MATERIALS DAY 2003

Simulation of Light Metals Processing

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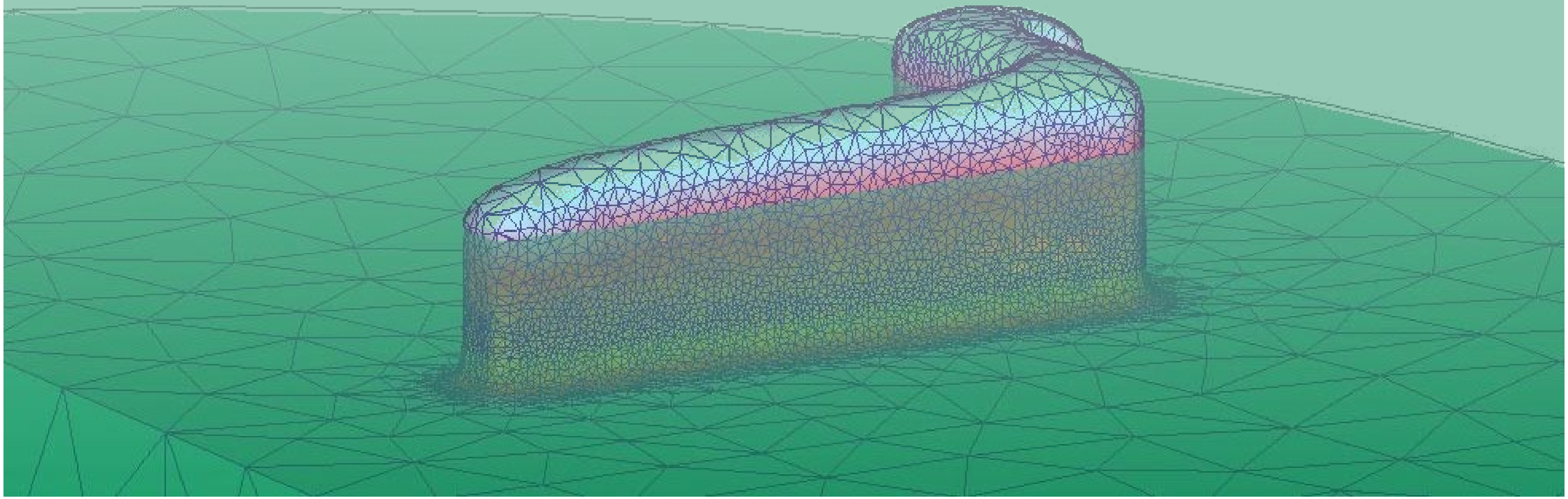
Peter J. Uggowitzer Institute of Metallurgy, ETH Zurich



Front Fender Specifications

- weight reduction
- same crashworthiness
- same production cost

Alloy Development	Production Processes
Aluminium	Deep drawing
Magnesium	Extrusion
Steel	Bending
Composites	Welding

Alloy-specific process adaption

→

Alloy Development

- Aluminium
- Magnesium
- Steel
- Composites

Production Processes

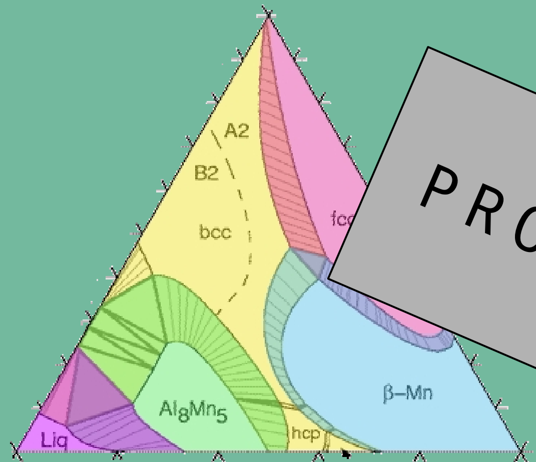
- Deep drawing
- Extrusion
- Bending
- Welding

←

Process-oriented alloy design

ETH

Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich



Alloy Development

PROCESS CHAIN

LKR

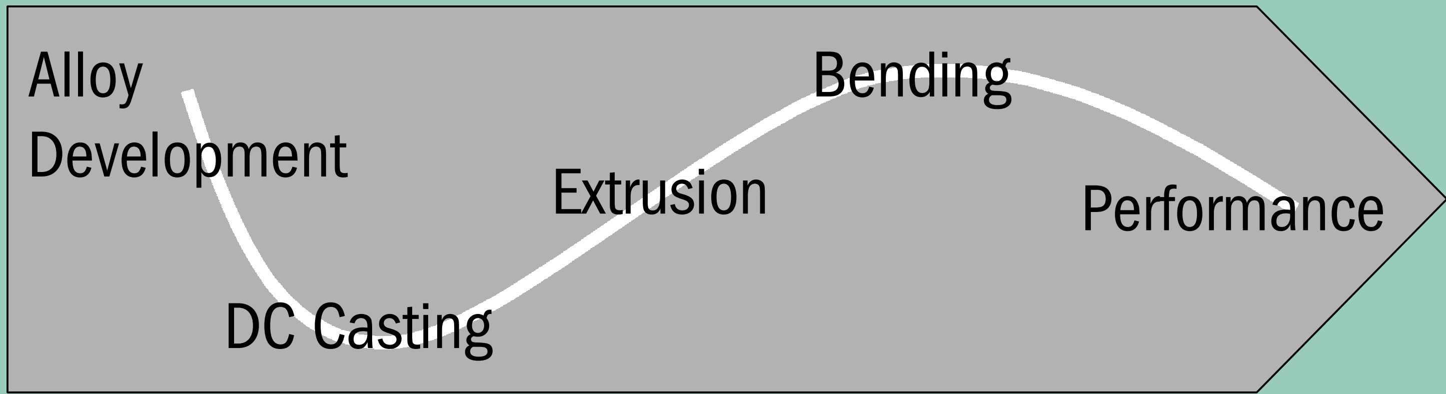
ARC LEICHTMETALLKOMPETENZZENTRUM RANSHOFEN GMBH
Ein Unternehmen der Austrian Research Centers

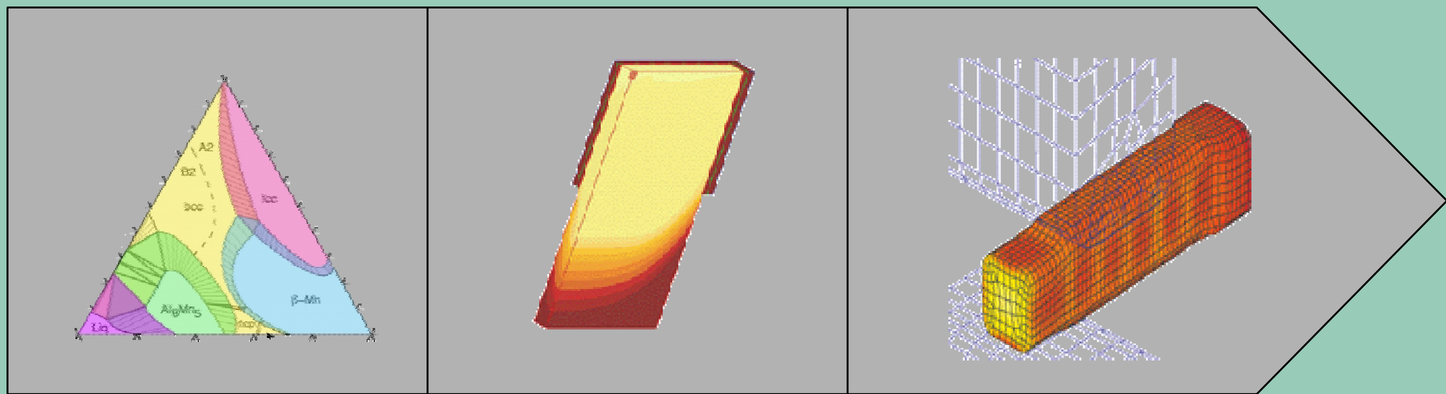
Production Processes

Motto of LKR

„From Materials to Component Systems“

P R O C E S S C H A I N





S I M U L A T I O N T O O L S

MOTIVATION

12 years

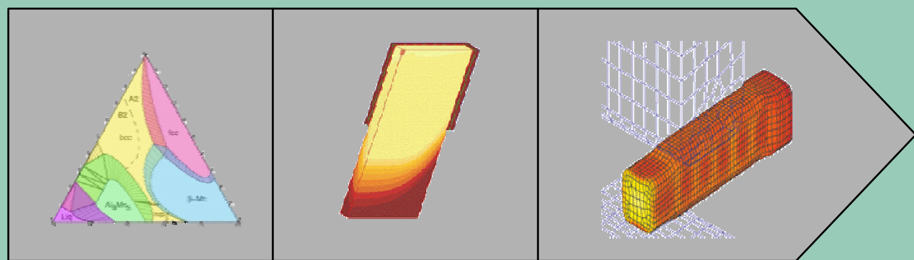
10 years

7 years

Product development times shortened dramatically

New materials development time not reduced significantly

Barrier to achieving optimum final product performance!



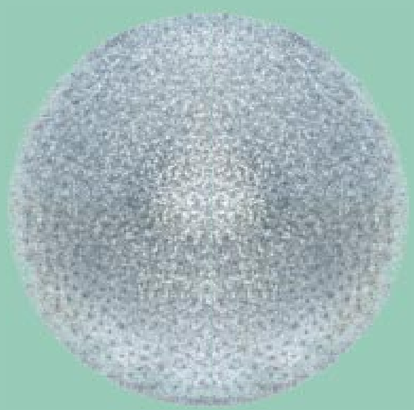
S I M U L A T I O N T O O L S

CASE STUDY: Extruded Magnesium Front Fender

Front Fender Specifications

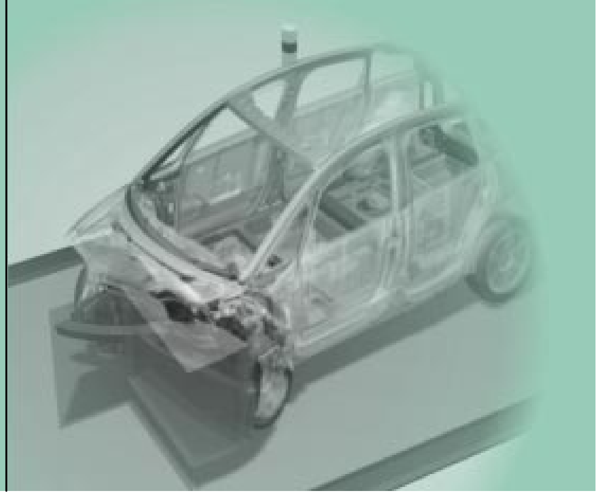
- weight reduction
- same crashworthiness
- same production cost

1 DC Casting of AZ31

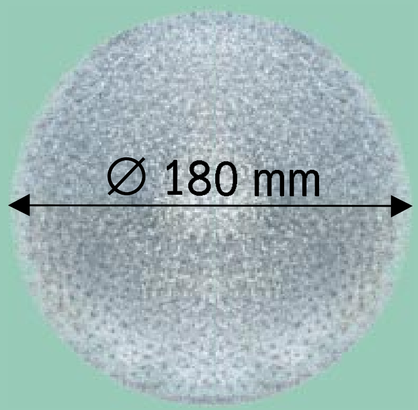


2 New Design & Extrusion

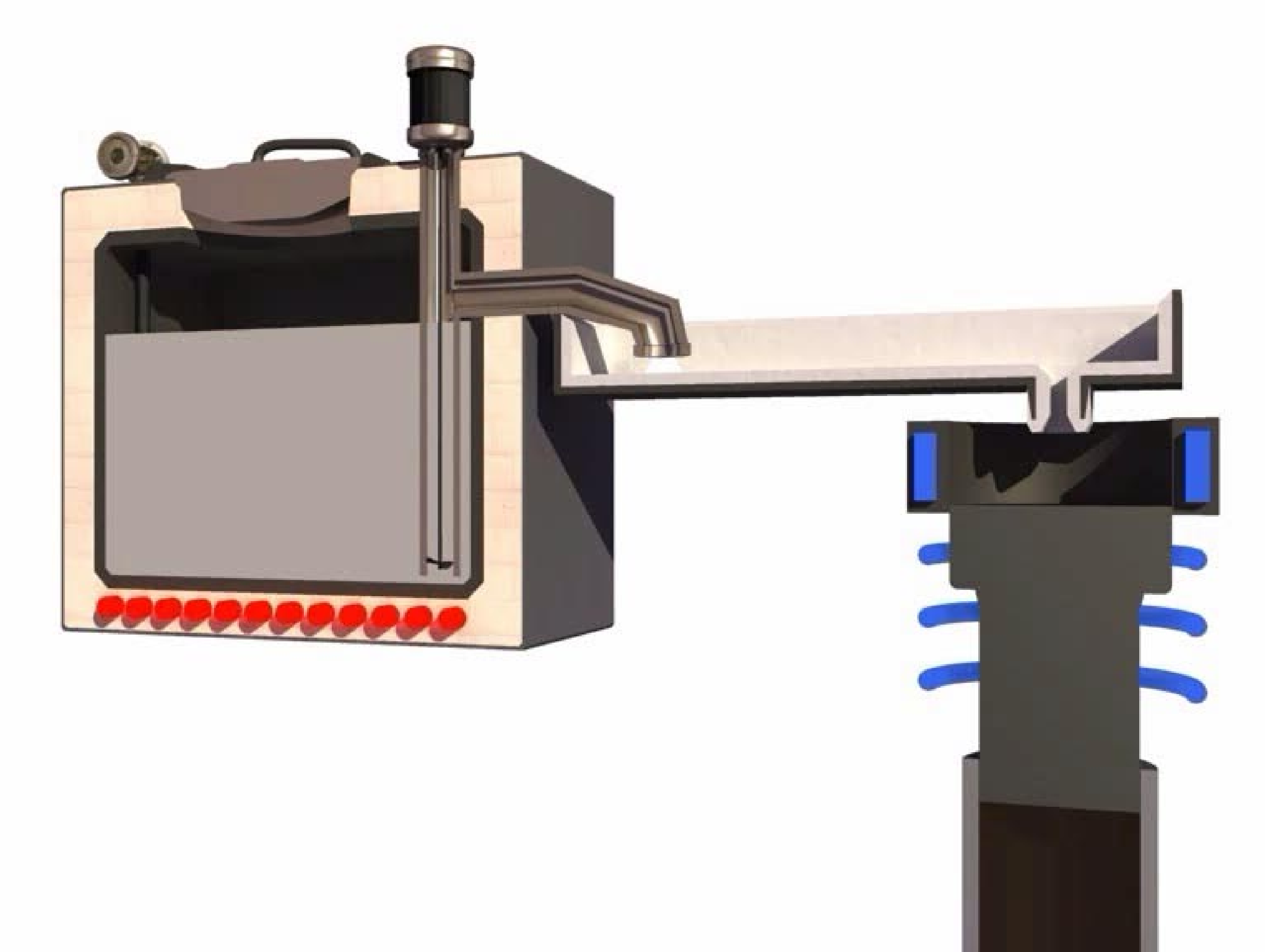
3 Crashworthiness



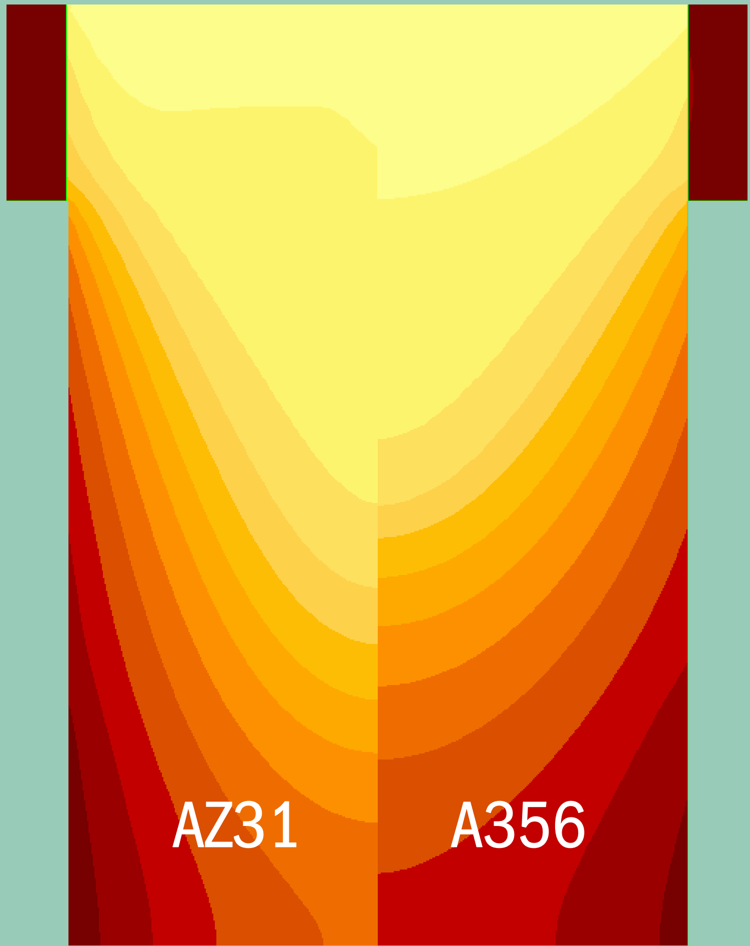
1 DC Casting of AZ31



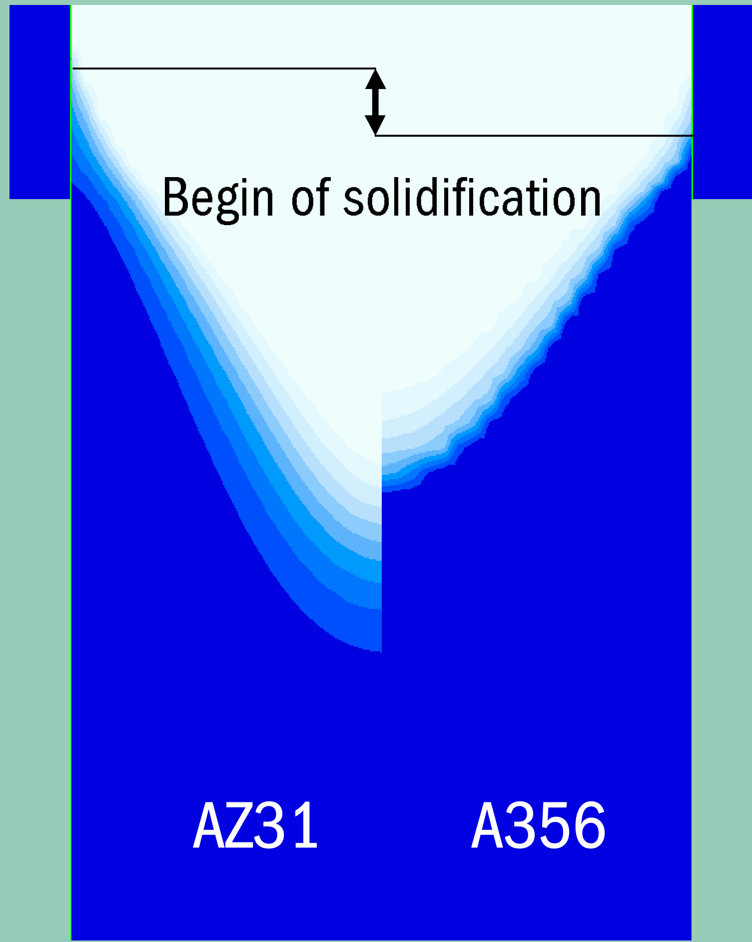
AZ31: Mg alloy
with 3% Al, 1% Zn
UTS(F): 260 MPa
YS(F): 200 MPa
Liquidus: 630 °C
Solidus: 605 °C
c_p: 1 J/gK



DC Casting Simulation with calcosoft

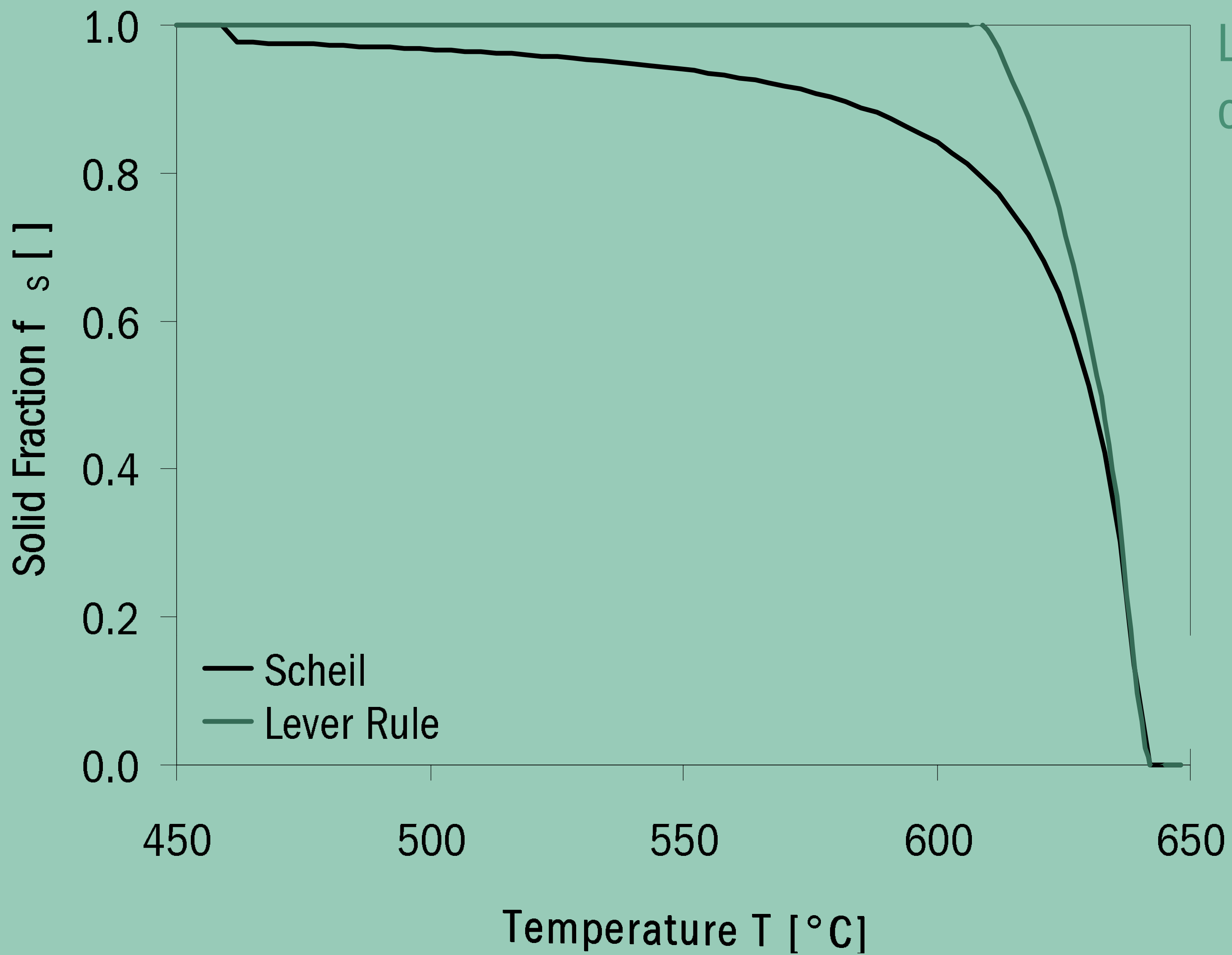


Temperature Profile



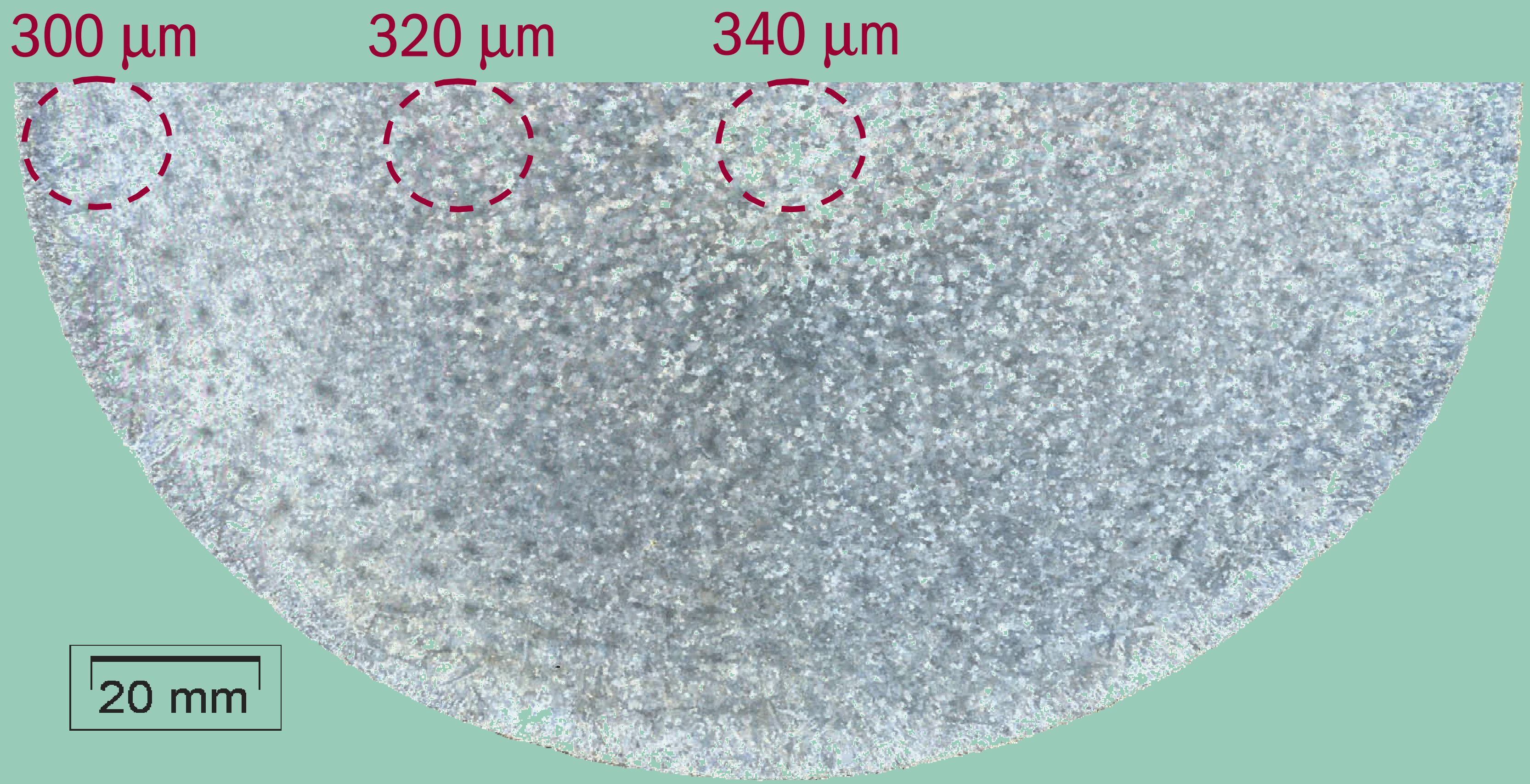
Solidification Profile

Solidification Model: Lever Rule vs. Scheil



Limited Diffusion of Al in Mg: Scheil!

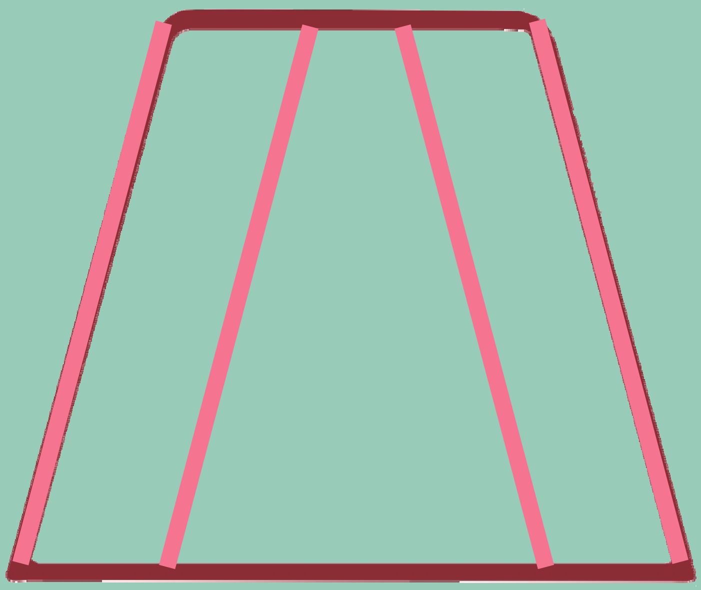
AZ31 Billet (cast without grain refiner)



2 New Design & Extrusion

Original Front Fender:

- Hollow Extrusion Profile, 1 chamber
- AA7075, ρ = 2.81 g/cm^3, E = 72 GPa
- Wall thickness 2.5 mm
- Cross section: 816 mm^2
- Weight: 3.44 kg



New Front Fender:

- Hollow Extrusion Profile, 3 chambers
- AZ31, ρ = 1.77 g/cm^3, E = 45 GPa
- Wall thickness 2.5/2.0 (flange/web) mm
- Cross section: 1072 mm^2
- Weight: 2.84 kg Weight Reduction: 21%

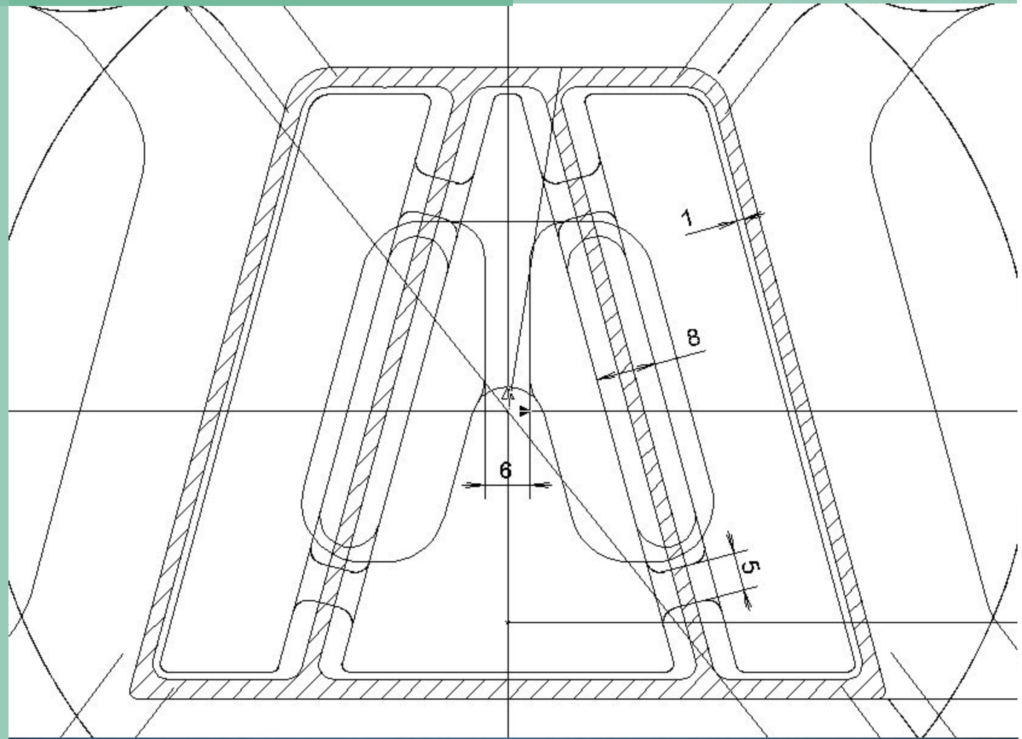
Direct Extrusion of AZ31

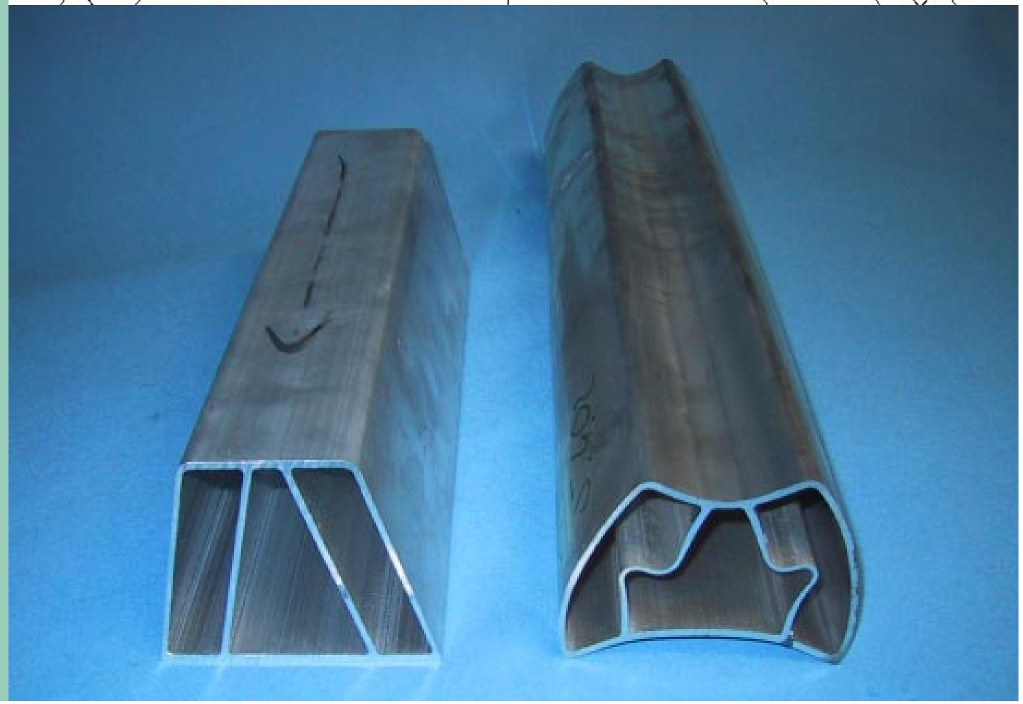
Billet Temperature: 380 °C

Container Temperature: 360 °C

Extrusion Ratio: 35

Extrusion speed: 1.5 to 4 m/min





Redesign of Extrusion Die

CASE STUDY

Simulation of Extrusion Process with DEFORM

Design Environment for FORMing

Pre-Processing

Geometries

Billet, Die, Container: CAD Import

Materials Data

Flow Stress: Model? Extrapolation?

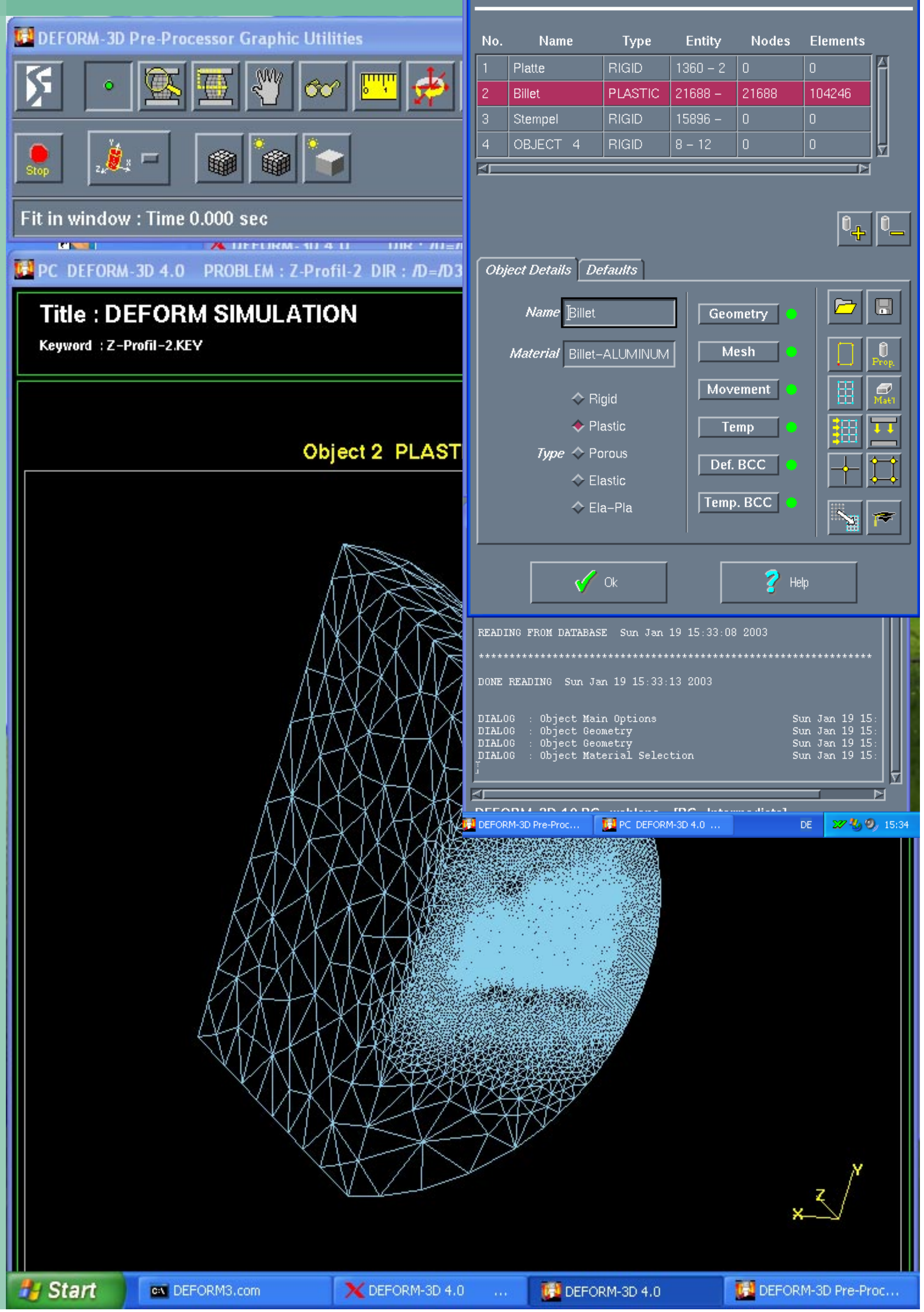
Specific Heat, Conductivity: f(T)?

Process Parameters

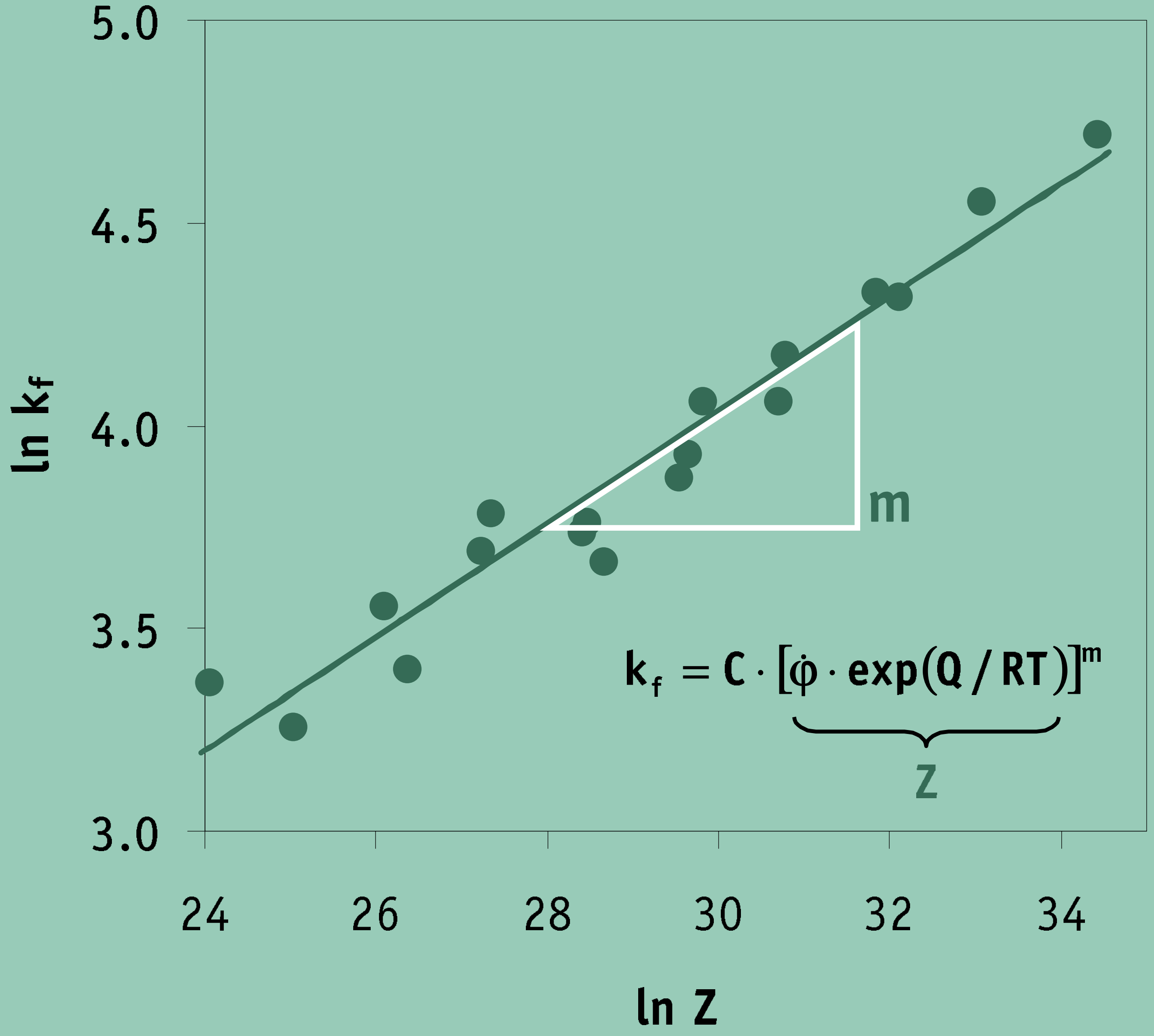
Friction Model? Heat Transfer?

Simulation Parameters

Rigid Die? Elasto-plastic Billet?



Modelling of Flow Stresses

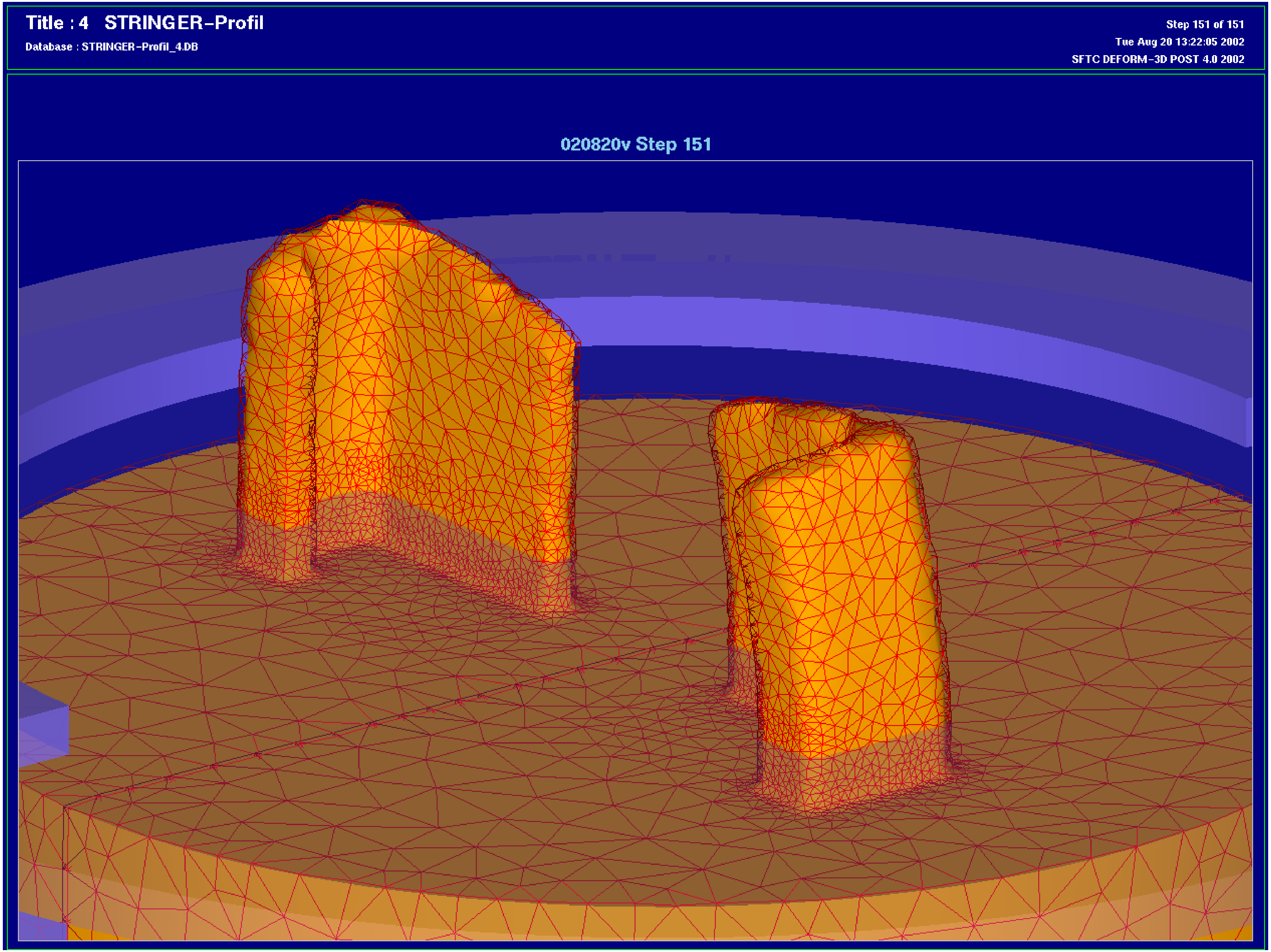


Approximation by Zener-Hollomon

C = 0.85
m = 0.14
Q = 153 kJ/mol

Activation Energy for Interdiffusion of Al in Mg
Q_1 = 143 kJ/mol

Activation Energy for Self-Diffusion in Mg
Q_2 = 135 kJ/mol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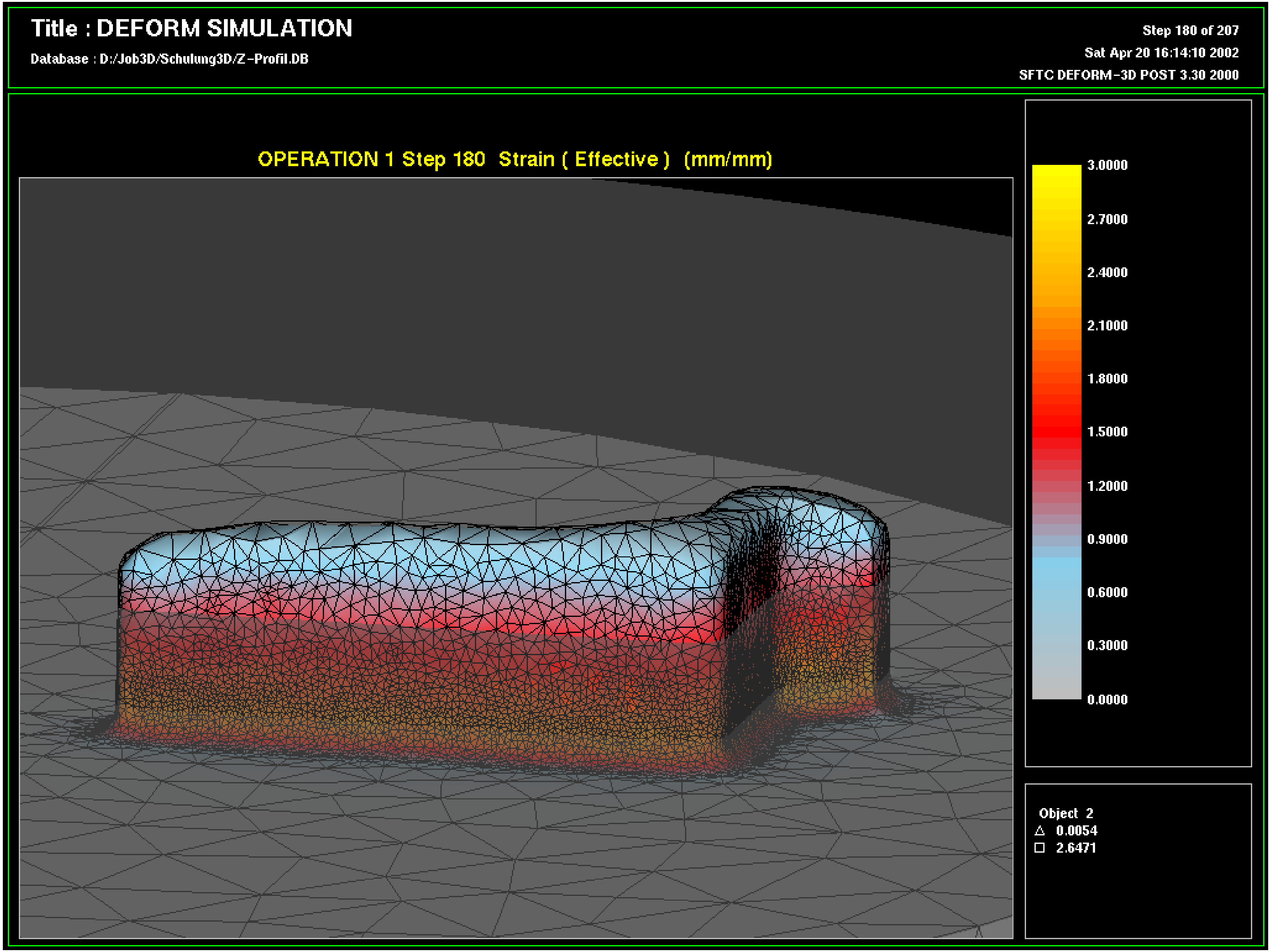
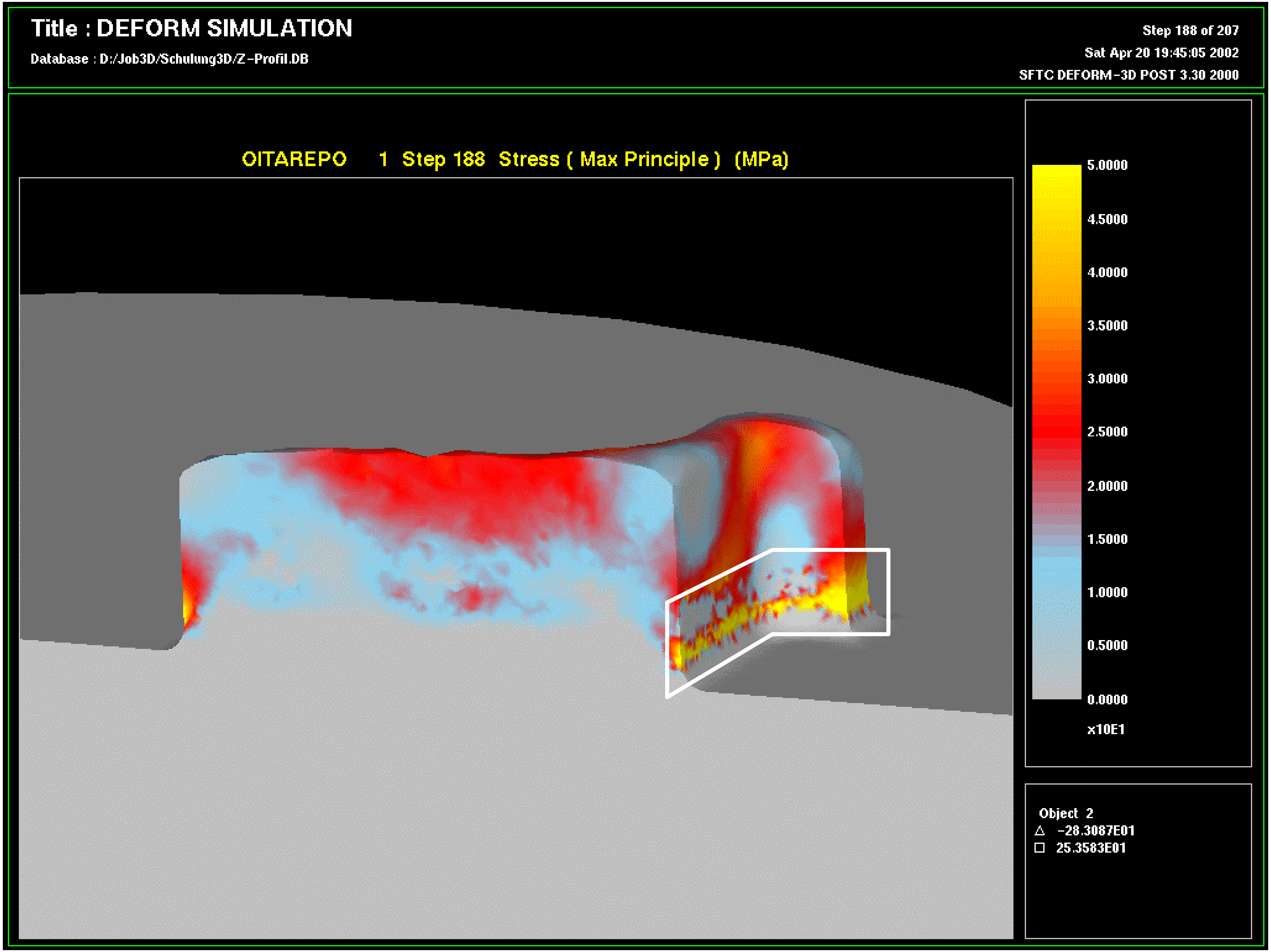
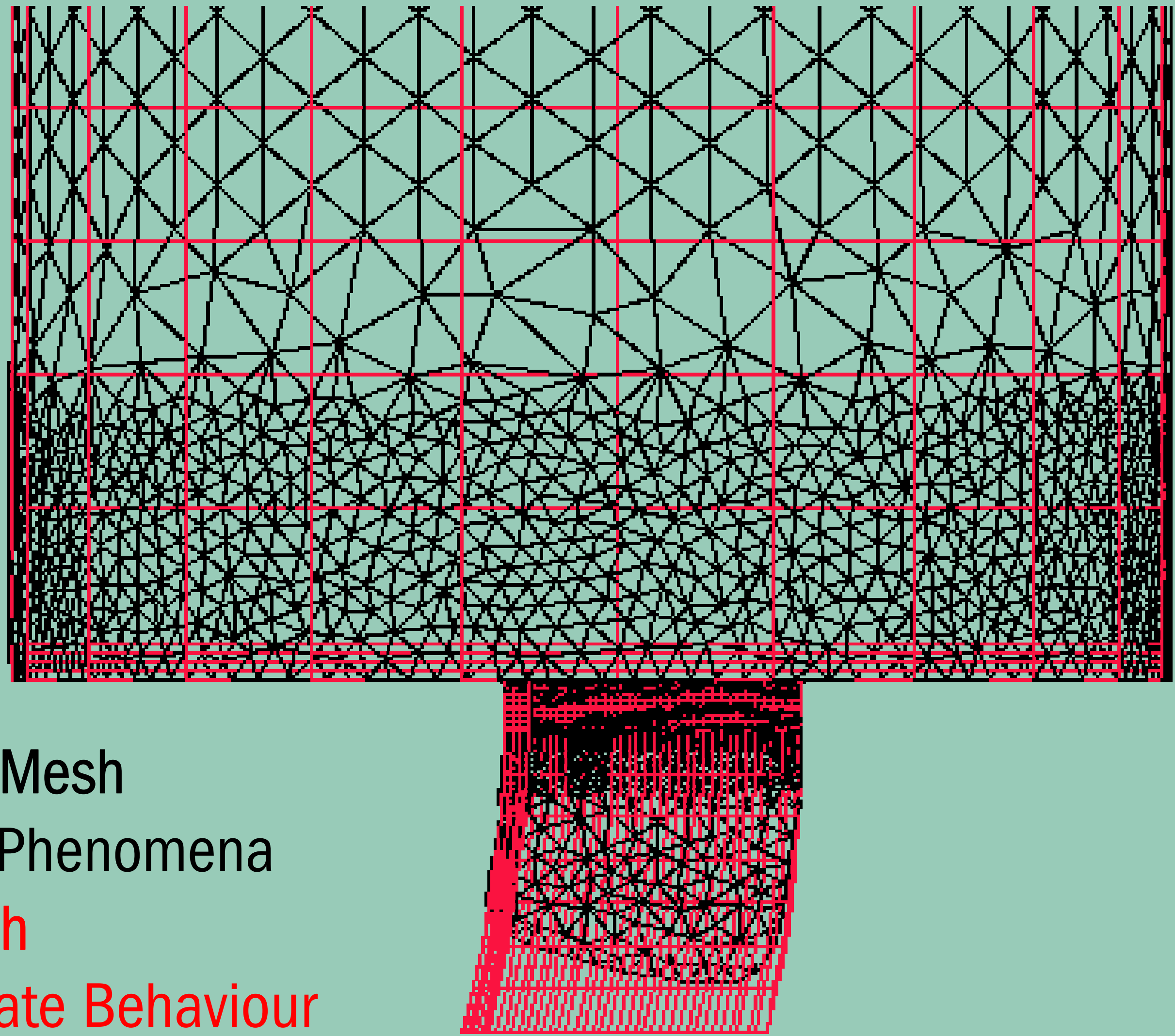
Database : STRINGER-Profil_4.DB
Step 151 of 151
Tue Aug 20 13:22:05 2002
SFTC DEFORM-3D POST 4.0 2002
020820v Step 151


Title : DEFORM SIMULATION
Database : D:/Job3D/Schulung3D/Z-Profil.DB
Step 180 of 207
Sat Apr 20 16:14:10 2002
SFTC DEFORM-3D POST 3.30 2000
OPERATION 1 Step 180 Strain (Effective) (mm/mm)
3.0000
2.7000
2.4000
2.1000
1.8000
1.5000
1.2000
0.9000
0.6000
0.3000
0.0000
Object 2
△ 0.0054
□ 2.6471



Title : DEFORM SIMULATION
Database : D:/Job3D/Schulung3D/Z-Profil.DB
Step 188 of 207
Sat Apr 20 19:45:05 2002
SFTC DEFORM-3D POST 3.30 2000
OITAREPO 1 Step 188 Stress (Max Principle) (MPa)
5.0000
4.5000
4.0000
3.5000
3.0000
2.5000
2.0000
1.5000
1.0000
0.5000
0.0000
x10E1
Object 2
△ -28.3087E01
□ 25.3583E01

Lagrangian vs. Arbitrary Lagrangian-Eulerian Formulation



Lagrange Mesh

Transient Phenomena

Euler Mesh

Steady-State Behaviour

Lagrangian vs. Arbitrary Lagrangian-Eulerian Formulation

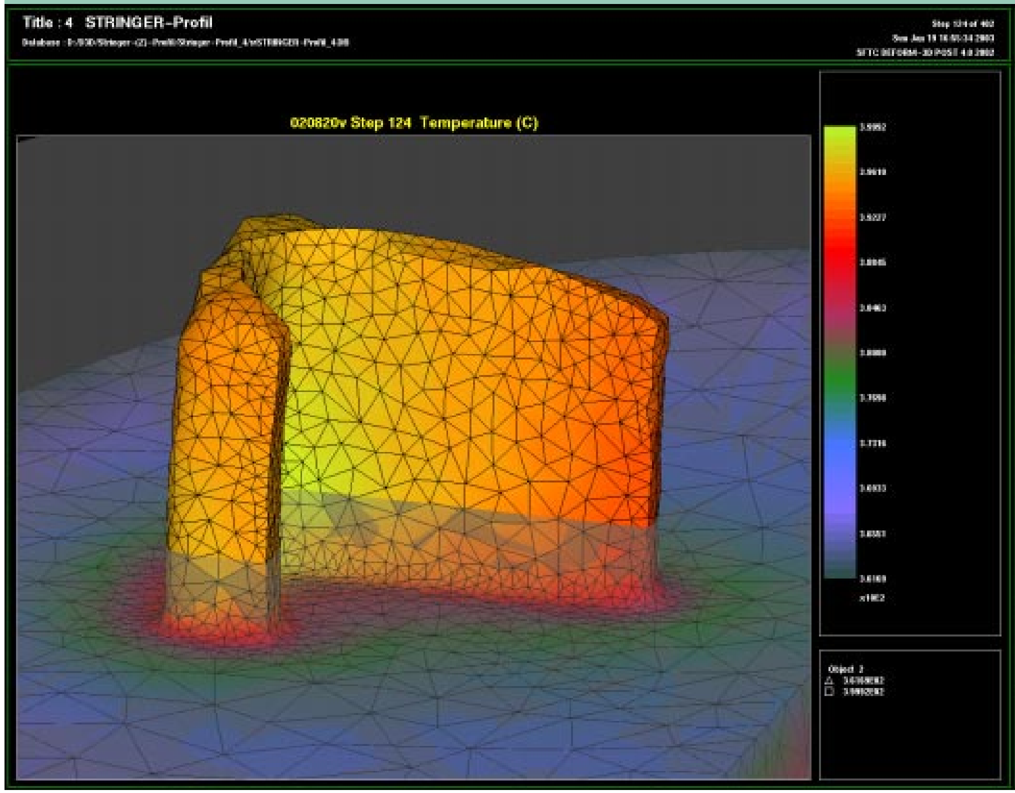
Pure Lagrangian Mesh

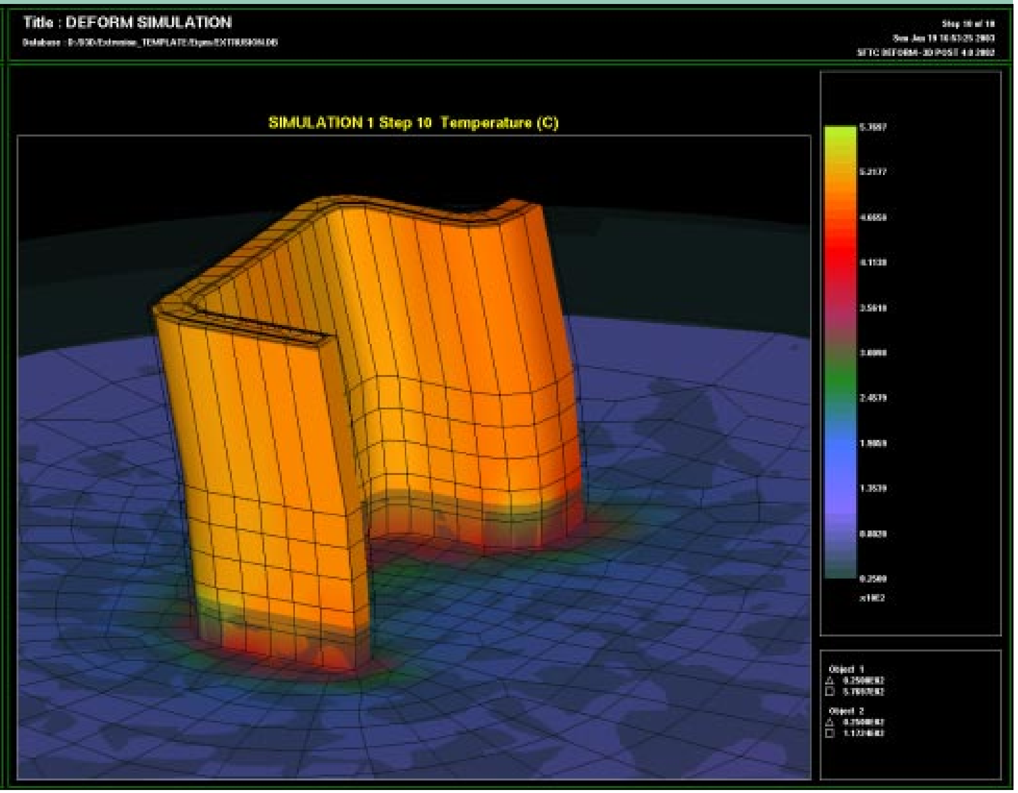
More suceptible to mesh failure (stopping/aborting simulation with negative volume error)

ALE Mesh

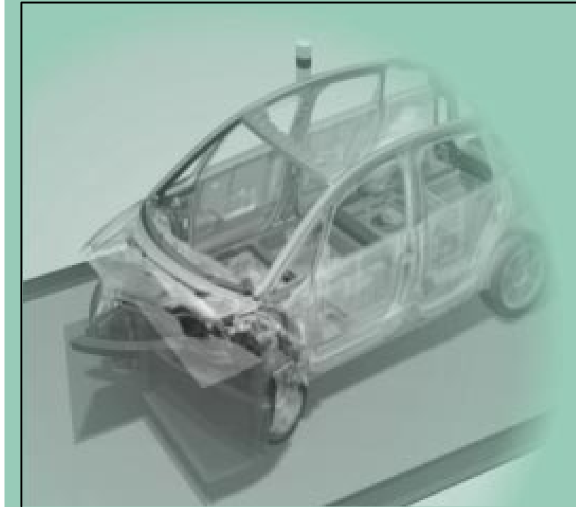
Mesh motion is independent of material motion (less failures)

Requires predictable material flow (single material)

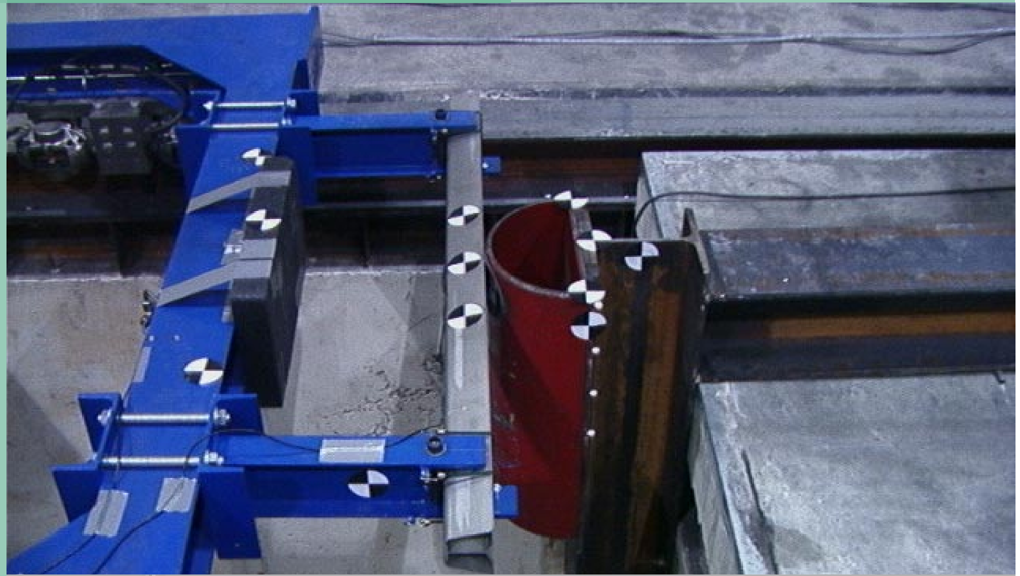


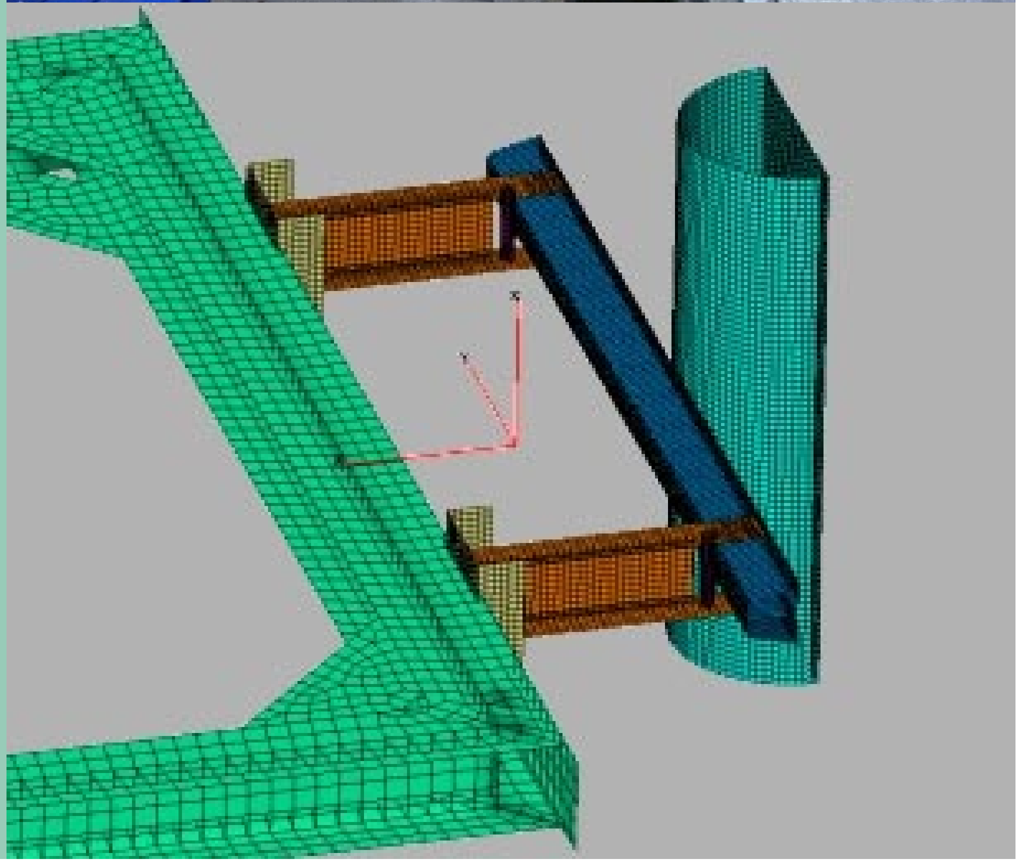


3 Crashworthiness

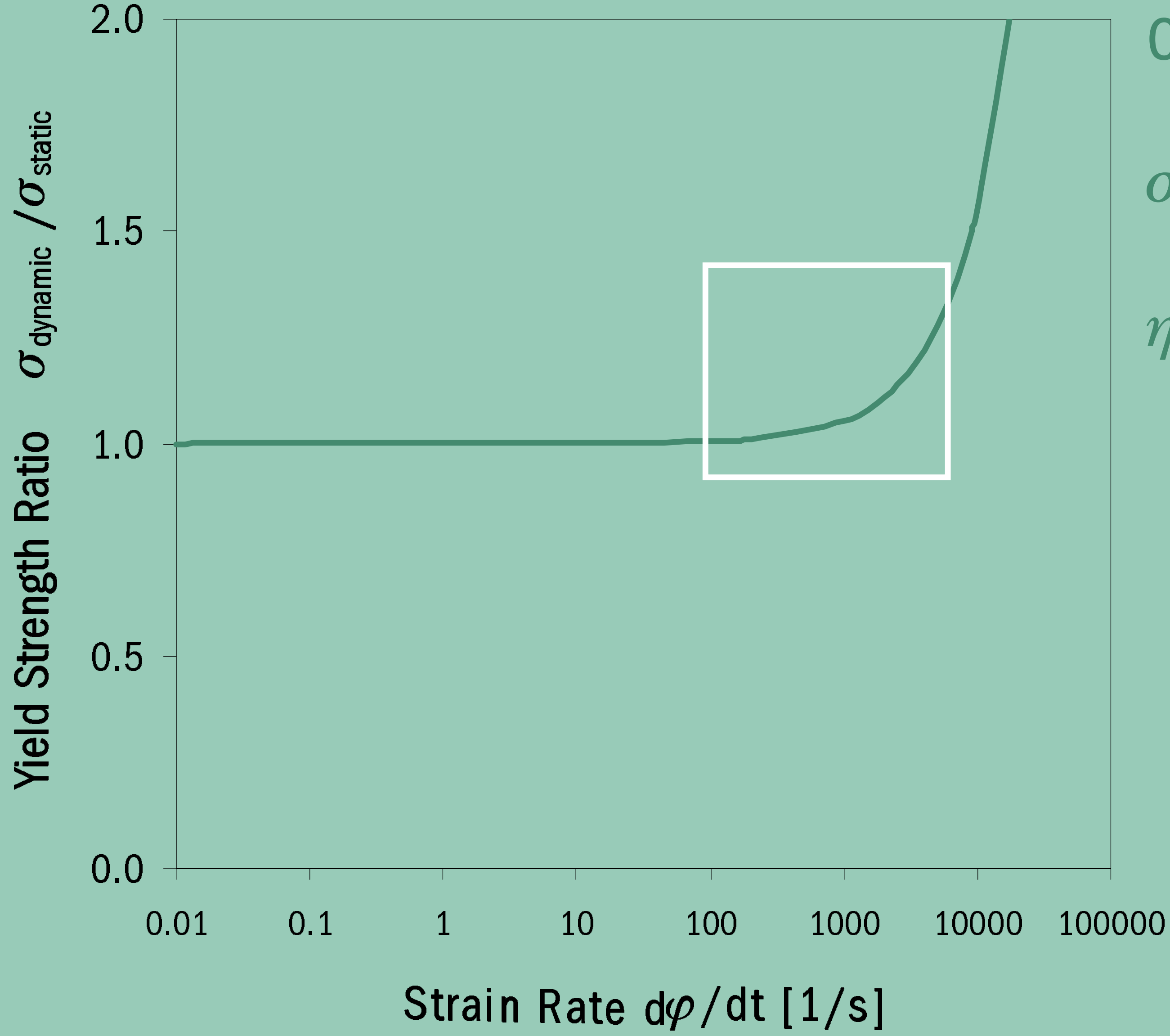


- Collision test with v = 7 km/h
- Carriage weight 830 kg
- Experiments and PAM-CRASH Simulations carried out by DSD, A-Linz





Static vs. Dynamic Flow Stresses

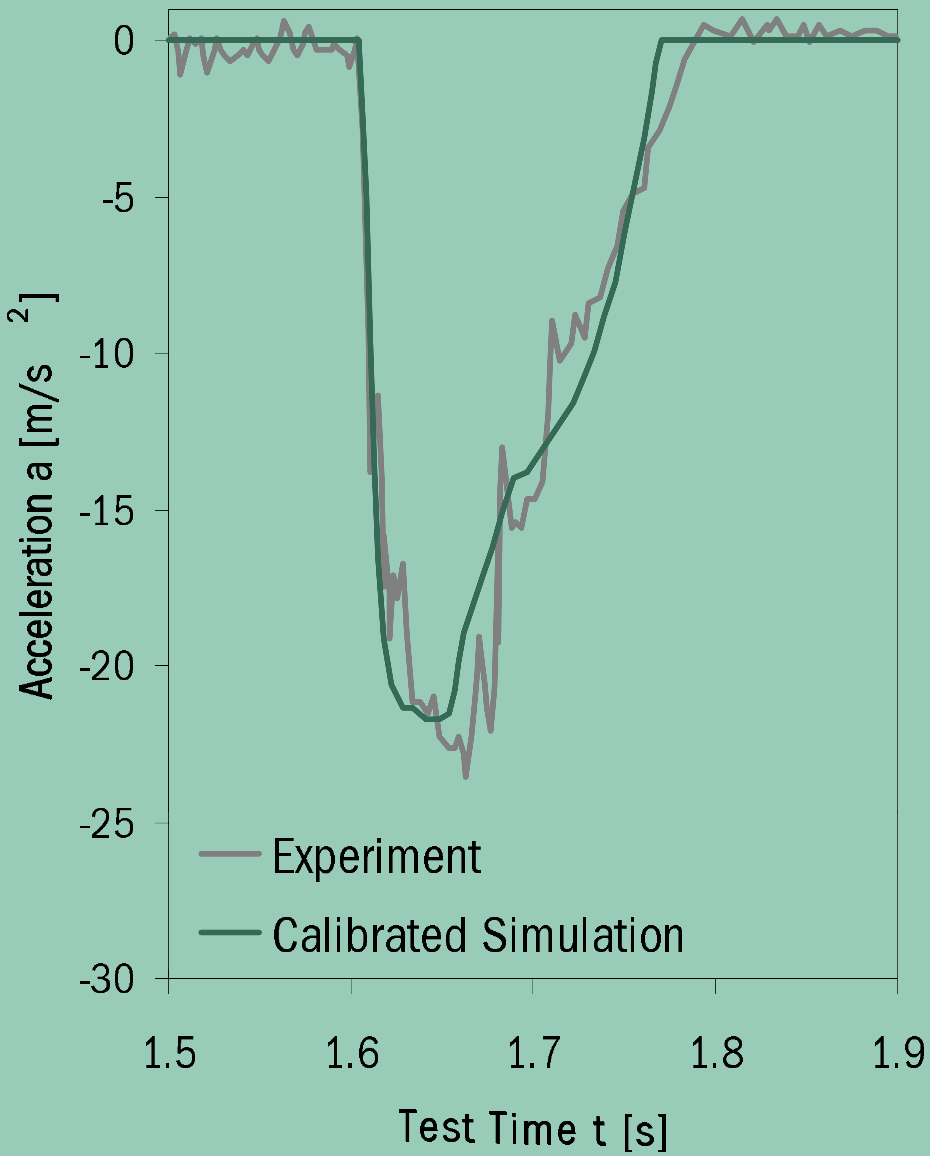


Campbell-Ferguson

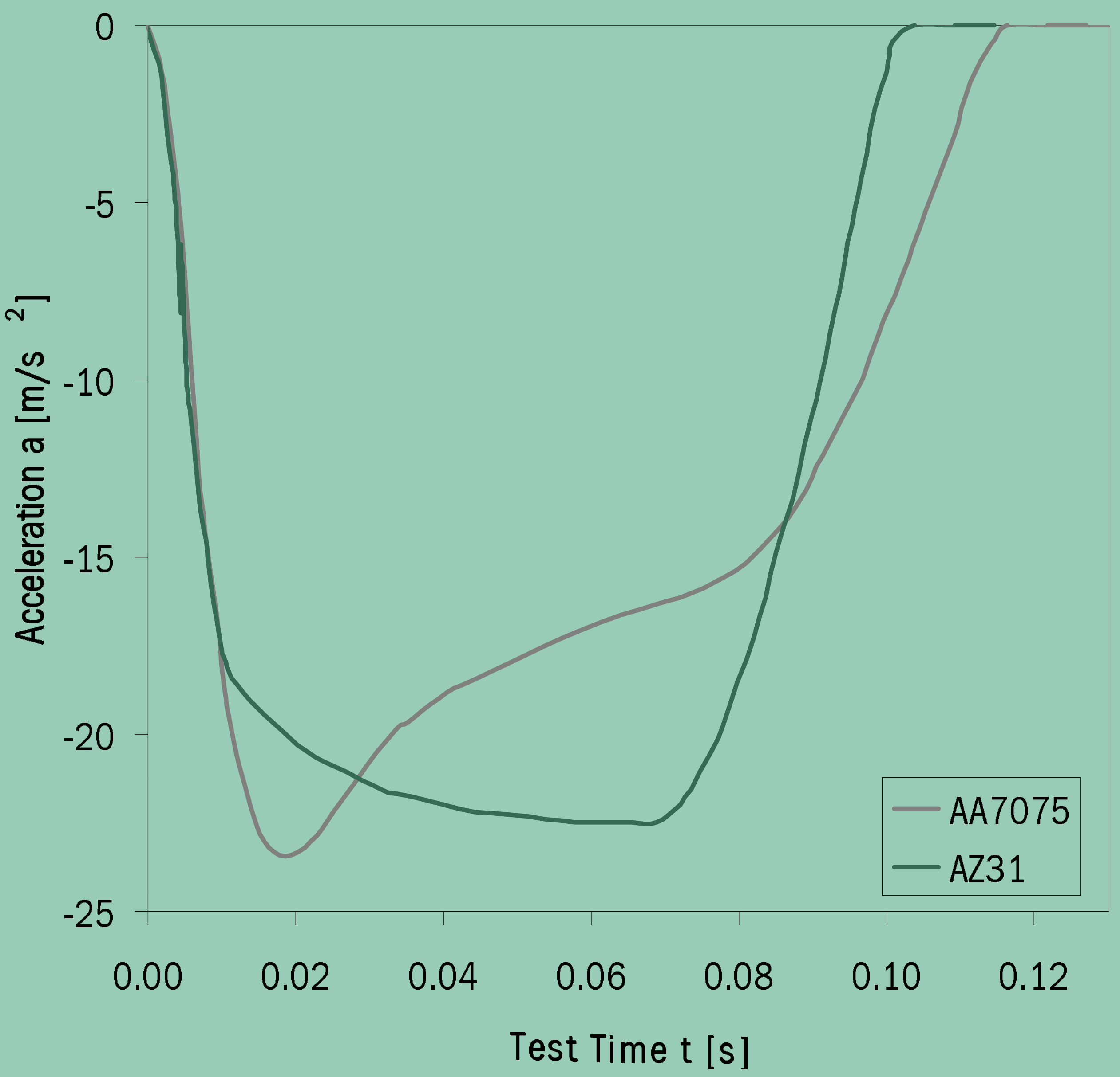
$\sigma_{dyn} = \sigma_{stat} + \eta \cdot d\varphi/dt$

$\eta_{Mg} = 1.1 \cdot 10^4$ Pa·s

Calibration with Crash Test



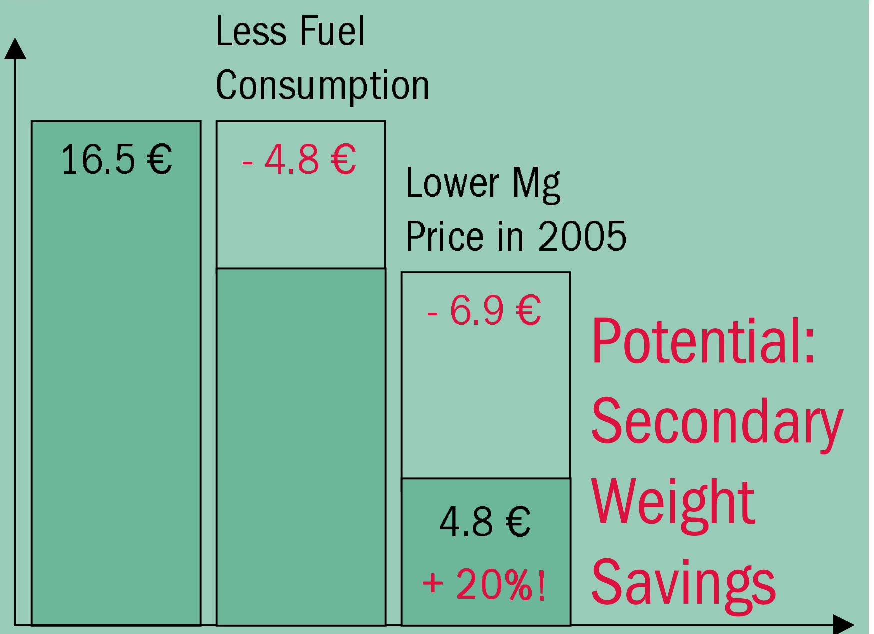
Benchmark with Original Front Fender (AA7075)



Front Fender Specifications

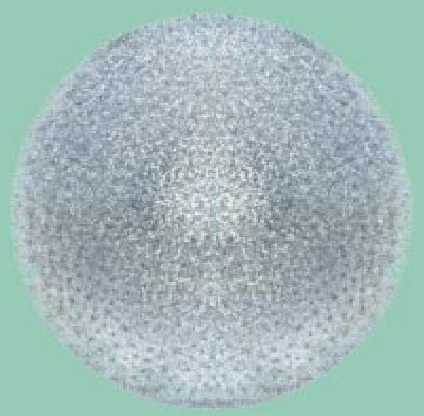
- weight reduction ✓
- same crashworthiness ✓
- same production cost ?

	AZ31	AA7075
Billet	5.15 €/kg	2.55 €/kg
Extrusion	14.20 €/kg	7.00 €/kg
	27 €/m	16 €/m
Extruded Fender	40.5 €	24 €
	+ 68%!	



Designing Materials: Computer vs. Laboratory?

1 DC Casting of AZ31



2 New Design & Extrusion

3 Crashworthiness

COMPUTER TOOLS

& EXPERIMENTS