Drop Test Analysis of a LAMY Pencil

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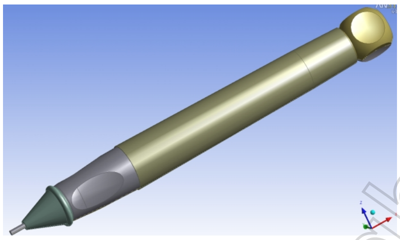
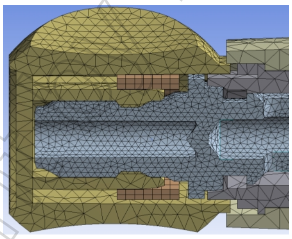
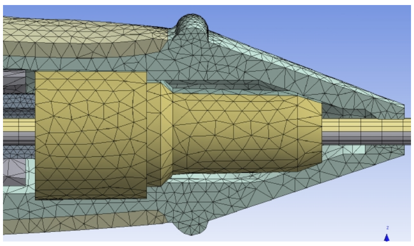
Summary:

Consumer products like cell phones, personal digital assistants, dish washers or cookers, to name just a view of them, are often exposed to drop during transportation to the customer and during usage in life time. Pre-damage, failure or malfunction due to drop is typically not acceptable and will lead to refusal through the costumer in addition with a correspondingly amount of financial and prestige loss.

The present work deals with the numerical simulation of a drop test of a LAMY pencil. Special emphasis is put on the drop onto the apex of the pencil, which is most harmful to the lead mechanics. In experiments, failure of the lead mechanics was observed for this drop position, which was a result of localized high stresses in combination with plastification in those regions.

It was the goal of the simulations to investigate whether an exchange of the used material for the lead mechanics would meet the requirements. Special emphasis was hereby placed on the reproduction of the overall lead kinematics translational and rotational wise as well as to account for the behavior of the floor material.

Keywords:
Droptest, Material failure, Consumer products

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LAMY & CADFEM

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Motivation

Motivation for this Pencil

- Failure in the lead mechanics during drop test observed using Ultraform material
- Investigation of other material combinations in order to fullfil drop test requirements
- No change in production tools allowed because of cost requirements

Long-term Motivation

- Simulation of all relevant loading cases (drop test, bending, clip loading, etc.) upfront in order to detect weaknesses in design at much earlier development state
→ Upfront Simulation
- Reduce development cycle time and costs due to less experiments and prototypes
→ Reduce Time to Market
- Get detailed insight into the pencil for all structural parts (glassy pencil) in order to get thorough understanding of behavior and derive/detect potential for optimization
→ Saving Material and Costs

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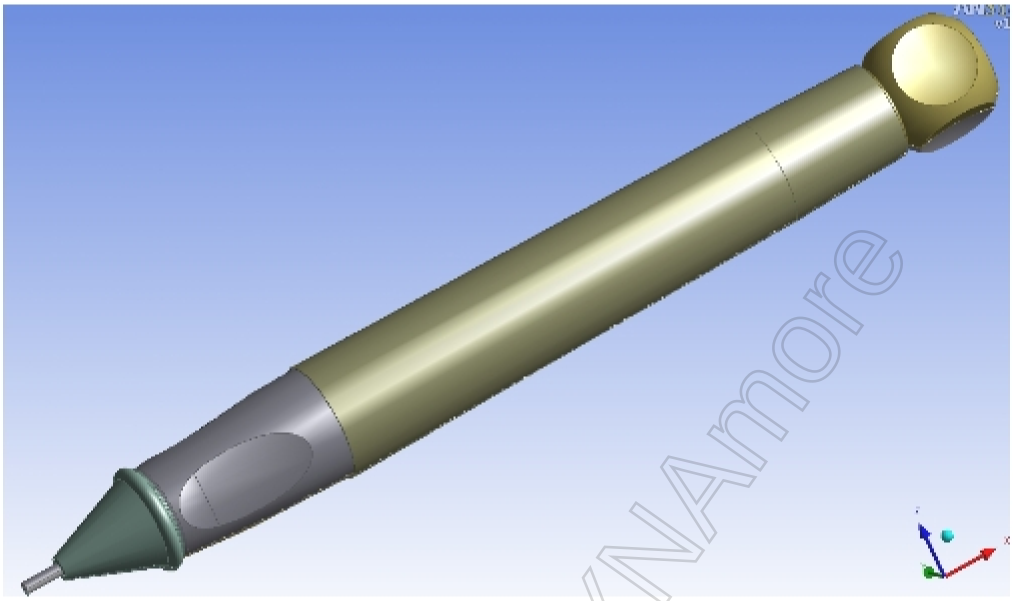
CAD-Model



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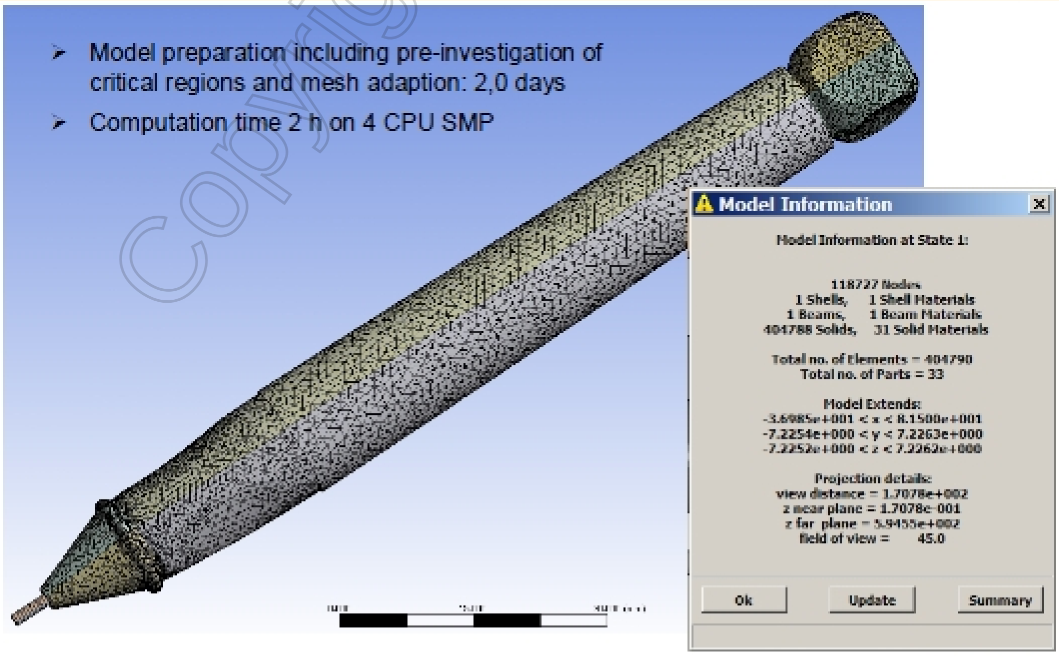
Simulation Model

- Model preparation including pre-investigation of critical regions and mesh adaption: 2,0 days
- Computation time 2 h on 4 CPU SMP



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Simulation Model

To be shown during the presentation

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Materials

Material Properties Ultraform S2320, BASF

Produktmerkmale			
Polymer-Kurzzeichen	-	-	POM
Dichte	ISO 1183	kg/m³	1400
Wasseraufnahme, Sättigung in Wasser bei 23°C	ähnlich ISO 62	%	0.8
Feuchtigkeitsaufnahme, Sättigung bei Normalklima 23°C/50% r.F.	ähnlich ISO 62	%	0.2
Verarbeitung			
Verarbeitungsverfahren: Spritzgießen (M), Extrusion (E), Blasformen (B)	-	-	M
Schmelztemperatur, DSC	ISO 11357-1/-3	°C	167
Schmelze Volumenrate MVR bei 190 °C und 2.16 kg	ISO 1133	cm³/10min	11
Massetemperaturbereich, Spritzgießen	-	°C	190 - 230
Werkzeugtemperaturbereich		°C	60 - 100
Werkstoffkennwerte zum Brennverhalten			
Prüfung nach UL-Standard bei d = 1,6 mm Dicke	UL-94	class	HB
Kfz-Innenausstattung: Dicke >= 1mm	-	-	+
Mechanische Eigenschaften			
Zug-E-Modul	ISO 527-1/-2	MPa	2700
Streckspannung, 50 mm/min	ISO 527-1/-2	MPa	65
Streckdehnung, 50 mm/min	ISO 527-1/-2	%	9
Nominelle Bruchdehnung, 50 mm/min	ISO 527-1/-2	%	25
Zug Kriechmodul, 1000 h, Dehnung <= 0,5%, 23°C	ISO 899-1	MPa	1300
Charpy-Schlagzähigkeit (23°C)	ISO 179/1eU	kJ/m²	180
Charpy-Schlagzähigkeit (-30°C)	ISO 179/1eU	kJ/m²	170
Charpy-Kerbschlagzähigkeit (23°C)	ISO 179/1eA	kJ/m²	5.5
Charpy-Kerbschlagzähigkeit (-30°C)	ISO 179/1eA	kJ/m²	5
Kugeldruckhärte H	ISO 2039-1	MPa	145
Prüfkraft	ISO 2039-1	N	358
Zeitdauer	ISO 2039-1	s	30

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Material Properties Delrin, DU PONT

Property	Test Method	Units	Value
Mechanical			
Yield Stress	ISO 527-1/-2	MPa	72
Yield Strain	ISO 527-1/-2	%	15
Nominal Strain at Break	ISO 527-1/-2	%	30
Strain at Break	ISO 527-1/-2	%	45
Tensile Modulus	ISO 527-1/-2	MPa	3200
Tensile Creep Modulus	ISO 899	MPa	
1h			2900
1000h			1700
Flexural Modulus	ISO 178	MPa	3000
Notched Izod Impact	ISO 180/1A	kJ/m2	
-40C			9
23C			9
Notched Charpy Impact	ISO 179/1eA	kJ/m2	
-30C			8
23C			9
Unnotched Charpy Impact	ISO 179/1eU	kJ/m2	
-30C			300
23C			340
Thermal			
Deflection Temperature	ISO 75-1/-2	°C	
0.45MPa			165
1.80MPa			100
1.80MPa, Annealed			115
Melting Temperature	ISO 3146C	°C	178
Vicat Softening Temperature	ISO 306	°C	
50N			160

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Comparison of Ultraform and Delrin

	Ultraform	Delrin
Density [kg/m3]	1400	1420
Young's Modulus [MPa]	2700	3200
Yield Strength [MPa]	65	72
Strain at Break [%]	28/	30/45

- No nonlinear stress-strain characteristic available
  → simplified approach with bilinear stress strain curve
- No information on strain rate dependency of material
  → not accounted for

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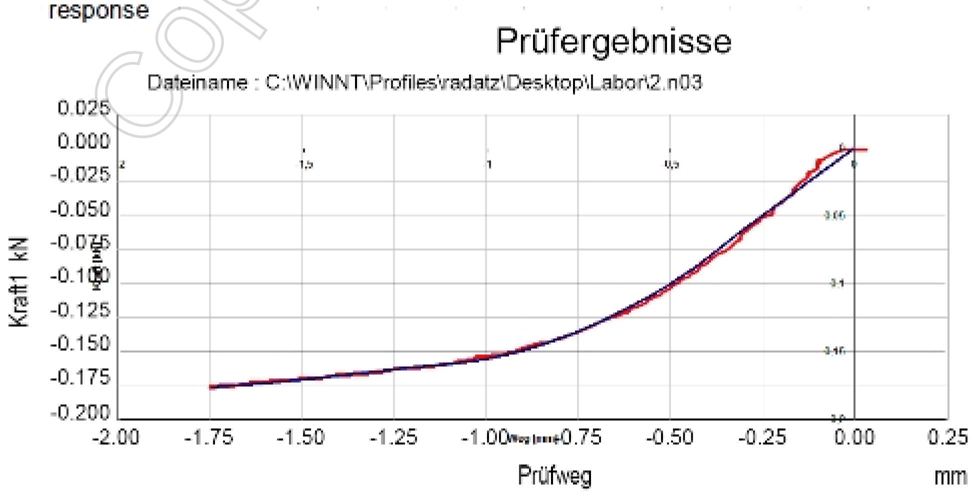
Material of Floor

- Indentation test into floor material → resulting force-displacement-response
- Numerical model with spring characteristic according to force-displacement-response



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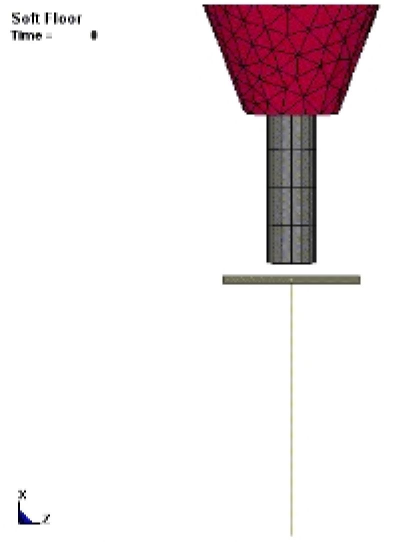
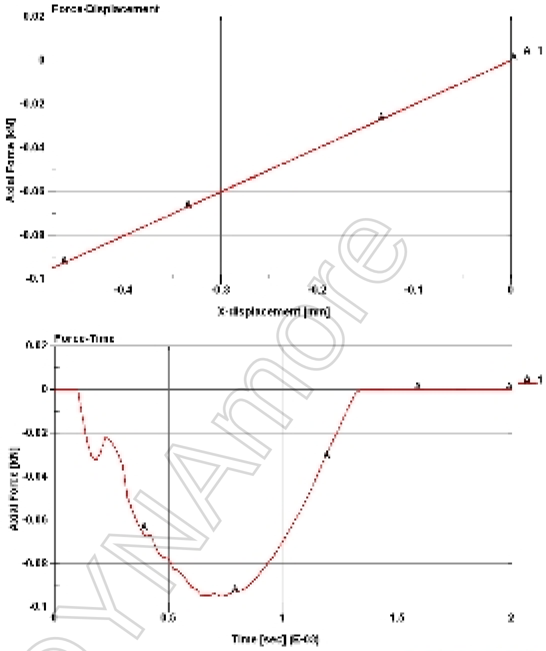
Soft Floor





- Still in linear regime of floor material
- Rotation of lead clearly observed

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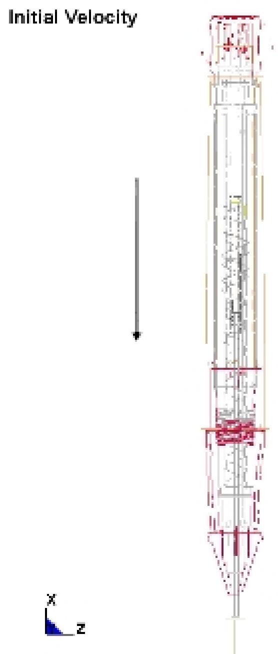
Initial Conditions

Initial Velocity

- Pencil drops from an initial height of 1 meter onto ground
- Converting potential energy into kinetic energy leads to an initial velocity of 4430 mm/s
- Impact in the direction of lead in order to load lead mechanics maximal
- Other initial drop positions possible and easily generated



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Ultraform Deformation

To be shown during the presentation

- Extensive bending of lead observed → material properties & failure?
- Rotation of lead according to winding in pencil
- Localized deformation in lead mechanics

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Ultraform Deformation & von Mises Stress

To be shown during the presentation

- Extensive bending of lead

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Conclusions

General

- Extensive bending of lead is observed → proper material parameters needed and inclusion of lead failure might be necessary
- Rotation of lead mechanics due to winding slope in pencil is reasonable → model represents overall kinematics of pencil
- Comparison with high speed movies is necessary

Material Ultraform

- Simulation of drop test using Ultraform simplified material properties shows indication for failure in lead mechanics
- Localized permanent deformations and high plastic strains can be observed
- Failure and damage on winding slope might be critical and must be checked

Material Delrin

- Simulation of drop test using Delrin simplified material properties shows clear improvement and no indication for failure in lead mechanics
- Less localized permanent deformations and smaller plastic strain can be observed

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