TECHNISCHE UNIVERSITÄT DRESDEN

Fraunhofer Institut Keramische Technologien und Systeme IKTS

# Instrumented Uniaxial Compaction Experiments on Silicon Nitride Granulates under Varied Climatic Conditions

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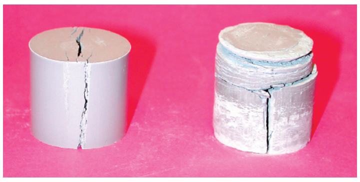
## The Mystery of Compaction

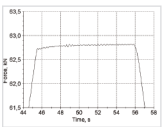


Both Compacts **Pressed from the Same Barrel** with Identical Concentrations of Additives and Moistures at the Same Temperature

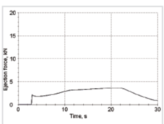
Results of Instrumented Compaction

| Property | | | Part 1 | Part 2 |
|---|---|---|---|---|
| Moisture of granulate | | [%] | 0.55 | 0.56 |
| Compact properties | $\rho$ | [g/cm$^3$] | 1.90 | 1.92 |
| | $\sigma_{Diam.}$ | [N/mm$^2$] | 1.33 | (0.98) end-capping |
| Friction | $F_2/F_1$ | [%] | 82 | 61 |
| | $\mu_W$ | | 0.110 | 0.278 |
| | $\mu_P$ | | 0.390 | 0.391 |
| | $F_{Ej}$ | [kN] | 2.2 / 3.8 | 5.5 / 19.8 |
| Energy | $A_2$ | [Nm] | 147 | 144 |
| | $A_4$ | [Nm] | 19 | 44 |
| Relaxation | $\Delta Tot$ | [mm] | 0.94 | 0.86 |
| | $\Delta i$ | [%] | 83 | 60 |
| Stress distribution | $\Delta\sigma_{ax}$ | [MPa] | 70 | 152 |
| | $\tau_{max}$ | [MPa] | 11 | 32 |

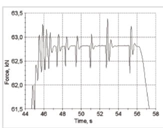
Characteristic Compaction and Ejection Curves



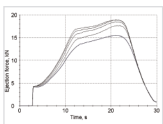
Homogeneous (Part 1)



Low Ejection Forces (Part 1)



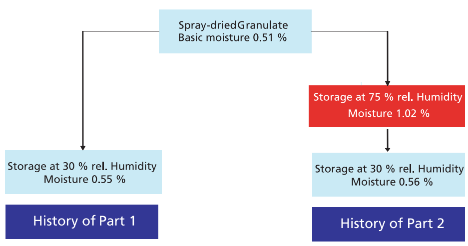
Stick-Slip-Mechanisms (Part 2)



High Ejection Forces (Part 2)

**What may be the Reason for that?**

## Explanation of the Mystery

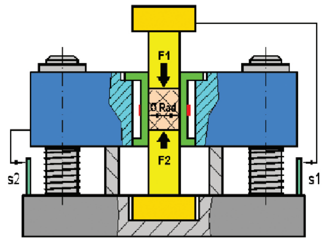



## Instrumented Compacting Tool

**Material Test Equipment**
Electromechanically (250 kN), Electromechanically (2,5 kN)
Optional Force and Way Drive Systems; Possibility of Ramp Driving

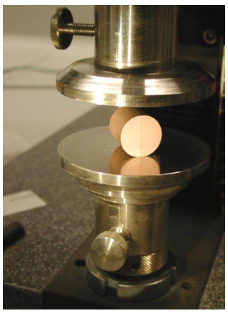
**Instrumented Inserts**
Die Materials (Hardened Steel, CPM-Steels, Tungsten Carbide)
Geometry (cylindrical, ∅ 9 - 25 mm), Pressure Range (20 - 600 MPa)

**Laboratory with Adjustable Climatic Conditions**
Relative Humidity 20 - 80% , Temperature 16 - 28°C




| | |
|---|---|
| $F_1$ | Force at the Upper Punch |
| $s_1$ | Way of the Upper Punch |
| $F_2$ | Force at the Lower Punch |
| $s_2$ | Way of the Die (optional) |
| $\sigma_{Rad}$ | Radial Stress |

System of Specific Compaction Parameters



**Parameters of the Compacts**

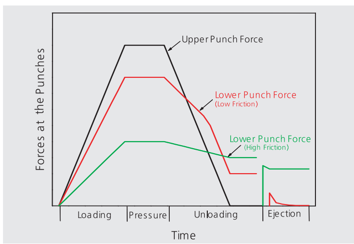
| | |
|---|---|
| $\rho_G$ | Geometrical Density |
| $\sigma_{Dia}$ | Diametral Compressive Strength |

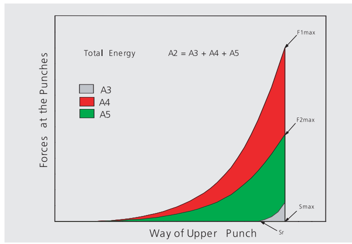
**Elastic Relaxation**

| | |
|---|---|
| $\Delta Tot$ | Total Axial Relaxation |
| $\Delta i$ | Part Inside the Die |
| $\Delta ej$ | Part at and after Ejection |
| $\Delta d$ | Radial Relaxation |

**Distributions**

| | |
|---|---|
| $\Delta\sigma_{ax}$ | Axial Pressure Stress Gradient |
| $\Delta\sigma_{rad}$ | Radial Pressure Stress Gradient |
| $\Delta\tau$ | Distribution of Shear Stresses |
| $\Delta\rho$ | Distribution of Density |




**Specific Friction Parameters**

| | |
|---|---|
| $\mu_W$ | Wall Friction Coefficient |
| $\mu_P$ | Powder Friction Coefficient |
| $\eta$ | Radial Stress Coefficient |
| $F_2/F_1$ | Force Transmission Quotient |
| $F_A$ | Ejection Force |

**Compaction Energies**

| | |
|---|---|
| $A_2$ | Total Compaction Energy |
| $A_3$ | Relaxation Energy |
| $A_4$ | Friction Energy |
| $A_5$ | Consumed Energy |

## What are the Benefits of an Instrumented Compacting Tool?

- Characterization of the Compaction Behavior Based on Well-defined Physical Parameters beyond the Empirical Level
- Evaluation of the Efficacy of Organic Binders and Lubricants; Essential for the Development of New Formulations
- Measurements of the Influences of Changing Properties of One and the Same Additive
- Monitoring of the Manufacturing Process with Respect to Reproducibility and Charge Effects
- Analyses of the Influence of Climatic Conditions on the Compaction Behavior and Properties of Green Compacts
- Study of Interactions between Powder Properties - Organic Additives - Parameters of Granulation - Compaction and Tool Parameters - Properties of Compact and Sintered Ceramics