

# Impact of Geometry Simplification and Element Size on the FEM-MBS-Coupling-Process

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## 1 Introduction

The elastic multi-body simulation (EMBS) progressively constitutes the established method when dealing with elastic deformations of components due to lightweight design [1]. This paper illustrates the FEM-MBS-coupling-process at the example of a diesel-hydraulic locomotive at which the impact of geometry simplifications and element size is demonstrated. The drive train is modeled in detail and contains gears, bearings as well as elastic wheel set axles and elastic gear boxes – the latter are realized as reduced FE-models, see figure 1.

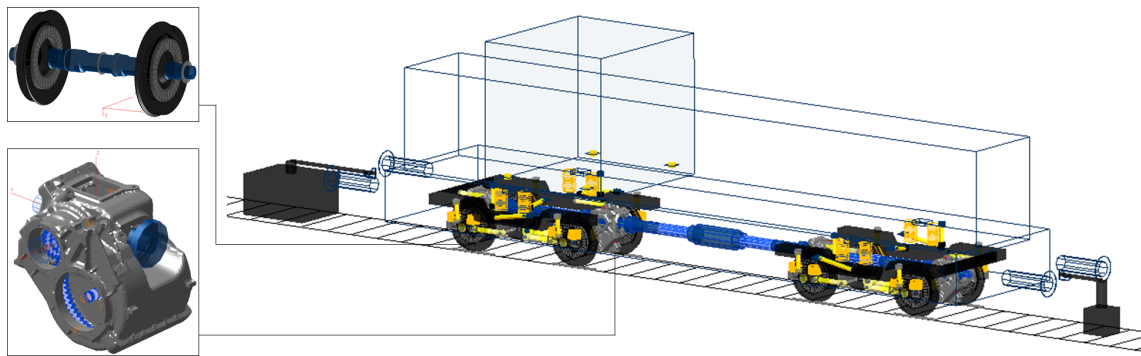


Figure 1: Elastic multi-body-model of a diesel-hydraulic locomotive with elastic wheel set axles and elastic gear boxes

The respective process chain consists of the required steps starting with a CAD-model through to the elastic body for the EMBS-model, see figure 2. Four essential steps can be identified: (1) generation of CAD- and FE-model, (2) definition of connections and interfaces, (3) model reduction as well as (4) integration of the elastic body into the multi-body system. Within each process step individual options are available (figure 2). Each option requires a suitable decision-making followed by a mandatory assessment criterion.

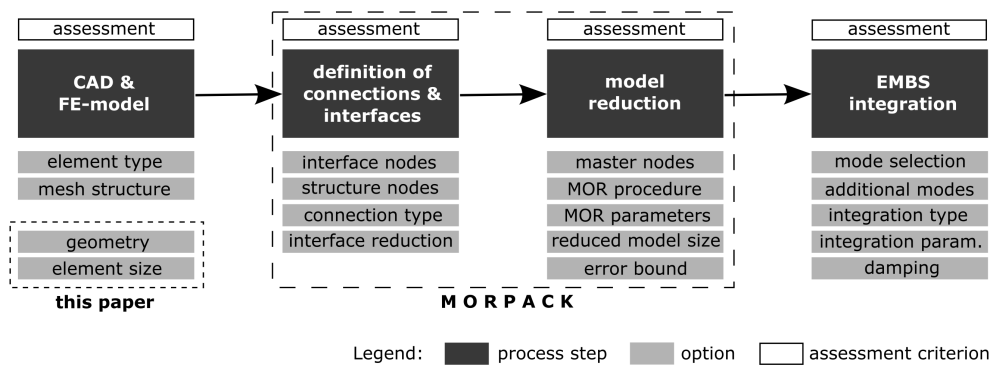


Figure 2: Process chain for integrating elastic bodies into multi-body systems

The currently established standard coupling-process evokes four major problems: (1) The variety of process steps allows a large spectrum of decisions. (2) The single process steps are coupled and interconnected. (3) For the whole process a variety of different software packages, export macros and interface programs is necessary. (4) Numerous options need to be set manually and the impact caused needs to be assessed – both tasks require advanced user knowledge.

Summarizing, the coupling-process mainly depends on the user intervention as well as on the application and consequently provides a subjectively shaped and variable result. Additionally, on the way to a demand-based

elastic body with adequate approximation quality many iteration steps are necessary, which generally require an enormous amount of time. In order to reduce the variety of decisions and computation time, this paper gives general recommendations concerning the two process steps geometry and element size.

## 2 Modeling of a casted axle gear box

This paper only focuses on the first process step (figure 2), which will be analyzed in detail. Due to its complexity, the casted axle gear box (figure 1) represents a suitable object of study for the investigation of geometry simplification and element size. According to the usual practice, the geometry information is provided via a STEP-file, which means that any geometry features cannot be reconstructed afterwards. Despite the utilization of current defeaturing-tools, the effort by the user is still vast to manipulate or simplify the geometry. Nevertheless, this additional effort is accepted in this investigation to estimate the impact and benefit of the measures.

### 2.1 Model with geometry simplifications

Four geometry configurations I to IV are generated by gradually simplifying or removing geometry features like lettering, holes, rounds, chamfers and brackets, see figure 3. Configuration I represents the basic configuration containing the full geometry details.

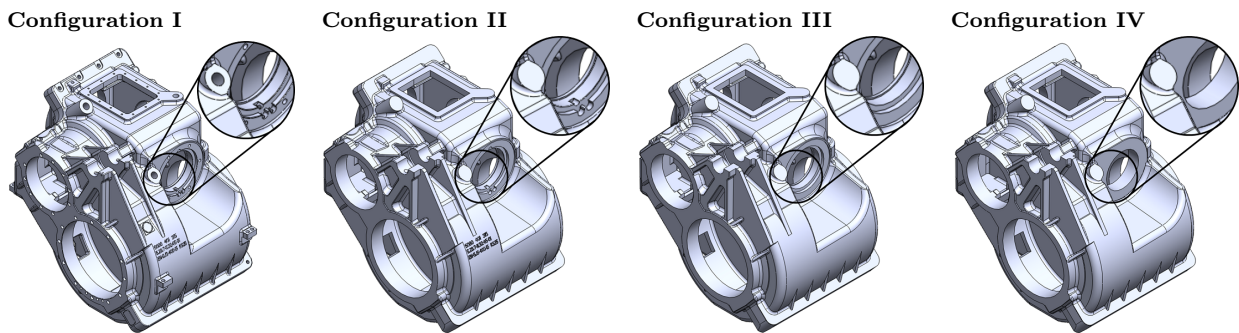


Figure 3: Model-configurations I to IV (I: basic model, II-IV: decreasing geometry details)

### 2.2 Model with varying element size

The impact of the meshing on the coupling-process is investigated by generating four different FE-meshes based on the basic configuration I. All FE-models are dominantly meshed with 10-node-tetraeder-elements and the average element size varies from 30 mm to 6 mm, see figure 4. The meshes were generated automatically by using ANSYS Workbench v14.0, whereby the finest model (6 mm) is only used for convergence observations.

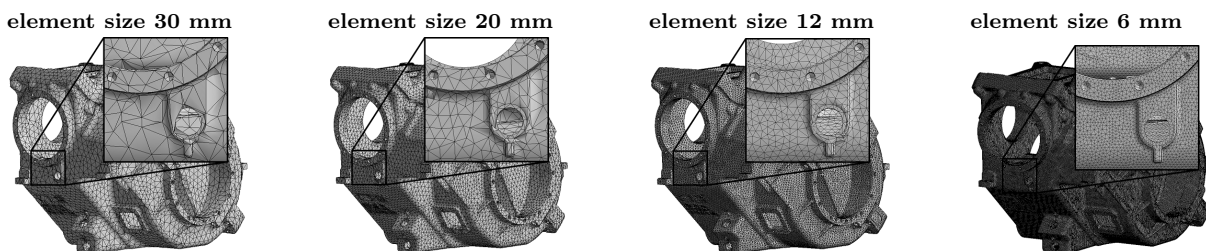


Figure 4: Model-configuration I with varying mesh density (average element size 30/20/12/6 mm)

### 2.3 Model order reduction by MORPACK

To preclude influences caused by subsequent process steps as well as to reduce the parameter variety and number of programs used, the MORPACK (Model Order Reduction PACKage) [2] software is employed, which is developed at the Chair of Dynamics and Mechanism Design and consists of the modules listed in figure 2. Among others, MORPACK is used for the model order reduction (MOR), the modal analysis and for the assessment of the dynamic behavior by using correlation criteria, e.g. the modal assurance criterion (MAC) [3].

### 3 Simulation results

Based on a transient analysis of the diesel-hydraulic locomotive model in SIMPACK, the influence of geometry and FE-mesh on the bearing forces is pointed out and the effect on the computation time is identified. The following results are gained during a run-up simulation over 10 s of the locomotive, where sliding effects are investigated, which occur due to the spinning of the wheel set axles. Thereby the cutting forces of the tapered roller bearings, which support the gear box on the wheel set axle, are recorded.

#### 3.1 Impact of geometry simplifications

First of all, the impact of geometry simplifications considering configurations I to IV is investigated. Figure 5 shows the bearing forces in the z-y-plane for all four model-configurations, each with an element size of 12 mm. Obviously, only marginal differences can be determined among the four plots. For more detailed information, figure 6 provides an insight of the results in the time domain. From here it can be observed that configuration III and IV lead to considerable deviations. More precise conclusions can be drawn by transforming the results of figure 6 into the frequency domain by means of a Fast-Fourier-Transformation (FFT), which is illustrated in figure 7. It is obvious that the deviations among the four configurations are neglectable at the resonant peaks, e.g. around 32 and 65 Hz. Only in between the peaks the deviations become dominant.

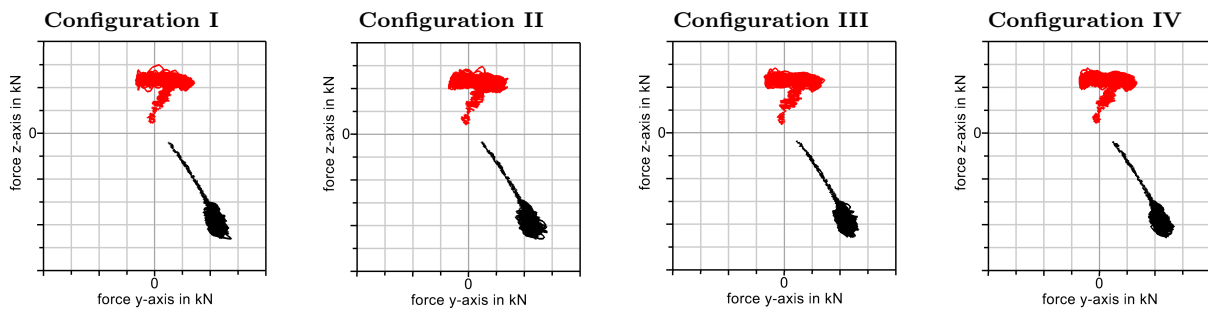


Figure 5: Bearing forces of trailing bogie for model-configurations I to IV (z-y-plane)

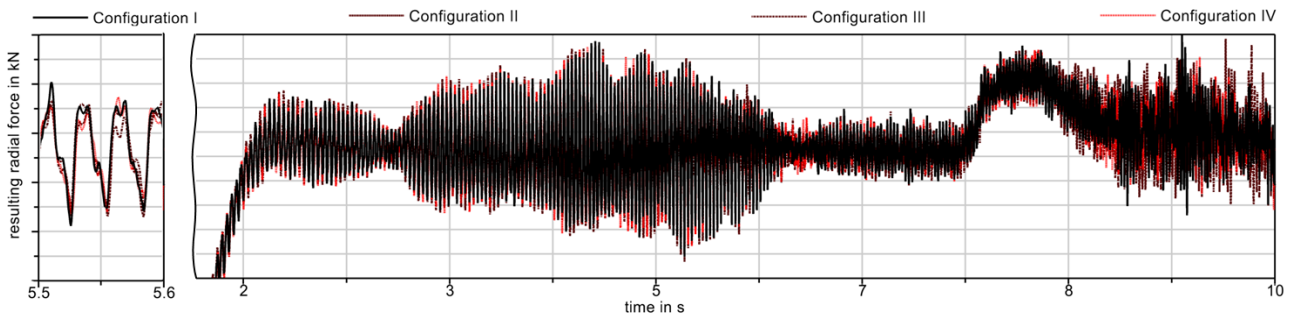


Figure 6: Bearing forces of trailing bogie for model-configurations I to IV (resulting radial component)

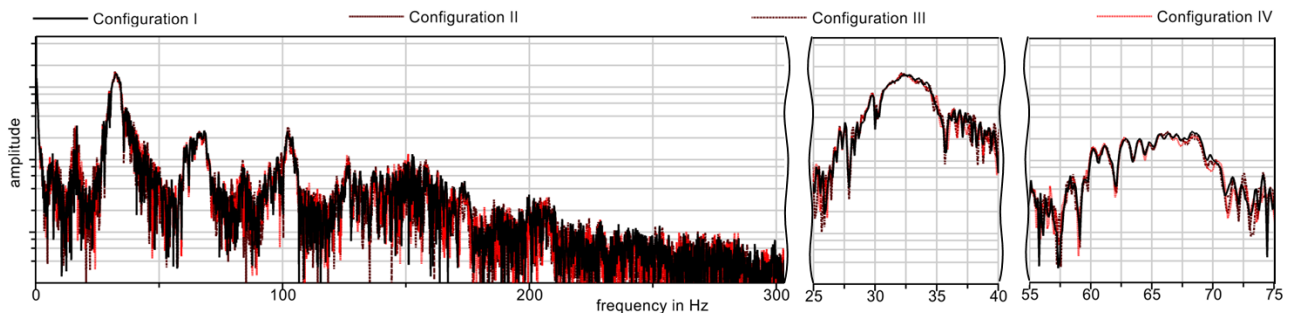


Figure 7: Bearing forces of trailing bogie for model-configurations I to IV (FFT of resulting radial component)

### 3.2 Impact of element size

Secondly, the impact of the mesh density is investigated. For this purpose, configuration I is automatically meshed by using three different mesh densities. Analogously to section 3.1, the results are observed and illustrated in figures 8 to 10. As deviations are marginal again in figure 8, the results in the time and frequency domain (figures 9 and 10) show that both coarser meshes yield considerable deviations. Compared to the results of the geometry simplifications, the variation of the average element size has a greater influence.

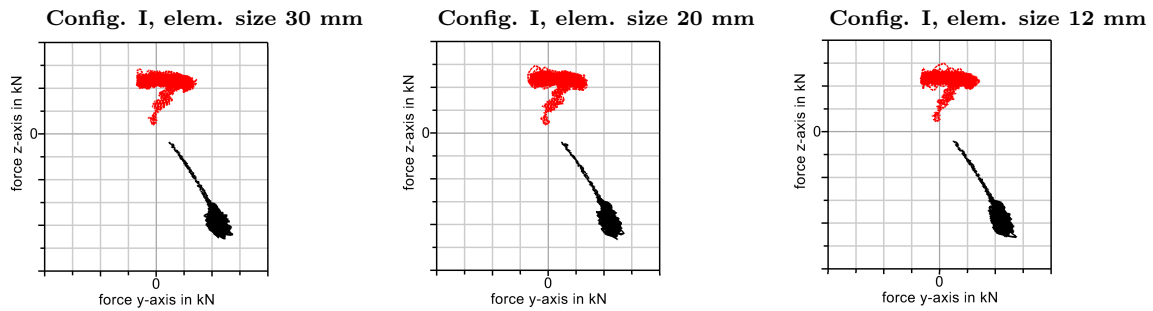


Figure 8: Bearing force of trailing bogie for average element size 30 to 12 mm (z-y-plane)

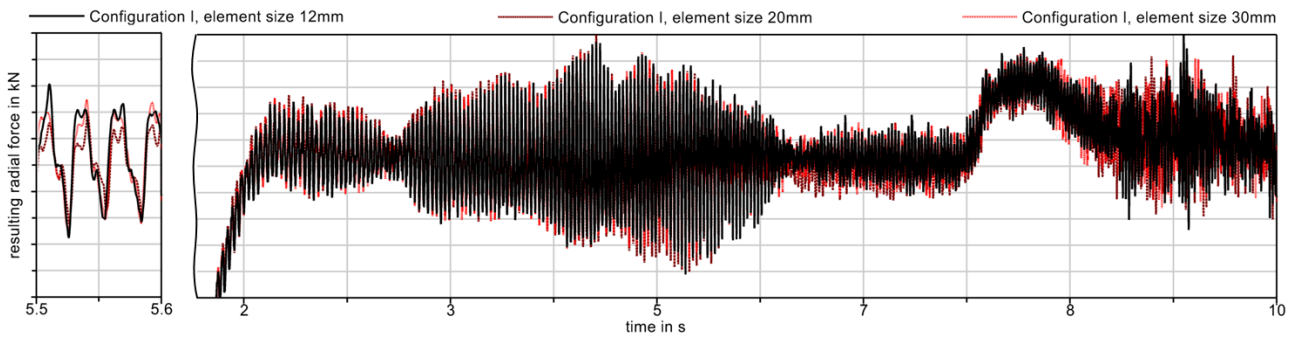


Figure 9: Bearing forces of trailing bogie for average element size 30 to 12 mm (resulting radial component)

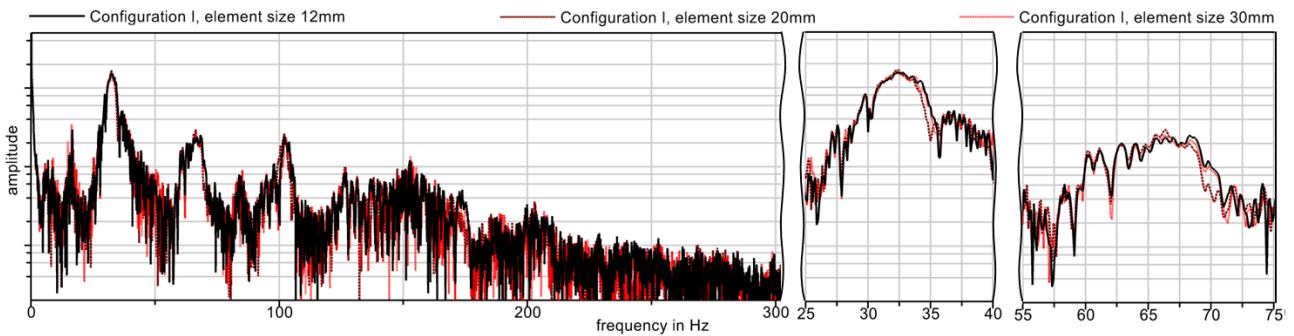


Figure 10: Bearing forces of trailing bogie for average element size 30 to 12 mm (FFT of resulting radial component)

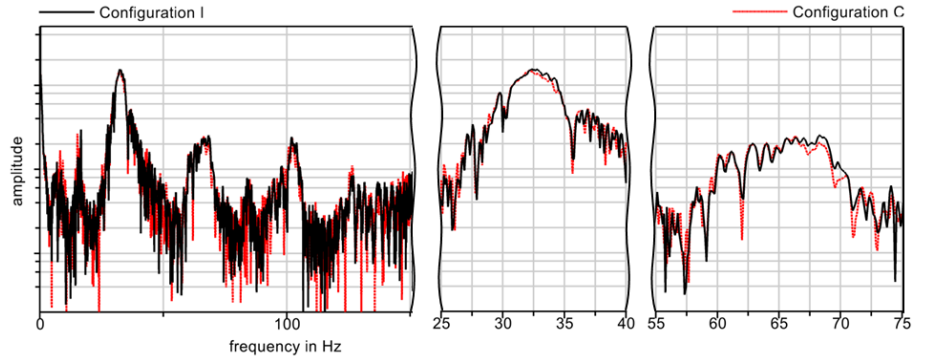
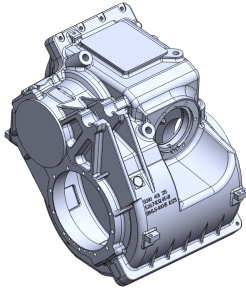
### 3.3 Impact of gear box caps

Finally, the influence of the gear box caps is determined. Therefore, the model is complemented by four additional caps and equipped with a 12 mm mesh, named configuration C. Figure 11 shows the corresponding model and the results in the frequency domain. It can be seen, that the impact of the caps is comparable to a coarse mesh.

### 3.4 Time requirement

The generated models and results are now compared regarding the consumed time. For this purpose, three categories are deployed: (1) Preparation time for realization of geometry simplifications of the CAD-model.

### Configuration C



**Figure 11:** Model-configuration C and bearing forces of trailing bogie (FFT of resulting radial component)

(2) Time for model order reduction and modal analysis in ANSYS. (3) Time for transient analysis of the locomotive model in SIMPACK. The preparation time is of course a subjective aspect and furthermore not necessary for the meshing process, since the mesh is created automatically. The results and meta data of all models are gathered in table 1. It can be noticed that an advanced modeler takes up to one hour to simplify the CAD-model, but the time costs for the simulation remain almost constant. Reversely, mesh refinement only affects the time costs for the model order reduction and modal analysis, but not for the EMBS simulation.

**Table 1:** model overview and time requirements

Configuration	I	II	III	IV	I	I	I	D
Element size in mm (average)	12	12	12	12	30	20	12	12
Element number in thousands	589	610	609	615	53	142	589	629
Degree of freedom in thousands	2777	2830	2824	2846	304	734	2777	2954
Preparation time in min (subjective rating)	≈ 5	≈ 15	≈ 45	≈ 65	-	-	-	≈ 25
Time for MOR and modal analysis in min	280	277	273	269	30	83	280	276
Time for EMBS simulation in min	76	75	81	80	74	75	76	74

## 4 Conclusions

At the example of an elastic axle gear box the impact of geometry simplifications and element size on the FEM-MBS-coupling-process is investigated. The following conclusions and general recommendations can be derived: (1) The deviations are mainly detectable in the frequency domain and become dominant between the resonant peaks. The amplitude at the resonant peaks is mostly unaffected. (2) Mesh refinement and the consideration of the caps have a greater impact on the results than geometry simplifications. (3) Time costs for manual preparation can always be saved by automatically meshing the detailed, not simplified CAD-model. (4) Caution is needed for the global mesh refinement, since simulation results and time are mainly affected. (5) The model topology itself must be assessed, because a faulty model can be worse than a poor mesh.

## 5 Acknowledgement

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## 6 References

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