung Dresden (IPF) and Hightex Verstärkungsstrukturen GmbH.

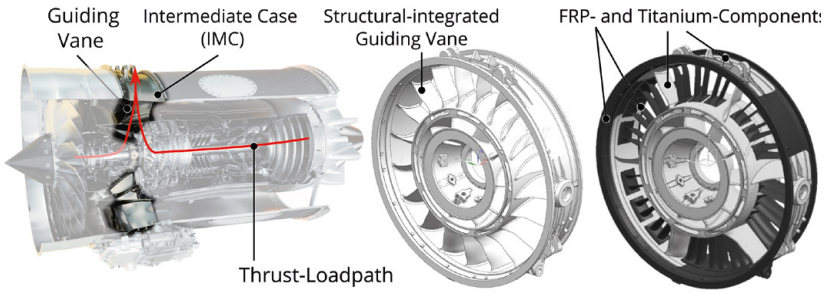


Fig. 01 Rolls-Royce Pearl 15 (left), metallic aerodynamic IMC of the Pearl 700 (centre) and fibre reinforced composite metal IMC of future generations (right).

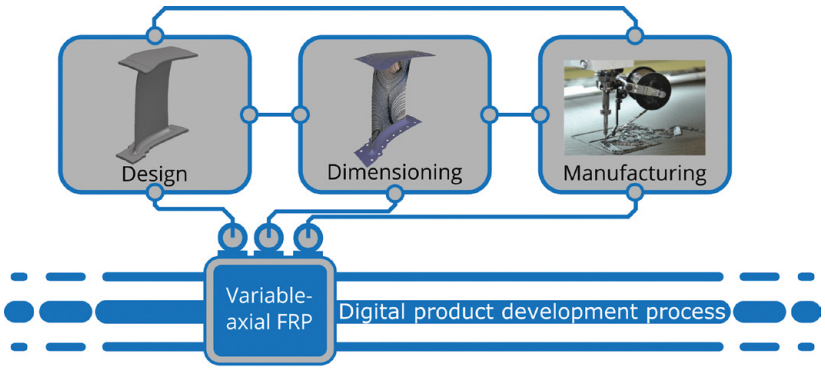


Fig. 02 Interaction of the individual disciplines of component design, dimensioning and manufacturing within the development of CFRP structures.

Period

01.07.2018 – 30.06.2023

Project management

Prof. Dr.-Ing. habil. Maik Gude

Contact

Dr.-Ing. Sebastian Spitzer

Project partners

Rolls-Royce Deutschland Ltd. & Co. KG

Funding

Supported by:

Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag

Federal Ministry for Economic Affairs and Climate Action (BMWK): Federal Aviation Research Programme LuFo V-2

Funding code: 20X1717B

Managed by:

DLR Projektträger

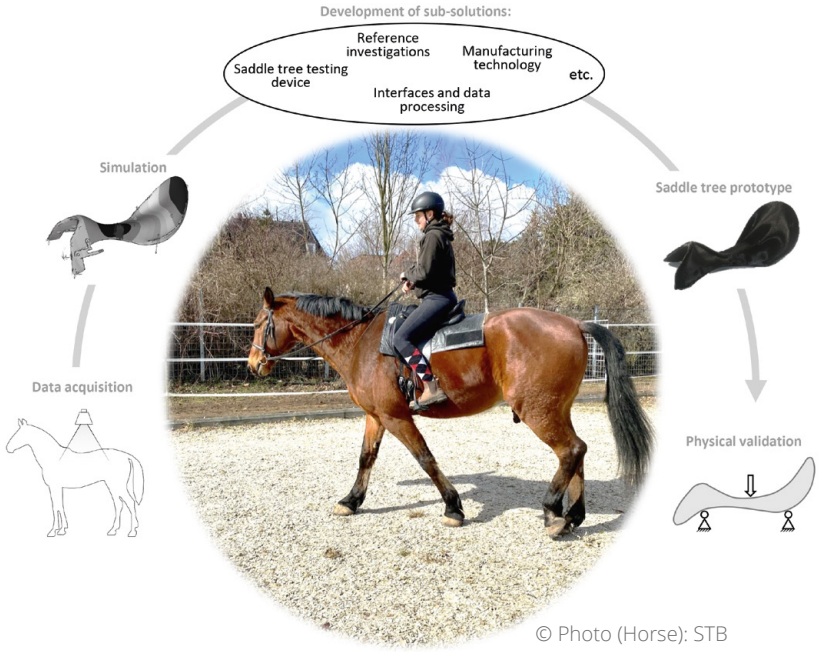
German Aerospace Center (DLR)

Fostesa

Development of a saddle tree adapted to the individual horse's back in terms of shape and stiffness

Riding saddles are often selected by experience according to established sizing systems depending on the intended use (dressage, show jumping, etc.) as well as the individual characteristics of the horse and rider (size, build, etc.). An important component of the saddle is the saddle tree inside, which has load-bearing and form-giving functions. For currently available saddles, changes to the saddle tree geometry to adapt it to the shape of the horse's back are often only possible to a limited extent. Further fine adjustments are mainly made by saddle upholstery work.

The aim of the Fostesa cooperation project, which was completed in 2021, was to develop an innovative saddle tree that is adapted to the individual horse's back in terms of shape and stiffness. Special attention was paid to the realisation of a continuous development chain from individual data acquisition of the horseback geometry to experimental mechanical tests and calculation simulations of saddle tree structures to the development of the manufacturing technology by rapid prototyping process. With the 3D scanning processes and data processing solutions developed, new principles were created for assessing the manufacturing and thus the fitting accuracy of saddle trees. The novel saddle tree was tested experimentally with a specially developed testing device for stiffness analysis and physical simulation of long-term behaviour, and its high potential was demonstrated.



© Photo (Horse): STB

Acquired solutions for the development of a novel saddle tree.

Period

01.07.2018 – 31.03.2021

Project management

Prof. Dr.-Ing. Niels Modler

Contact

Dr.-Ing. Robert Gottwald

Project partners

Sattlerei Thomas Büttner (STB)

Funding

Supported by:

Federal Ministry for Economic Affairs and Climate Action

ZIM Zentrales Innovationsprogramm Mittelstand

on the basis of a decision by the German Bundestag

Federal Ministry for Economic Affairs and Climate Action (BMWK): Central Innovation Programme for SMEs (ZIM)

Funding code: ZF4024709SU8

Managed by:

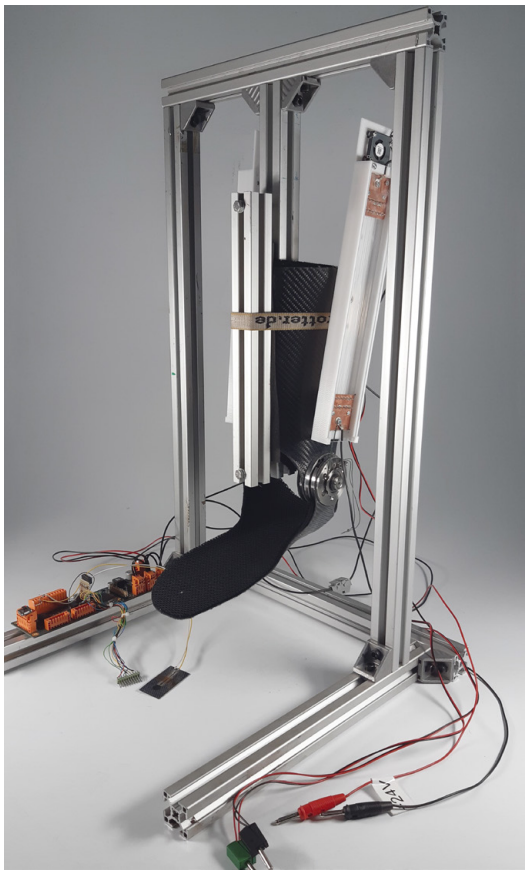
AiF Projekt GmbH, Subsidiary of the German Federation of Industrial Research Associations "Otto von Guericke" e. V. (AiF)

pro-O-light – FußhebOr

Development of a foot lifter orthosis with kinematic, actuator functions

In a cooperative project with academic and industrial partners, a function-integrating foot lifter orthosis was developed. Patients who have a foot-lifting weakness can no longer lift their foot on their own when walking, so that when they lift their foot off the ground it folds downwards which results is an increased risk of tripping. Foot lifter orthoses serve to prevent bending and are therefore currently comparatively rigid. The goals of the project were on the one hand the use of adapted lightweight or fibre composite materials and on the second hand the development of an actuator concept using shape memory materials.

For this purpose, existing orthoses were analysed and redesigned with regard to the actuators to be integrated. In the context of choosing materials, composite plates were manufactured and tested with regard to their mechanical and processing properties so that they can also be easily and safely processed in orthopaedic technology. A cable pull mechanism with a smooth-running bearing was designed to generate movement. The actuator itself consists of shape memory wires, which can be specifically controlled and cooled. With two actuators, arranged on the left and right side of the orthosis, a tractive force on the bearing of over 220 N and a frequency of deflection of approx. 0.7 Hz can be achieved. Within the framework of the project, it was thus possible to build and test a prototypical active foot-lifting orthosis.



Active foot lifter orthosis in test bench.

Period

01.12.2018 – 31.05.2021

Project management

Prof. Dr.-Ing. Niels Modler

Contact

Dr.-Ing. Anja Winkler

Project partners

- Institute of Mechatronics (IfM) at the TU Chemnitz
- TRANSCERAM GmbH
- Borgmann Ortopädietechnik GmbH
- Dr. Schwab Gesellschaft für Technologieberatung GmbH

Funding

Supported by:

Federal Ministry for Economic Affairs and Climate Action

ZIM Zentrales Innovationsprogramm Mittelstand

on the basis of a decision by the German Bundestag

Federal Ministry for Economic Affairs and Climate Action (BMWK): Central Innovation Programme for SMEs (ZIM)

Funding code: 16KN067344

Managed by:

VDI|VDE|IT

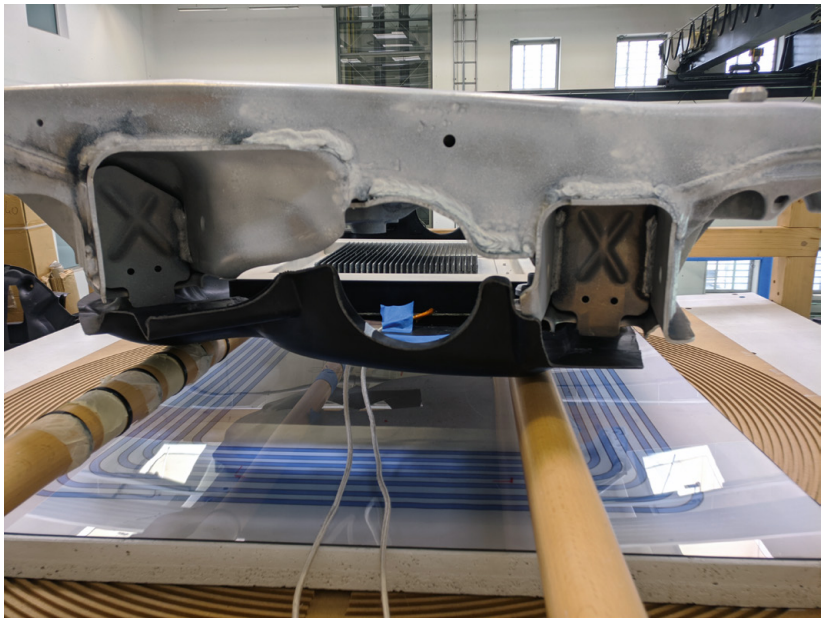
VDI/VDE Innovation + Technology GmbH

ArchitectECA2030

Trustable architectures with acceptable residual risk for the electric, connected and automated cars

ArchitectECA2030 is a European project with 20 partners from 8 countries. The aim of this collaboration is to increase the safety of electrically powered, connected and automated vehicles. For this purpose, electrical components and systems (ECS) are to be investigated, validated and their design developed towards more robust versions. In addition, the residual risk of the ECS is to be described in order to increase the acceptance of such systems by the end user.

The ILK of the TU Dresden is pursuing two main topics in this project: The detection of metallic foreign objects in inductive charging systems for the traction battery in electric vehicles and the detection of wear and aging of electric drive motors. For the inductive charging systems, passive inductive sensors are characterised with regard to the detection of foreign objects. This requires measuring the magnetic field of the charging system's ground assembly and determining the thermal behaviour of standardised test objects in this magnetic field. Initial measurements with selected sensor geometries have already been carried out. Based on the findings obtained, the next step will be to virtualize foreign object detection in the charging system. The characterisation of the motor is carried out by deliberately introducing imbalances on the rotor and by determining the resulting vibrations. Sensors that can be integrated in the motor's end shield will be used for this purpose.



Test bed with ground and vehicle assembly coil of the wireless charging system as well as parts of the real vehicle.

Period

01.12.2018 – 31.05.2021

Project management

Prof. Dr.-Ing. Niels Modler

Contact

Dr.-Ing. Anja Winkler
Dr.-Ing. Uwe Hentschel

Project partners

- Infineon Technologies AG
- AVL List GmbH
- Brno University of Technology
- Infineon Technologies Austria AG
- Institut Mikroelektronických Aplikací s.r.o.
- NxTech AS
- NXP Semiconductors Netherlands BV
- TracSense AS
- SafeTRANS e. V.
- SBA Research gGmbH
- SINTEF AS
- UAB TeraGlobus
- TU Graz
- Board of Regents of Nevada System of Higher Education
- Virtual Vehicle Research GmbH
- DATASOFT Embedded GmbH
- Institut National de Recherche Eninformatique et Automatique
- TU Delft
- Volkswagen AG

Funding

European Union

ECSEL Joint Undertaking

Supported by:

Federal Ministry of Education and Research

on the basis of a decision by the German Bundestag

This project has received funding from the ECSEL Joint Undertaking (JU) under grant agreement No 877539. The JU receives support from the European Union's Horizon 2020 research and innovation programme and Germany, Austria, Czech Republic, Netherlands, Lithuania, Latvia, France, Sweden, Norway.

Managed by:

VDI|VDE|IT

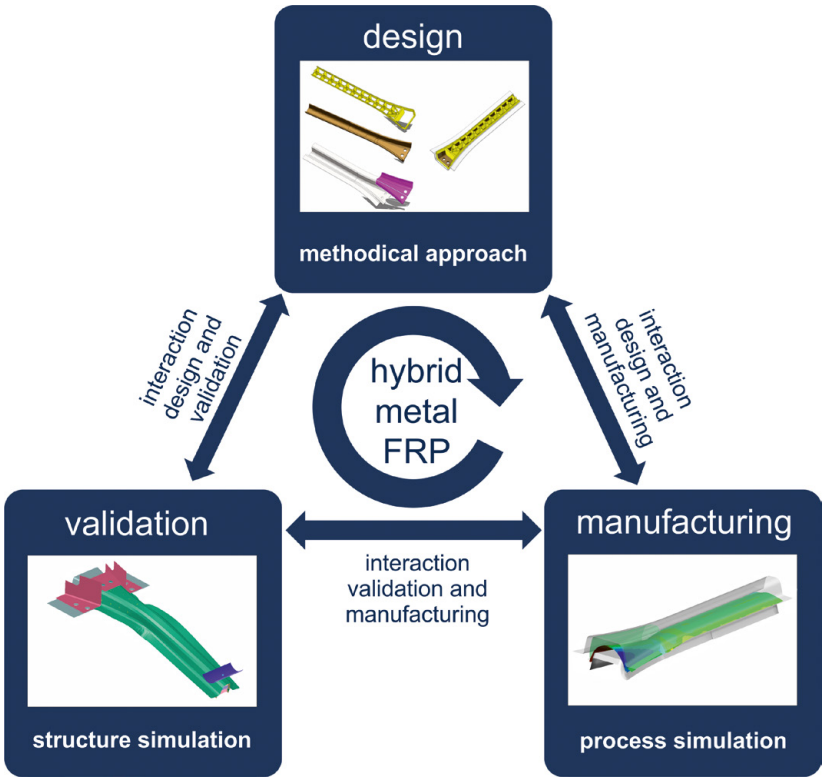
VDI/VDE Innovation + Technology GmbH

robust EVP 4.0

Efficient and robust development, validation and production processes for hybrid metal FRP structures for transport and energy systems in the context of industry 4.0

The robust EVP 4.0 project involves researching and demonstrating a holistic approach for the efficient implementation of hybrid lightweight structures through linked development, validation and production processes with an continuous data structure. The aim of the project is to lower the development and industrialization barriers for hybrid lightweight structures for small and medium-sized companies by means of the methods and tools developed.

Hybrid structures in combination with metal and fiber-reinforced plastic (FRP) show great lightweight potential, but the high number of degrees of freedom in the development leads to a complex and multidisciplinary process due to the different material properties and their interactions. For this purpose, methods were developed to support a digitally linked development process in the development phase by structuring the relevant product data and providing engineering knowledge. Furthermore, a validation strategy and its integration into the development process was developed using the example of a hybrid generic demonstrator component and non-destructive testing procedures and evaluation methods were further developed for this application. To investigate the production process of hybrid lightweight structures a quality-assured production process chain with automated data acquisition was set up for the demonstrator component using inline measurement technology.



Interaction of the engineering disciplines in the development procedure of metal-FRP structure.

Period

16.02.2019 – 31.07.2021

Project management

Prof. Dr. rer. nat. Hubert Jäger

Contact

Dr.-Ing. Michael Krahl
Daniel Haider

Project partners

Fraunhofer Institute for Ceramic Technologies and Systems (Fraunhofer IKTS)

Funding

European Union
Europe funds Saxony. EFRE European Regional Development Fund

European Regional Development Fund (EFRE) in Saxony: Funding guideline "EFRE-RL Forschung InfraPro"

Project number: 100339955

This measure is co-financed with tax funds based on the budget approved by the Saxon state parliament.

Managed by:

SAB
Sächsische Aufbaubank (SAB)

K-Crash

Crash Simulation Technology for Composite-based Novel Lightweight Structures

To establish composite materials for technical products, such as lightweight body structures, any crash and impact events must also be taken into account in the engineering process. In the K-Crash project, KIMS and ILK were investigating the crash behaviour of a novel thermoplastic fibre composite material.

In this context, tubular test specimens were investigated experimentally under axial compressive loading and numerically on high-performance computing facilities at the ZIH of TU Dresden. A pronounced splaying failure of the specimen was observed in the tests, which leads to a promising force-displacement response in terms of peak force and specific energy absorption. The local and time-related changes of deformation and damage were recorded via high-speed cameras at a frequency of up to 30.000 frames per second. Computed tomography was used to identify and evaluate the damage mechanisms.

The robust crash simulation at the structural level pursued the goal of a high-fidelity modelling approach taking into account every single ply and interfaces of the composite layup. This allows the adequate representation of both all relevant local deformation and damage phenomena under crash loading and the resulting force-displacement response of the structure.

Period

01.01.2018 – 30.06.2021

Project management

Prof. Dr.-Ing. Niels Modler

Contact

Holger Böhm
Jonas Richter
Dr.-Ing. Andreas Hornig

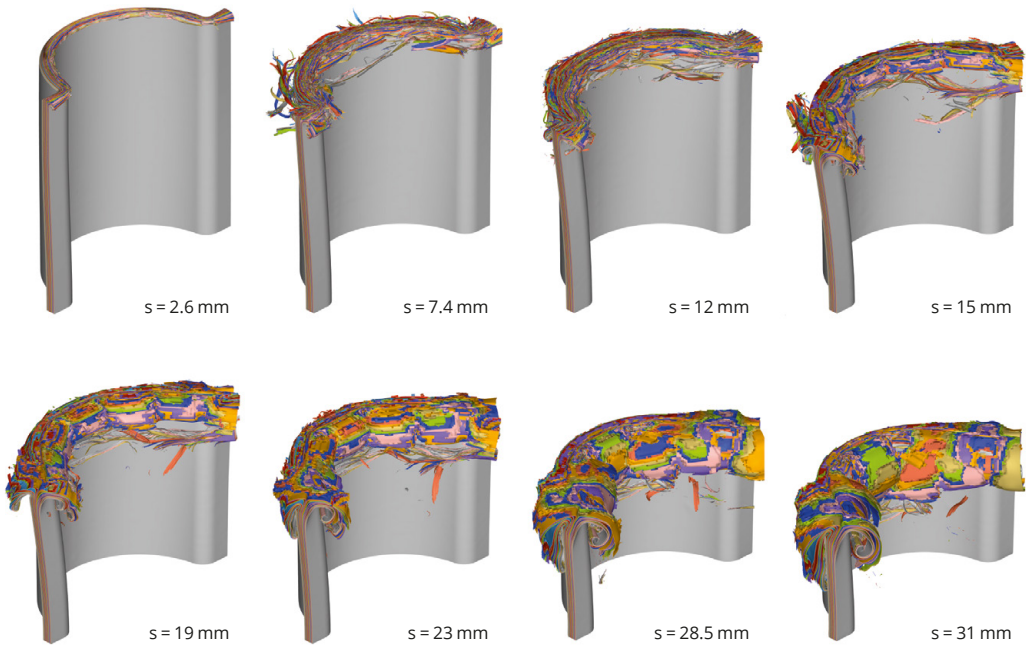
Project partners

- Korea Institute of Materials Science (KIMS)
- Center for Information Services and High Performance Computing (ZIH) at the TU Dresden

Funding

KIMS

Korea Institute of Materials Science (KIMS)



Failure pattern of half-circle specimen.

i3U

Integration von induktiven Ladesystemen in Unterbodenstrukturen

In the i3U project, an ultra-thin, highly integrated inductive charging module for automotive wireless charging systems was developed which increases installation space utilization in the vehicle underbody without simultaneously reducing ground clearance. For this purpose, an interdisciplinary development process for functionally integrated mechanical-electrical lightweight systems was designed and implemented. In this context, electrical, mechanical and process characterization of high-frequency litz wire, ferromagnetic sheet and metal wire mesh were carried out for the first time. Complementing the development, a multiphysical simulation model was set up from component to system level to calculate the electromagnetic-thermal behavior. This was successfully validated on the hardware-in-the-loop test bench with the hardware demonstrator, which was manufactured in a 3-stage process using RTM and VARI. With an assembly height of 15 mm and a total weight of 8 kg, the charging system achieves a transmission efficiency (according to SAE J2954) of up to 92 % at 7.2 kW nominal power and active air cooling.

Period

01.02.2017 – 31.10.2020

Project management

Prof. Dr.-Ing. Niels Modler

Contact

Martin Helwig
Dr.-Ing. Anja Winkler

Project partners

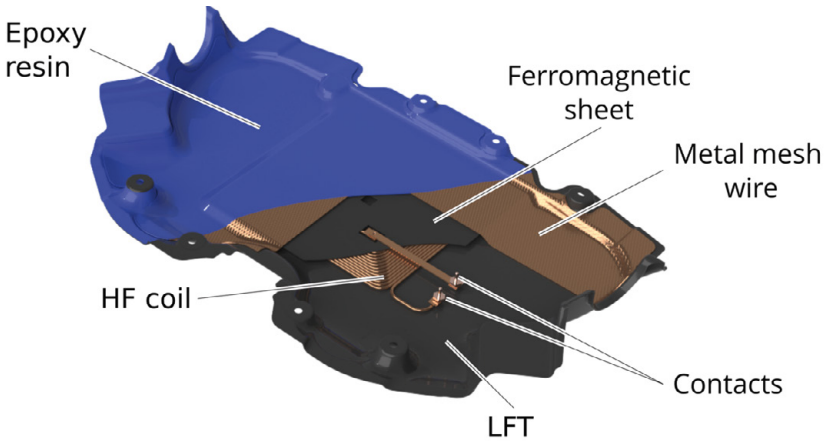
Mercedes-Benz AG

Funding

Mercedes-Benz

Mercedes-Benz AG

Inductive 7.2 kW charging module with 92% efficiency and thickness of 15 mm.



CAD sectional view of the charging module and representation of the individual components.

Project Overview (Selection)

1000KM+	Scalable European Powertrain Technology Platform for Cost-Efficient Electric Vehicles to Connect Europe
ABSOLUT	Automatic bus shuttle – self-organizing between Leipzig and the BMW terminal
ADAPT	Self-adapting cutting system and in-process quality assurance in the CFRP processing process
ADHYBAU (ex. BASELA)	Development of additive processes and fiber composite-metal hybrid designs for the Use in cryogenic environments (AdHyBau) SP: Novel designs for structures in electric drives with cryogenic cooling
AI4CSM	Artificial Intelligence for/at Connected Shared Mobility
AI4DI	Artificial Intelligence for Digitalizing Industry
AMARETO	Saxon alliance for material- and resource-efficient technologies
AMSIM	Development of a sequential simulation methodology for the analysis and optimization of the design of additively manufactured components considering process- and structure-related anisotropies in the fused layer modeling process
AMTWIN	Data-driven process, material and structure analysis for additive manufacturing
ARCHITECT	Trustable architectures with acceptable residual risk for the electric, connected and automated cars
BIIAX	Description of the fatigue behavior of fabric-reinforced fiber-plastic composites under combined interlaminar shear and out-of-plane compressive stress
BRYSON	Space-efficient hydrogen storage with optimised usability SP: Process development for the manufacturing of thermoplastic warp tank systems
C3-V2.5A	Beanspruchungsgerechte Carbonbewehrungsstäbe für einen wirtschaftlichen Einsatz im Bauwesen SP: Entwicklung angepasster Bewehrungsstabprofilierungen und Fertigungskonzepte
C3-V4.16	Multiaxiale Garnablage im automatisierten Umlaufprozess (Multi-2D Druck) SP: Grundlagenuntersuchungen zur Entwicklung einer neuartigen Prüfmethode für Carbonbewehrungsstäbe mit variablen Oberflächentopologien
CECO	Development of a manufacturing process for injection moldable cellulose-based composites
CHANGE!	Change! From resource efficiency towards neutrality
CIRCECON	Survey concept for the Trilateral Research Centre for circular and organic economy of the Saxon Technical Universities Chemnitz, Dresden and Freiberg in Lusatia

Project management	Expert group	Start	End	Funding	Project executing agency
Prof. Dr.-Ing. Niels Modler	Function Integration	01/2019	06/2022	EU	
Prof. Dr. rer. nat. Hubert Jäger	Lightweight Design	01/2019	09/2022	BMWK	DLR
Prof. Dr.-Ing. habil. Maik Gude	Thermoset Processing and Preforming	11/2018	04/2021	BMBF	PTKA-PFT
Prof. Dr.-Ing. habil. Maik Gude	Joining Technologies	05/2020	04/2023	BMWK	DLR
Prof. Dr.-Ing. Niels Modler	Function Integration	07/2021	04/2024	EU/BMBF/SAB	VDI/VDE
Prof. Dr.-Ing. Niels Modler	Function Integration	05/2019	11/2022	EU/BMBF	VDI/VDE
Prof. Dr.-Ing. habil. Maik Gude	Calculation Methods and Simulation	01/2017	02/2021	SAB	
Prof. Dr.-Ing. habil. Maik Gude	Joining Technologies	06/2019	11/2021	AiF	FSKZ
Prof. Dr.-Ing. habil. Maik Gude	Testing Methods and Material Models	12/2019	06/2022	SAB	
Prof. Dr.-Ing. Niels Modler	Function Integration	07/2020	06/2023	EU/BMBF	VDI/VDE
Prof. Dr.-Ing. habil. Maik Gude	Testing Methods and Material Models	03/2021	02/2024	DFG	
Prof. Dr.-Ing. habil. Maik Gude	Thermoplastic Processing	12/2019	05/2023	BMWK	PTJ
Prof. Dr. rer. nat. Hubert Jäger	Material Models	01/2019	02/2021	BMBF	PTJ
Prof. Dr.-Ing. habil. Maik Gude	Material Models	09/2018	03/2021	BMBF	PTJ
Prof. Dr. rer. nat. Hubert Jäger	Neutral Lightweight Engineering	08/2019	01/2022 VL bis 4/2022 beantragt	AiF	DECHEMA
Prof. Dr.-Ing. habil. Maik Gude	Neutral Lightweight Engineering	10/2021	12/2022	SMWK	
Prof. Dr. rer. nat. Hubert Jäger	International	01/2021	07/2021	SAB	

COMPOLL	Combating environmental pollution through internationalisation of education in Germany and India
DAHLIA	Digital technologies for hybrid lightweight structures SP: Fusion of the material and process models into a digital twin
DIGI-KUNST	Digital learning tools in the training of process mechanics for plastics and rubber technology for securing the next generation of professionals
DIWA	Analysis of the influence of production-related fibre misalignments on the material behaviour of thick-walled fibre-reinforced plastic composites
EACPLUS	Sustainable Electric Architecture Casings
EDI:TUD	Successful – Digital – Integrated: Studying at TU Dresden
EPREDICT	Predictive Maintenance for e-Mobility; sub-project ILK: Reliability of polymer structures at thermo-mechanical loading in electric power trains
EVHY (HYBRID-STRUKTUREN)	Properties of the joint zone in textile-reinforced thermoplastic hybrid structures
FASSADE	Development of a reproducible manufacturing process for variably curved façade elements made of metal-plastic composite sheets SP: Development of an FE simulation for the effective development of the manufacturing process
FATIIGUE	Experimental analysis and numerical modelling of microcrack induced delaminations under cyclic loading with load reversals
FAVILEIT	Development of a test stand for the simultaneous characterization of fibers and yarns, regarding their electrical and mechanical properties
FELISA	Automated production of fibre-thermoplastic composite profiles for open and closed aerospace structures in series application SP: Tape-Braid-Patch Preforming for Complex Shaped Fibre Thermoplastic Composite Profiles
FLEUR	Aktive Flächen mit Reaktionsstrukturen für urbane Räume SP: Entwicklung von Modellen zur Auslegung hybrider aktiver Tragwerksstrukturen mit Funktionsintegration
FLIER	Flexible wall structures for acoustic LInERs
FOSTESA	Development of a shape- and stiffness-adapted saddle tree adapted to the individual horse's back. SP: Design, dimensioning and testing of a shape- and stiffness-adapted saddle tree structure and research into suitable polymers for the development of a manufacturing process.
FURNIER	Development and technological implementation of load-bearing profile structures based on wood veneers for an ultra-light tripod for photographic applications SP: Characterization and modeling of material and structural behavior
FUSSHEBER	Development of a foot lifter orthosis with kinematic, actuator functions SP: Composite material and kinematics for the active foot lift orthosis

Project management	Expert group	Start	End	Funding	Project executing agency
Prof. Dr.-Ing. habil. Maik Gude	International	07/2020	06/2024	DAAD	
Prof. Dr.-Ing. habil. Maik Gude	Calculation Methods and Simulation Function Integration	02/2020	03/2022	SAB	
Prof. Dr.-Ing. habil. Maik Gude	Neutral Lightweight Engineering	06/2019	05/2022	SAB	
Prof. Dr.-Ing. habil. Maik Gude	Testing Methods and Material Models	04/2020	03/2023	DFG	
Prof. Dr.-Ing. habil. Maik Gude	Neutral Lightweight Engineering	12/2021	11/2024	BMWK	PTJ
Prof. Dr.-Ing. Niels Modler	Internationales	01/2021	12/2023	DAAD	
Prof. Dr.-Ing. habil. Maik Gude	Material Models	08/2019	06/2022	SAB	
Prof. Dr. rer. nat. Hubert Jäger	Joining Technologies	06/2018	02/2021	AiF	FSKZ
Prof. Dr.-Ing. Niels Modler	Lightweight Design	12/2018	05/2021	AiF	AiF
Prof. Dr.-Ing. habil. Maik Gude	Testing Methods and Material Models	09/2021	08/2023	DFG	
Prof. Dr.-Ing. Niels Modler	Function Integration	04/2021	03/2023	AiF	AiF
Prof. Dr.-Ing. habil. Maik Gude	Thermoplastic Processing	04/2019	09/2022	BMWK	DLR
Prof. Dr.-Ing. Niels Modler	Material Models	04/2019	03/2022	SAB	
Prof. Dr.-Ing. Niels Modler	Function Integration	06/2020	08/2023	BMWK	DLR
Prof. Dr.-Ing. Niels Modler	Lightweight Design	07/2018	03/2021	AiF	AiF
Prof. Dr.-Ing. habil. Maik Gude	Thermoset Processing and Preforming	10/2019	06/2022	BMEL	FNR e. V.
Prof. Dr.-Ing. Niels Modler	Lightweight Design	12/2018	08/2021	AiF	VDI/VDE

GEPART	Development of efficient process technologies within the closed particle foam material cycle SP: Virtual and experimental material characterisation for rEPP and EPP particle foam
GERUSAM	Additive manufacturing technologies for functionalized lightweight structures
GESCHA II	Investigation of the regularities of foam structure formation in freeze foaming processes of biocompatible ceramic foams
GRETA	Generative production of recyclable basic structures for theatre sculpture from natural-based materials
GRK 2430 **I-FEV**	Research Training Group 2430 Interactive Fiber Rubber Composites
HORA	High-performance radial impellers in modular metal-fibre composite design
HYBSCH	Design development and technology synthesis for the production of cellular hybrid plastic structures for application in acoustic resonators
HYDRUN	Boundary layer analysis for the inline hybridization of metal die casting and plastic injection molding
HYFOTOOL	Hybrid Forming Tool - Development of an ultra-light, high-performance steel/plastic hybrid tool for deep-drawing sheet metal, including a first-time integration of RVDT sensor technology for recording the tool stresses. SP: Investigation of the material properties and development of the reinforcement structures for the HyFo tool on the basis of FE simulations.
HYPRO	Holistic implementation of hybrid design in series production
HYSTERESIS	Cyclic-dynamic properties of particle foams
ICLIMABUILT	Functional and advanced insulating and energy harvesting/storage materials across climate adaptive building envelopes
I-DETEKT	Intelligent battery protection system for electric vehicles for detection of undesired mechanical damage SP: Development e-Preform
ILK2PATRAS	1st Greek-German Summer School of University of Patras & TU Dresden
ILKINAUS	Development of tailored carbon fibres for multifunctional composites
IMEM	Development of an innovative membrane press for the efficient manufacturing of fibre composite components made of thermoplastic semi-finished products in small and medium series sizes. SP: Development of an optimised process control as well as a temperature management for the efficient manufacturing of composite fibre components in the innovative membrane press

Project management	Expert group	Start	End	Funding	Project executing agency
Prof. Dr.-Ing. habil. Maik Gude	Calculation Methods and Simulation	12/2020	11/2023	BMWK	PTJ
Prof. Dr.-Ing. Niels Modler	Function Integration Novel Materials and Special Processes	05/2020	10/2021	BMBF	DLR
Prof. Dr.-Ing. habil. Maik Gude	Novel Materials and Special Processes	01/2020	06/2022	DFG	
Prof. Dr.-Ing. Niels Modler	Novel Materials and Special Processes	09/2021	08/2024	SAB	
Prof. Dr.-Ing. Niels Modler	Calculation Methods and Simulation	11/2018	01/2023	DFG	
Prof. Dr.-Ing. habil. Maik Gude	Lightweight Design	06/2021	05/2023	AiF	FK Maschinenbau
Prof. Dr.-Ing. Niels Modler	Function Integration	04/2020	03/2023	DFG	
Prof. Dr. rer. nat. Hubert Jäger	Novel Materials and Special Processes	06/2021	11/2023	BMBF	PTJ
Prof. Dr.-Ing. Niels Modler	Testing Methods and Material Models	04/2019	03/2022	AiF	AiF
Prof. Dr.-Ing. habil. Maik Gude	Joining Technologies	05/2020	10/2022	BMBF	PTJ
Prof. Dr.-Ing. habil. Maik Gude	Thermoplastic Processing	12/2020	11/2023	DFG	
Prof. Dr. rer. nat. Hubert Jäger	Testing Methods and Material Models	03/2021	02/2025	EU	
Prof. Dr.-Ing. Niels Modler	Function Integration	12/2020	11/2023	BMWK	PTJ
Prof. Dr.-Ing. habil. Maik Gude	Internationalisation	01/2021	12/2021	DAAD	
Dr.-Ing. habil. Robert Böhm	Internationalisation	01/2020	12/2021	DAAD	
Prof. Dr.-Ing. Niels Modler	Thermoplastic Processing	01/2020	06/2022	AiF	AiF

INDIRA	Integration of customized load introduction elements in a single-stage manufacturing process suitable for SMEs for complex-shaped sandwich composite structures SP: Development and implementation of material and functionally adapted insert elements for highly loaded sandwich composite structures
INPRO	Integral lightweight profile systems made of fibre-thermoplastic composite functionalised in the injection moulding process SP: Concept, design and process-technological description of functionalised fibre-thermoplastic composite hollow profiles
INSERT	Simulation-assisted development of material-, load- and process-specific inserts for thermoplastic composites
K-CRASH	KIMS Academic Laboratory: Technology transfer for crash and impact modelling, simulation and testing for composite based lightweight structures
KOBRA	Compact X-ray tube made of fibre reinforced ceramics for mobile computer tomographs SP: Structural mechanical design and experimental testing of a rotation unit made of fibre composite ceramics for compact X-ray tubes
KODAV	Simulation-supported research of novel textile-based adaptive fiber plastic composite structures with shape memory alloy elements for complex deformation patterns
KOKO	2nd Dresden International Colloquium on Tailored Carbon Fibres (RCCF II - Konferenz)
KOKOMAG	Development and evaluation of a corrosion-protected, non-combustible carbon fibre reinforced magnesium material for aeronautical applications
KOLIBRI-S	Complex lightweight structures for electronic applications in mobility SP: Simulation methods for the coupled thermo-structure-flow behavior
KORESIL	Strategies for the resource-efficient and reliable production of lightweight structures SP: Cyber-physical interfaces for mobile injection moulding
LE2GRO	Lightweight multi-material carrier for performance enhancement of large-area fertiliser spreaders SP: Development and experimental validation of a design system for functionalised fibre thermoplastic profiles based on a large-area fertiliser spreader
LEVADI	Fatigue analysis for adhesively bonded joints in large FRP structures with varying adhesive layer thicknesses
LIGNOBRAID	Biobased lightweight hollow profiles with braided wood tapes SP: Lightweight hollow profiles
LIKE	Lightweight construction technologies in cross-life cycle products of the energy transition SP: Digitally networked design methodology for recyclable lightweight structures
LITAPROP	Light-weight composite structures with tailored mechanical, electrical and thermal properties
LIWEKO	Weight-reduced lightweight clamping devices, tools and components for efficient, highly dynamic machining processes. SP: Development of hybrid designs as well as design and testing of weight-reduced rotors for highly dynamic grinding processes

Project management	Expert group	Start	End	Funding	Project executing agency
Prof. Dr.-Ing. habil. Maik Gude	Thermoset Processing and Preforming	11/2019	06/2022	AiF	AiF
Prof. Dr.-Ing. habil. Maik Gude	Thermoplastic Processing	08/2020	07/2023	BMWK	DLR
Prof. Dr.-Ing. habil. Maik Gude	Joining Technologies	07/2019	03/2022	DFG	
Prof. Dr.-Ing. Niels Modler	Calculation Methods and Simulation	05/2018	06/2021	KIMS	KIMS
Prof. Dr.-Ing. habil. Maik Gude	Novel Materials and Special Processes	10/2019	09/2022	BMBF	VDI
Prof. Dr.-Ing. habil. Maik Gude	Calculation Methods and Simulation	09/2021 (01/2022)	08/2024 (12/2024)	DFG	
Prof. Dr.-Ing. habil. Maik Gude	Novel Materials and Special Processes	01/2021	12/2021	TUD/SG 8.3 Internationalisation	
Prof. Dr.-Ing. habil. Maik Gude	Novel Materials and Special Processes	08/2020	07/2023	BMWK	DLR
Prof. Dr.-Ing. habil. Maik Gude	Calculation Methods and Simulation	12/2021	11/2024	BMWK	PTJ
Prof. Dr.-Ing. habil. Maik Gude	Calculation Methods and Simulation	02/2021	01/2024	BMBF	PTKA-PFT
Prof. Dr.-Ing. habil. Maik Gude	Thermoplastic Processing	01/2021	12/2023	BMWK	PTJ
Prof. Dr.-Ing. habil. Maik Gude	Testing Methods and Material Models	04/2020	03/2023	AiF	DVS
Prof. Dr.-Ing. habil. Maik Gude	Neutral Lightweight Engineering	03/2021	08/2023	BMEL	FNR e. V.
Prof. Dr.-Ing. habil. Maik Gude	Lightweight Design	01/2021	12/2023	BMWK	PTJ
Prof. Dr.-Ing. habil. Maik Gude	Thermoset Processing and Preforming	07/2021	06/2024	SAB	
Prof. Dr.-Ing. habil. Maik Gude	Novel Materials and Special Processes	10/2019	09/2022	BMWK	PTJ

MEGRAV II	Model building for the design of Metal-Graphite Composites under consideration of application-related service conditions
METEOR	Methods and technologies for validating and optimizing the ressource efficiency of process networks in the production of hybrid lightweight structures SP: Set up process network and virtual process chain
MINDENDO2	Development of miniaturised fibre-reinforced composite structures for ultrasonic-based decontamination of non-shedding surfaces within the human organism
MLDDS	Investigation of damaged fibre-reinforced high-speed rotors using in-situ measurement systems
MM4R	Recycling-friendly multi-material design for lightweight structures SP: Resource-saving material, component and process design
MMSS (SCKOR)	Development of Mass Production Total Engineering Technologies for Metal-Composites Hybrid Process (Joining & Forming) & Over 25 % Lightweight Side Crash Carbody Structure Components
MONSTRAIN	Development of a novel spatially resolved carbon fiber-based strain measurement system for real-time structural health monitoring and validation of load assumptions
MUFUS	Development of multifunctional interfaces for joining FRP with metals using established joining processes
MULTCOMP	Towards a sustainable research cooperation on multifunctional nano-composites in multi-material design and beyond
ORGON	Thermoplastic organic sheet structures with functional surfaces
PDOCFIL	Towards an excellent scientific career on engineering intelligent, multifunctional composites in multi-material design
PEM	Polymere electrolyte membranes (PEM) for vanadium redox flow batteries
PEP4.0	Digitally synchronised development architecture for the product development process 4.0
PLRV	Development of a large-scale lightweight transportation box SP ILK: Development and application of test methods for material characterisation
PRILLIAND	Development of an additive production technology for manufacturing plastic-based components for maritime applications
PROPLUG	Development of a structurally integrated plug-in connection system for the electrification of functionalised fibre composite components SP: Integration concepts and technologies and mechanical characterisation
PULTIX	Novel pultrusion process for continuous production of thermoset rebars with helix profiling
RAVI	New generation of efficiency-enhanced, emission-free vibrating tampers

Project management	Expert group	Start	End	Funding	Project executing agency
Prof. Dr.-Ing. Niels Modler	Joining Technologies	06/2021	02/2024	AiF	FK Maschinenbau
Prof. Dr.-Ing. habil. Maik Gude	Novel Materials and Special Processes	12/2020	11/2023	BMWK	PTJ
Dr.-Ing. Martin Dannemann	Function Integration	05/2018	02/2022	DFG	
Prof. Dr.-Ing. habil. Maik Gude	Function Integration	06/2017	07/2021	DFG	
Prof. Dr.-Ing. habil. Maik Gude	Neutral Lightweight Engineering	12/2021	11/2024	BMWK	PTJ
Prof. Dr. rer. nat. Hubert Jäger	Calculation Methods and Simulation	07/2017	03/2021	KEIT	KIMS
Prof. Dr.-Ing. Niels Modler	Function Integration	01/2021	06/2024	BMWK	DLR
Prof. Dr.-Ing. habil. Maik Gude	Joining Technologies	10/2019	03/2022	AiF	EFB
Prof. Dr.-Ing. habil. Maik Gude		05/2021	10/2022	TUD/Graduate Academy	
Prof. Dr.-Ing. Niels Modler	Thermoplastic Processing	02/2020	07/2022	AiF	FVLK
Dr.-Ing. Angelos Filippatos		07/2021	12/2022	TUD/Graduate Academy	
Dr. Uwe Gohs	Novel Materials and Special Processes	06/2019	05/2022	DFG	
Prof. Dr.-Ing. habil. Maik Gude	Lightweight Design	07/2018	03/2022	BMWK	DLR
Prof. Dr.-Ing. habil. Maik Gude	Testing Methods and Material Models	08/2020	07/2022	AiF	AiF
Prof. Dr.-Ing. habil. Maik Gude	Novel Materials and Special Processes	04/2021	03/2024	BMWK	PTJ
Prof. Dr.-Ing. Niels Modler	Function Integration	12/2020	11/2023	BMBF	VDI/VDE
Prof. Dr.-Ing. habil. Maik Gude	Thermoset Processing and Preforming	10/2019	01/2022	AiF	Carbon Composites
Prof. Dr.-Ing. Niels Modler	Function Integration	07/2018	04/2021	SAB	

RECAR	Development of a modular heating system based on recycled carbon fiber nonwovens for use in forming and preforming tools SP: Characterization of the properties of heating nonwovens made from recycled carbon fibers and research into possible applications in the preforming process of textile semi-finished products
ROBIN	Robot-assisted mobile injection unit for the process-integrated manufacturing of hybrid component structures (Robotised Injection Moulding)
ROBUST	Efficient and robust development, validation and production processes of hybrid metal-fibre composite design methods for transport and energy technology systems in the context of Industry 4.0
SAXONHY	System-integrated H2 pressure tank assemblies for general aviation and feeder aircraft SP: MBSE-based methods for the development, integration and certification of system-integrated H2 pressure tank assemblies
SCADS2	ScaDS.AI Dresden/Leipzig - Center For Scalabel Data Analytics And Artifical Inteligence
SMARTMEMBRANE-C	Smart membrane pressing technology for manufacturing of high performance composite components SP: Develoment of a smart membrane for manufacturing of high performance composites with high geometric variability
SNAPCURE 4.0	Innovative process chains with fast-curing polymer systems (Snap-Cure-Polymers 4.0) SP: Development and validation of combined information- and description-based structure and process chain models
SPIFA	SpinnennetzFaserverbund: Development of a new lightweight partition wall for aircrafts based on a novel load insert made of thermoset hardpoints as well as fiber composite tapes with spider web structure for weight savings of at least 5 %. SP: Investigation of process parameters of a holistic manufacturing process for aircraft partition walls for the development of a sensor-based production process automation with a response time below 1 sec
SPP 1897 - II. Phase	Complex-Shaped Lightweight Structures with Adaptive Dynamic Behaviour through Evanescent Morphing
STYQZAHL	Structural metal-polymer hybrid design using the example of a bumper beam for electrified, large-scale automotive production – presentation of an economical manufacturing process through integration of on-line quality assurance and optimisation of material utilisation
SUMMER SCHOOL	Summer School "Intelligent Lightweight Systems" (13.–18.09.2020)
SWING	Modelling and simulation of the manufacture-dependent shrinkage behaviour of glass-fibrereinforced epoxy resins for the improved prediction of surface-waviness and warpage
TAPE-PROTHESE	Development of a technology for the production of sockets for transtibial prostheses on the basis of prefabricated blanks made of tape mesh for a quick, individual fitting to the patient. SP: Development of a process technology for manufacturing prosthetic sockets using OrganoTubes
TERESA	Thermoplastic final contour sandwich for innovative aerospace applications SP: Development of functionalised thermoplastic-based sandwich structures for aerospace application
THOPOL	Thermally highly resistant polymer structures for lightweight propulsion systems SP: Efficient processing technologies and robust design methods for rotating lightweight structures

Project management	Expert group	Start	End	Funding	Project executing agency
Prof. Dr.-Ing. Niels Modler	Thermoset Processing and Preforming	01/2020	06/2022	AiF	AiF
Dr.-Ing. Michael Krahl	Thermoplastic Processing	03/2020	02/2022	BMWK	PTJ
Prof. Dr. rer. nat. Hubert Jäger	Thermoplastic Processing	02/2019	07/2021	SAB	
Prof. Dr.-Ing. habil. Maik Gude	Lightweight Design	12/2021	05/2023	SAB	
Prof. Dr.-Ing. habil. Maik Gude	Calculation Methods and Simulation	10/2018	09/2021	BMBF	DLR
Prof. Dr.-Ing. habil. Maik Gude	Thermoset Processing and Preforming	01/2020	03/2022	AiF	FILK
Prof. Dr.-Ing. habil. Maik Gude	Thermoset Processing and Preforming	11/2018	03/2022	SAB	
Prof. Dr.-Ing. habil. Maik Gude	Thermoset Processing and Preforming	09/2021	02/2024	AiF	AiF
Dr.-Ing. Pawel Kostka	Function Integration	10/2019	09/2022	DFG	
Prof. Dr.-Ing. habil. Maik Gude	Thermoplastic Processing	05/2020	10/2022	BMBF	PTJ
Prof. Dr.-Ing. habil. Maik Gude	Internationales	03/2020	12/2022	TUD/Bereich ING	
Prof. Dr.-Ing. habil. Maik Gude	Calculation Methods and Simulation	02/2019	07/2022	DFG	
Prof. Dr.-Ing. Niels Modler	Thermoplastic Processing	05/2019	07/2021	AiF	VDI/VDE
Prof. Dr.-Ing. habil. Maik Gude	Thermoplastic Processing	05/2019	04/2022	BMWK	DLR
Prof. Dr.-Ing. habil. Maik Gude	Calculation Methods and Simulation	02/2019	12/2022	BMBF	PTJ

TI-MMC-3D	Development of the innovative technology of the production of hybrid structures
TRAKUBE	Development of a transport-optimized small wastewater treatment plant SP: Development of a location-independent joining system for a transport-optimized tank system in small wastewater treatment plants
SFB/TRR285-A03	Calculation and evaluation of process-induced material structure phenomena in FRP-metal connections
SFB/TRR285-C04	Local and integral in situ analysis of process- and operation-related damage effects of joints
VEDUFO	Development of a new manufacturing process for fiber-reinforced plastics using a heatable vacuum membrane and epoxy resin films that can be stored for 3 months at 25 °C and cured under 120 °C SP: Development of the process concept and process parameter determination of a new RFI process with heatable vacuum membrane
VITSCHA	Novel transparent showcase hinge SP: Development of the simulation as well as the bonding technology for a transparent hinge
XEROPUL	Development of a technology for the selective application of powder binder systems by means of xerography SP: Preliminary investigations and process studies for powder binder application by means of xerography

Project management	Expert group	Start	End	Funding	Project executing agency
Prof. Dr.-Ing. habil. Maik Gude	Novel Materials and Special Processes	01/2021	12/2022	DAAD	
Prof. Dr.-Ing. habil. Maik Gude	Joining Technologies	05/2021	04/2023	AiF	AiF
Prof. Dr.-Ing. habil. Maik Gude	Calculation Methods and Simulation	07/2019	06/2023	DFG	
Dr.-Ing. Robert Kupfer	Joining Technologies	07/2019	06/2023	DFG	
Prof. Dr.-Ing. habil. Maik Gude	Thermoset Processing and Preforming	11/2019	04/2022	AiF	AiF
Prof. Dr.-Ing. Niels Modler	Lightweight Design	12/2019	11/2022	AiF	AiF
Prof. Dr.-Ing. habil. Maik Gude	Thermoset Processing and Preforming	03/2019	08/2021	AiF	AiF

Selected Publications

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— Zichner, M.; Modler, N.; Wollmann, J.K.; Modler, K.-H.; Steinbild, P.J.; Dannemann, M.: A new modelling approach to determine the DOF of compliant mechanisms. New Advances in Mechanisms, Mechanical Transmissions and Robotics – Tagungsband „MTM & Robotics 2020", 14.-16. Oktober 2020, Timisoara (Rumänien), Mechanisms and Machine Science 88 (2021), S. 164-171, DOI: 10.1007/978-3-030-60076-1_15

— Köhler, D.; Kupfer, R.; Troschitz, J.; Gude, M.: In situ computed tomography – analysis of a single-lap shear test with clinch points. Materials 14 (2021) 8, Nr. 1859, DOI: 10.3390/ma14081859

— Penter, L.; Maier, J.; Kauschinger, B.; Lebelt, T.; Modler, N.; Ihlenfeldt, S.: 3D printing technology for low cost manufacturing of hybrid prototypes from multi material composites. Production at the leading edge of technology – Tagungsband 10. WGP-Jahreskongress (WGP2020), Dresden, 23.-24. September 2020, Lecture Notes in Production Engineering (2021), S. 396-405, DOI: 10.1007/978-3-662-62138-7_40

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Doctorates

Doctorate Dr.-Ing. Dustin Nielow

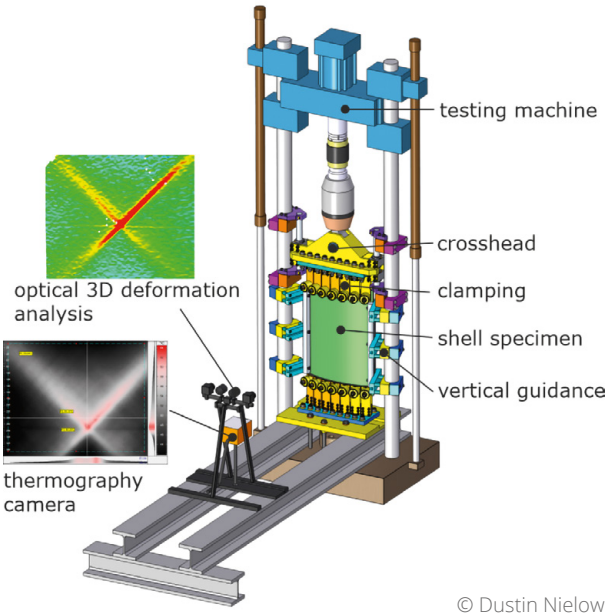
Effect of manufacturing-induced imperfections on the fatigue behavior of composite sandwich shell structures

Supervising Professor: Prof. Dr.-Ing. habil. Maik Gude

The PhD thesis, with a focus on renewable energies, was developed as part of a sub-project of the joint project "BladeTester" (of the Federal Ministry of Economics and Climate Protection – BMWK, FKZ: 0325298A) and in close cooperation between the Bundesanstalt für Materialforschung und -prüfung (BAM) and the TU Dresden. In detail, the following question was addressed: Wind turbines often exhibit cracks in the blade shells after only a few years in service, significantly before their expected 20 to 30 year design lifespan. This leads to complicated repairs on difficult to reach rotor blades, and can cause a cost-intensive stand-still of the turbine.

A possible source of these defects in the rotor blade shells are the imperfections which occur during production. In order to investigate the effect of these imperfections on the fatigue behavior of rotor blades, a test rig was developed at the BAM upon which intermediate scale static and cyclic-fatigue testing could be performed. The complementary sandwich shell specimens developed and investigated with the test rig are representative of the outer shell of wind turbine rotor blades in terms of materials and manufacturing processes, as well as structural mechanics. The specimens were built with reproducible imperfections, including laminate overlaps in the face sheets and gaps of varying size in the foam core. The damage condition was monitored during cyclic-fatigue testing under realistic load cases using a combination of in-situ passive thermography and strain field measurement.

The test concept developed in this work, which consists of the intermediate scale test rig with the corresponding specimen and condition monitoring as well as the validated FEM model, makes it possible to examine the substructures similar to the rotor blade shell under realistic load scenarios without stability failure and to represent their complex deformation behavior numerically. The influence of manufacturing-induced imperfections on damage initiation and the significant reduction of service life, as well as the design rules derived from this work, provide important design information for engineering practice and support the operationally safe design of curved sandwich structures such as wind turbine rotor blades.



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CAD-Figure of the developed intermediate scale test rig with integrated condition monitoring.

Doctorate Dr.-Ing. Richard Protz

On the influence of defects on the strain rate-dependent material behaviour of fibre-reinforced plastics

Supervising Professor: Prof. Dr.-Ing. habil. Maik Gude

Fibre-reinforced plastic (FRP) composites are predestined for crash-loaded lightweight structures due to their adjustable energy absorption capacity. However, in FRP can occur defects that develop during manufacture (voids) and in operation (fatigue) (Fig. 02). The influence of such defects, especially on the strain rate-dependent material behaviour, is currently still insufficiently researched and can represent a safety risk. Therefore, in this successfully completed doctorate (Fig. 01), the formation and characteristics of defects were analysed in detail and a damage model was developed for their mathematical description.

Fig. 01 PhD Committee Attendees (from left to right): Prof. Ullrich, Prof. Gude, Dr. Protz (doctorate), Prof. Kyosev.

Through a fundamental description of the formation mechanisms of voids and of fatigue-related defects, manufacturing and testing methodologies for defined defect initiation were developed. These allow the investigation of the influence of separately and jointly occurring manufacturing- and operation-related defects on the strain rate-dependent material behaviour for the first time. The characterisation of the introduced defects by means of In-situ computed tomography under tensile load showed that voids with a low void volume content have no influence on the crack progression. At higher pore volume contents, voids act both as crack stoppers and as source of cracks. When voids and fatigue-related cracks are present in the material at the same time, they partially appear independently of each other, but can also overlay.

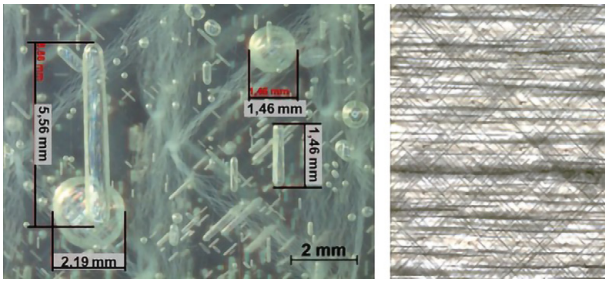


Fig. 02 FRP with productional (left) and operational (right) defects.

The analysis of the influence of defects on the strain rate-dependent material behaviour under tensile load at different strain rates showed an increasing material degradation with increasing pore volume contents and higher pre-fatigue. Pre-damage due to interacting pores and fatigue impair additionally the strain rate-dependent material behaviour to a significant amount.

Based on the experimental work, a phenomenological Adjoint Damage Model (ADM) was developed. The ADM can described mathematically the strain rate-dependent stress-strain behaviour of nominally defect-free and defect-affected FRP. The interaction of both defect types is formulated in logic terms as an adjunctive OR operation of the defect parameters. With increasing defect sizes and the associated increase in defect interactions, the strain rate-dependent deformation behaviour can be precisely predicted. The result is a flexible and practical model approach for describing the strain rate-dependent material behaviour. Furthermore the transferability of the ADM to another FRP has already been successfully demonstrated.

The knowledge gained makes a significant contribution to an improved understanding of materials, which will enable the future defect-tolerant design of FRP structural components.

Doctorate Dr.-Ing. Shahan Tutunjian

Ultrasonic Spot Welding of Thin Walled Fibre-Reinforced Thermoplastics

Supervising Professor: Prof. Dr.-Ing. Niels Modler

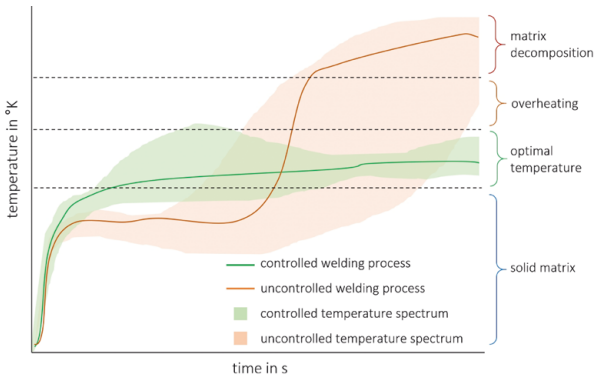
The ultrasonic spot welding of fibre-reinforced thermoplastic composites has recently received strong interest among researchers mainly in the fields of aerospace and automotive industries. It offers an efficient solution to join large thermoplastic composite parts through the spot welding approach with a high level of automation.

In this study, a new technique for focusing the ultrasonic vibration energy at the desired spot between two mating thermoplastic composite laminates was investigated. In this method, no additional energy directing protrusions between the weldments were required to focus the vibration energy. It was found that by welding the laminates amid an ultrasonic sonotrode and an anvil in which the prior had a larger contact surface with the laminate as the latter, it was possible to generate a localised frictional heating.

In the initial phase of the welding, the frictional heating softened the interfacial layers and thus caused the focusing of the strain energy in the weld spot centre. The assumption for the presence of the friction and its influence on the heat generation was investigated by means of finite element method analysis. Microscopic analysis of the weld spot delivered the proof for the melt initiation at a ring around the weld spot and subsequent inwards growth of the weld spot. In order to gain a better understanding of the temperature spatial distribution and its temporal development in the weld zone during the ultrasonic welding process, the thermal problem was analysed using the explicit finite difference method. The mathematical model was verified through a comparison between the calculated temperature curves and the experimentally obtained counterparts. It was found that after a certain weld duration the temperature in the weld centre underwent a sudden increase and caused the overheating and decomposition of the polymer in the weld spot.

It was observed that the time trace of the consumed power curve by the welder followed a similar pattern as the time trace of the temperature in the weld spot centre. Based on this observation, a control system was developed accordingly. The time derivative of the weld power was monitored in real time and as soon as it exceeded a critical value, the ultrasonic vibration amplitude was actively adjusted through a microcontroller. In this approach, the temperature in the weld spot was indirectly controlled to remain within an adequate range throughout the welding duration.

The results of the controlled welding process were evaluated by means of temperature measurements and computed tomography scans. It was concluded from the study that the power-controlled differential ultrasonic spot welding process could be an efficient method to fusion bond the fibre-reinforced thermoplastic parts in an automated manner.



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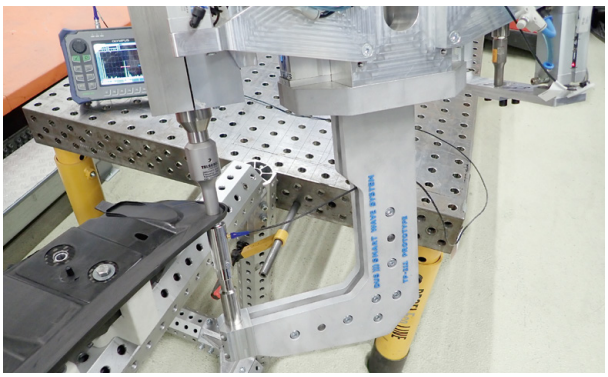
A comparison between the temperature curves in the centres of the weld spots performed by the controlled and uncontrolled ultrasonic spot welding techniques.



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Ultrasonic spot welding of a carbon fibre-reinforced thermoplastic liftgate.

Dual-Doctorate: University of Bristol and TU Dresden
Dr.-Ing. Mario Valverde

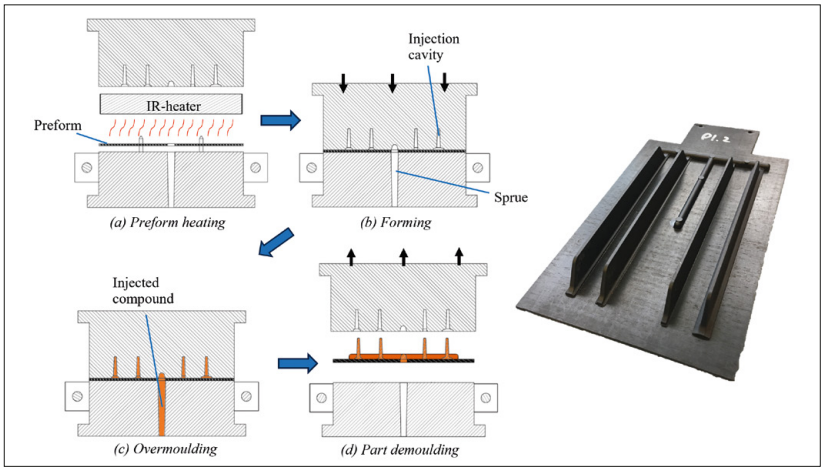
An Improved Description of the Bonding and Consolidation for Overmoulded Thermoplastic Composite Ribbed Plates

Supervising Professor: Professor Stephen Hallett (University of Bristol), Prof. Dr.-Ing. habil. Maik Gude (TU Dresden)

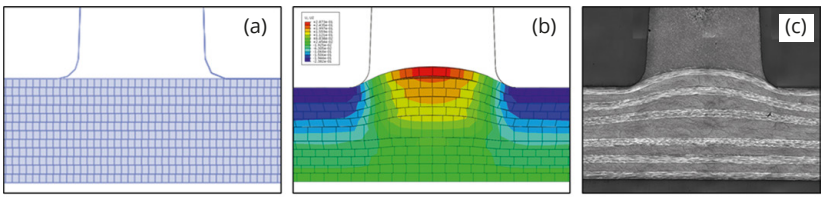
Thermoplastic composite overmoulding is an integrated process to manufacture components with combined continuous and short fibre reinforcements. These components benefit from high intrinsic mechanical properties, geometric complexity, and low production cycle times. The continuous fibre substructure is commonly designed as the main load-carrying region, whereas the injection moulded substructure, typically serving as stiffening, impact absorbing or functional features, can be tailored to carry significant loads. Thus, ensuring a strong bond at the overmoulded interface between the two substructures becomes a key objective.

Characterisation of the overmoulded interface has been a focal topic of research within the scientific community, where models developed initially for non-isothermal thermoplastic bonding have been used to describe the average strength development across the interface area. However, little to no work has been devoted to understanding the variation of bond strength as well as the preform insert consolidation, where process-induced deformations have been shown to affect the mechanical performance, overall structural integrity, and component processability. This means that the modelling capabilities for predicting the mechanical performance at the overmoulded interface lack the required levels of complexity to capture the response of the interface, in the absence of bonding- and consolidation-influencing factors.

The aim of this PhD thesis was to provide a refined description of the bonding and consolidation phenomena at the overmoulded interface in CF/PPS (Carbon Fibre/Polyphenylene Sulphide) and CF/PEEK (Carbon Fibre/Polyetheretherketone) overmoulded ribbed plates. Through manufacturing trials, process simulations and experimental testing, the mechanical performance was able to be accurately predicted. The investigation of different part designs and process parameters led to the identification of key structure-process-property relations and served to develop a set of design and manufacturing guidelines specific to overmoulding technologies.



Diagrams of key stages during the overmoulding cycle, showing final manufactured CF/PPS ribbed plate.



As-designed a), as-predicted (b), and as-manufactured (c) overmoulded interfaces of a ribbed plate specimen.

Teaching in pandemic times: Digital versus on-site?

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Since the beginning of the summer semester 2020, we unfortunately had to forego any presence in lectures, tutorials and even practical courses due to the pandemic. With the firm intention of making more face-to-face teaching possible again for our students in the winter semester 2021/22, we have pulled out all the stops to develop and use new hybrid teaching formats within the framework of the hygiene rules that have been set. Thus, despite the spacing rules in the lecture halls, we were able to offer face-to-face teaching for a large proportion of students at the beginning of the semester, while at the same time streaming or recording the lecture events at great technical expense. However, the rising incidence figures and the subsequent emergency decree in Saxony from the end of November 2021 forced the well-prepared lecturers back into purely digital teaching, so that disillusionment and frustration on both sides of the cathedron could not be avoided.

So what lessons can be learned from the past months? And can digital teaching replace on-site teaching in the future? As part of the internal evaluation, we conducted an anonymous survey with both students and teachers in order to obtain as open an opinion as possible. In the following, we would like to present two replies that give a good impression of the challenges of teaching in 2021 and can serve as examples for the multitude of feedback.

Reply of a student (7th semester)

The sudden changeover from face-to-face to digital teaching in the summer semester of 2020 posed great challenges for teachers, but certainly also for students. How did you perceive the changes at that time? And how are you coping after almost 4 semesters without continuous face-to-face teaching?

In the first Corona Wave 2020 – still started at the kitchen table – we have settled quite well into studying from home over the last four semesters. Commitment and flexibility are the key qualities required of students and lecturers. However, if both groups brought these skills with them, good teaching took place despite all adversities.

What do you miss most? Do you think there is actually a need for face-to-face lectures in order to get the study content across well?

Lectures that have been well adapted to the digital format over the last four semesters should not be forced back into the classroom. Clear explanatory videos supplemented by regular consultations can certainly keep up with earlier face-to-face formats, if they do not even surpass them in some cases.

Which changes were particularly serious for you? Which would you describe as advantageous?

A suitable workspace at home is a basic prerequisite for digital teaching. Without it, no learning success is possible. However, setting it up costs time, space and money. Once the set-up is in place and you have found your personal way of acquiring knowledge in digital teaching, you can definitely draw advantages from it. For example, commuting times are eliminated. Also freer time management and repetitive learning with recorded lectures are possible.

Have you attended hybrid lectures, if offered in your degree programme? What, if anything, has prevented you from doing so?

There was offer of hybrid lectures in my degree programme in 2021. At the beginning of the semester, I was very happy to be allowed to sit in the lecture hall with fellow students again. However, as the semester progressed, this turned out to be a rather unplannable pleasure. Illnesses, quarantine or the compulsory stop around Christmas made continuous participation on site difficult. Therefore, parallel videos of the classroom events or lecture videos from previous semesters proved to be important learning tools when another Corona wave intervened.


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What alternative teaching formats did your lecturers use? Which of them do you consider particularly useful?

In digital teaching, a clear, well-structured course calendar at the beginning of the semester is worth its weight in gold. This is the most effective way to design the curriculum for studying from home. In teaching itself, good lecture videos are sufficient if they are supplemented by consultations. For tutorials, much depends on the complexity and degree of freedom of the task. Simple calculations can be taught well with a video or a detailed solution via PDF. Using simulation software, on the other hand, requires a live event.

Would you like to see some of the alternative formats also used in regular teaching? Which formats do you consider suitable for this?

Questions tend to be better formulated after you have thought about the lecture material. In the lecture hall, it was sometimes difficult to take notes, think and then formulate a suitable question simultaneously, which often resulted in the question "Do you have any questions?" being answered by the sound of crickets only. Lecture videos supplemented by consultations can really be an improvement on this point.

How important is personal contact (in face-to-face events) with teachers for you? Can social networks, e-mail, video conferences, etc. well or even fully substitute this? Were your lecturers always available for you? What means of communication, if any, did you use?

For communicating technical questions, e-mail and video-conferences are suitable tools and have proven their worth. With questions that are more complex and require calculations or sketches, it was a more difficult task. It is sometimes hard to formulate the question so clearly that it can be understood without three follow-up e-mails. This is then a considerably time-consuming matter.

What major advantages, if any does in your opinion digital teaching or learning offer to you as a student? What would you not want to do without in the future?

Location-flexible working offers considerable advantages and I would not want to do without it. Especially the elimination of commuting times.

How did you get to know or keep in touch with fellow students? In general, how does networking work for you without face-to-face teaching?

Establishing contact with each other only via digital formats is complicated. Many people still draw on existing friendships or learning communities from the times before Corona. Group work during the course is one way of breaking things up, which in a purely digital format can provide the necessary impetus for joint learning and exchange.

Have you found (good) substitutes for the limited or even temporarily suspended sports courses offered by the university sports centre?

Especially after a whole day of digital teaching in front of the computer at home, the urge for movement and exchange with friends is huge. The discontinuation of the previously broad sports programme at the University Sports Centre was a considerable loss.

Reply of a lecturer (46 years)

The sudden changeover from face-to-face to digital teaching in 2020 demanded a lot of additional work from lecturers. Not only did complete lecture series have to be made available as video formats, exercises and practical courses had to be partially redesigned. In addition, a large part of the face-to-face lectures were cancelled last year due to the ongoing pandemic or had to be held as so-called hybrid lectures. How well were you able to profit from the preparatory work of the first pandemic year? What impression or opinion, if any, did you gain from the hybrid events?

On the one hand, it is convenient to be able to rely on already existing videos and instructions. On the other hand, it is particularly difficult to incorporate changes and extensions, which are always part of scientific teaching. In my experience, students also lack direct contact with the lecturers.

Have you perhaps discovered and used completely new formats or didactic methods for yourself?

The integration of data, the transfer of larger amounts of data, and the use of freeware or open source software was new and inspiring for me. Even beyond the pandemic, students will now be better able to practise on their own with digitally influenced teaching content. Where we previously used the CAD pools once for exercises with expensive special software and there was hardly any further practicing time afterwards, now it simply continues at home.

How well were your teaching contents and methods received by the students? Was there any opportunity at all to get feedback?

The students obviously engaged with the provided content. The exercises conducted via video conferencing were received well. However, there was some "fatigue" towards the end of the semester. It can also be assumed that it is generally easier to criticise digitally, for example in surveys, than live in the course.

Would you also adopt digital formats in a regular course largely determined by face-to-face lectures, and if so, which ones?

As already indicated above, I will try to use the newly gained digital possibilities – software, experimental data evaluation, video lectures, etc. – for follow-up work in an appropriate way.

What major advantages, if any does in your opinion digital teaching offer for students?

The biggest advantage is probably the possibility of repeating and precisely analysing the learning content. Possibly, the freedom in time management is greater than before, since you can receive a lecture "on demand" rather than at the given time.

How important is personal contact (in face-to-face events) with students for you? Are social networks, e-mail, video conferences, etc. a fully-fledged substitute on this point?

Personal interaction is important for both students and teachers, but it is always challenging as well. You stand in front of the students with your whole personality and cannot hide. However, the higher effort involved seems to be worth it.

Even if the focus is somewhat different in each case, both statements show clear advantages of the much-maligned digital teaching. Teaching videos, for example, which are available at all times, are a considerable added benefit for both sides. Students with limited language skills in particular benefit from the ability to repeat rhetorically and substantively demanding passages of a lecture as often as they like. In addition, everyone benefits from greater flexibility in the timing of their daily study routine. Teachers can use the elaborately created lecture videos repeatedly and thus expand the consultation offer for understanding and deepening the subject matter. In this way, better teaching results can be achieved compared to regular lectures.

Both parties are painfully aware, however, that exclusively digitally-led teaching or pure distance learning cuts off direct contact. Thus, the isolation and loneliness of students is one of the biggest problem areas of the past semesters, because there is a pronounced desire for networking and personal and social development during the study period. In this context, the "faceless" teaching also makes communication across courses and semesters more difficult. The social losses of digital studies affect international students and freshmen who have just moved to Dresden in particular. After four semesters of digital teaching, there is a widespread concern that a personal network will not develop in an adequate form, which academics would normally develop in the course of their studies and which would then often sustain them throughout their entire professional lives. The lecturers also lack the direct, unfiltered feedback of a face-to-face event. In the end, one can only tell whether a break-up is effective, whether a repetition works out, or how the general attention suffers in a (necessary) debauchery, in front of the assembled audience. Without this feedback, both the contentual and the didactic improvement of the courses are noticeably held back. Overall, it is the "atmosphere" or the "study feeling" that is massively changed by digital teaching and is missed by both students and lecturers. "The flair of the university is lost through digital teaching. Getting a taste of campus air in the summer and entering the lecture hall is missing," we read in almost all replies.

In the future, we would like to address this most frequently mentioned shortcoming of digital teaching by focusing on small face-to-face events and also offering a non-university setting, such as barbecue evenings, scavenger hunts, and regulars' tables. Together with the students, we must create experiences that remain positively in the memory and inspire networking. After all, the most memorable and important moments of the whole study time are not only the exams that students pass, but also the experiences they have with their fellow students. They contribute in a special way to a successful graduation and essentially determine the network formation for individual professional development. On the surface, this does not seem to be the task of the institutes, but in times of the pandemic, it is becoming our new responsibility, which we are happy to accept.

Theses

Name	Type	Theme
Beinke, Hannes	DA	Numerical simulation of additive manufactured continuous fiber rein-forced thermoplastic structures
Böhm, Jonas	DA	Development of a rotor design for use in high-performance electric motors to increase their functionality and performance
Boos, Benedikt	DA	Development of a generic specimen geometry for fatigue testing of additive manufactured metal structures
Chu, Kecheng	DA	Numerical analysis and evaluation of fiber-reinforced composites with inte-grated sensors
Diekmann, Jana	DA	Conceptual design and characterisation of polymer based functional modules
Ding, Jiayue	DA	Development of a modelling strategy with a fluid-structure-interaction approach for a forming process
Eitel, Felix Stephan	DA	Development and implementation of a simulation strategy for an engine intermediate case in hybrid design
Emmez, Seren	DA	Investigations on enhancing the electromagnetic compatibility and fire behav-iour of CFRP-PUR sandwich composites and technological implementation of a demonstrator structure
Erlmann, Jonas	DA	Investigation of material-process-property interactions in the polypropylene-based large-scale fused layer modeling
Fan, Jinyu	DA	Development of a regression model for the forming air impact technology
Fischer, Philipp	DA	Application of fibre reinforced tapes on thermoplastic film material
Fuchs, Robert	DA	Development of intrinsic joining zones for metal/fibre reinforced composites hybrid structures in electric drives with cryogenic cooling
Götz, Jonas	DA	Study of primary and secondary materials processed in a novel portable injection moulding machine
Habel, Daniel	DA	Development and exemplary implementation of a validation strategy for a fiber-plastic composite engine vane
Heise, Jan-Lukas	DA	Development and implementation of a process-integrated fiber supply for the use in novel additive manufacturing technologies based on thermoset resins
Huang, Yun	DA	Development of an adaptive temperature control system for local temperature control of an additive manufacturing process
Hübschmann, Paul Daniel	DA	Investigation of optimisation methods for material model calibration and structural design
Jiang, Tao	DA	Investigation of the fiber distribution and the fiber-matrix adhesion in the production of natural fiber composites in the twin-screw extruder
Kehlen, Maximilian	DA	Development and analysis of different re-forming process for textile thermo-plastic hollow profiles

Name	Type	Theme
Kluger, Jonas	DA	Development and implementation of a simulation strategy for a structurally optimised and production-oriented design of an engine blade based on TFP
König, Richard	DA	Hail stone impact test of a composite vane of an engine intermediate case
Li, Bo	DA	Development of a loading system for tension impulses in split-hopkinson bars
Liu, Fangxu	DA	Design of a topology-optimized lever tool based on bionic structures in generative construction method
Liu, Xiaochen	DA	Experimental and numerical simulation of Wood-FRP composite subjected to mechanical loading
Martin, Benjamin	DA	Elaboration and Validation of a Simulation Methodology for Prediction of Residual Stresses in Adhesive Bonds within Housings
Masko, Alexander	DA	Impact Analysis of Process Parameters on Organosheet Surface Waviness
Mei, Ji	DA	Analysis of the residual load-bearing capacity of laminates after local loading by spherical indenters
Moll, Joshua	DA	Development of a modelling strategy for the progressive damage analysis in composite open hole tension test specimens considering intralaminar plasticity
Nagel, Simon	DA	Failure prediction of a composite pressure vessel ring from the cylindrical region taking into account local material properties
Piller, Christian	DA	An engineering solution for parameter identification of material-locking, thermoplastic joints for cohesive zone elements
Qiu, Yuan	DA	Plastic Deformation Analysis of Partially Cross-linked Thermoset Based FRP
Reinhard, Alex	DA	Pre-development of a boom in metal-fibre-composite design for a material handling device
Ritschel, Maximilian	DA	Numerical investigation of the influence of adhesion promoter systems on the mechanical behaviour of metal-plastic hybrid structures
Schilling, Levin	DA	Integration of the LCA into the development process of an engine intermediate case
Schmidt, Florian	DA	Conception and Construction of a CT-optimized Clinching fixtures
Shang, Nianwei	DA	Validation of embedded FEM for structural simulation of braided tubes
Stoll, Tobias	DA	Identification of suitable process parameters of dispensing processes with metallic pastes for the generation of homogeneous layers with defined layer thickness
Sun, Shuo	DA	Analytical description of cellular curved structures based on the origami technique
Tang, Binbin	DA	Determination of elasticity parameters with ultrasound - state of the art, testing, analysis
Töpfer, Friedrich	DA	Conceptual pre-development of a lightweight ring structure for engine intermediate case in metal-fibre composite design

Name	Type	Theme
Uhlig, Markus	DA	Development of air conditioning concepts for gliders
Wang, Yaqi	DA	Life Cycle Assessment of metal and composite shafts
Wang, Zhenbi	DA	Development of a monitoring system for force measurement of a laparoscopy instrument
Wolf-Wagenführ, Ronald	DA	Development of a process for producing a double-curved composite consisting of a non-combustible core and cover layers
Yang, Zhaoling	DA	Virtual data augmentation of shearographic images for defect detection by means of scripted multi-physics simulations
Yi, Cheng	DA	Analysis of the influence of important process parameters on the automatic taping laying process of thermoplastic composites
Yu, Tianliang	DA	Numerical and analytical studies on substitute models for press fits in fibre composit structures
Zhu, Shangrui	DA	Numerical sensitivity analysis of the quasi-static joint strength of semi-tubular self-pierce riveted joints with different part properties

Academic Club Lightweight Engineering

Academic Club Lightweight Engineering (Akademischer Club Leichtbau an der TU Dresden e. V., ACL) is an association of alumni, scientists and sponsors of the ILK at TU Dresden. Highly complex lightweight system developments also require a sustainable network of science and industry. Against this background, the ACL since its foundation in the year 2003 sees itself as a discussion platform for the exchange of experience and knowledge transfer from young graduates through proven experts. The aims of the association are the non-material and material support of teaching and research in the field of lightweight engineering and related areas, as well as the support of a cooperation network of alumni of the course in lightweighting at TU Dresden. This is achieved both by publishing research results at lectures and discussion conferences for the scientific exchange of ideas between university and practice, and by establishing and maintaining personal contacts between students, graduates, employees and sponsors of the ILK.

Annually during the International Dresden Lightweight Engineering Symposium, the ACL Young Talent Award is presented. For this prize, Students and graduates of TU Dresden can apply with outstanding papers or diploma theses in the field of lightweight engineering. In 2021, the laureates Dipl.-Ing. Tim Bätzel, Dipl.-Ing. Jonas Erlmann and Dipl.-Ing. Felix Wiebicke received their prize in the course of the virtual "Lightweighting Lounge 3D-World" of the symposium, which was organized as an online event this year.

Apart from that, the core of the activities is the regular ACL Round Table. It is the discussion platform for the exchange of knowledge and technology between industry and research. In addition to talks by regional players in the field of lightweighting or ILK staff, it also serves as a stage for the presentation of the finalists of the ACL Young Talent Award. The ACL also contributes by supporting various network events held annually at the ILK, such as the alumni meeting or the student meeting evening. Students and staff meet here in the relaxed atmosphere of the ILK's test hall. In this way, the "junior lightweight engineers" can exchange experiences beyond the boundaries of their year and get to know the ILK staff and professors personally outside the official framework. In addition, the ACL provides financial support for the annual excursions to lightweight manufacturing partners in industry and research. In 2021, however, all such activities once again had to be paused due to the pandemic.

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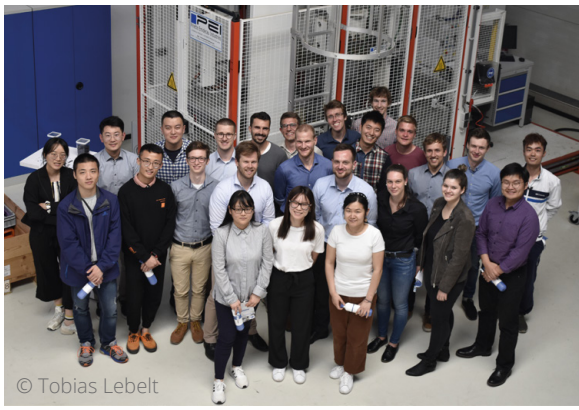
Virtual awarding ceremony of the ACL Young Talent Award 2021.



Student excursion, Netherlands 2019.

juniorIng.

Association for Engineering and Natural Sciences
Junior Education Saxony

The non-profit Asscociation for Engineering and Natural Science Junior Education Saxony (Verein für ingenieur- und naturwissenschaftliche Juniorenbildung Sachsen e. V.) – short: juniorIng. Sachsen e. V. – was founded by employees of the ILK already 2009. Our activities focus on the long-term encouragement of the technical interest of children and young people. To this end, we cooperate closely with with sponsors of scientific and cultural events in Dresden and all over in Saxony.

To our goal, we are organizing informative but also practically oriented events on a variety of topics from lightweight engineering, with a wide range of target audience: pre-school children, schools, technical high schools and colleges, but also open for the wide society. The addressed issues at these events go around the type and structure of lightweight materials, possible design methods or constructions as well as the integration of additional functionalities and especially the sustainability of lightweight materials and structures.

Moreover, our futher activities support educational staff by knowledge transfer in engineering and natural sciences, concerning primarily the age-appropriate and practice-oriented teaching in this fields. This is the spirit of e.g. our project days and weeks or of the supervision of scientific school term papers at the ILK. Additionally, we develop and provide informative and experimental working materials addressing lightweight materials, design concepts and processing technologies. In close cooperation with the ILK, we also organize child-friendly experiments with the respective target groups directly.

In the course of these activities, we have already experienced many interesting, exciting and hilarious moments with a lot of children and young people, as well as their parents, teachers or other caregivers. Thus, we have imparted knowledge in a playful way and gained educational experiences on both sides.

In 2021, our usual activities were limited due to the pandemic. Nevertheless, we were able to support the students of the Grammar school Martin-Andersen-Nexö-Gymnasium in the preparation and defence of their school works (KOLL and BELL) and inspire three prospective female students with the production and testing of fiber-reinforced composites as part of the tryING exploratory studying workshop. In addition, our association became member of the board of the State Association of Saxon Youth Education Centers (Landesverband Sächsischer Jugendbildungswerke e. V., LJBW) in 2021 and supports it in their Saxony-wide coordination of school social work and STEM programmes.

Experiencing lightweight materials..

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(from left to right) Prof. Dr.-Ing. habil. Maik Gude, Prof. Dr.-Ing. Martin Dannemann, Dr.-Ing. Anja Winkler and Dipl.-Ing. Sirko Geller.

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