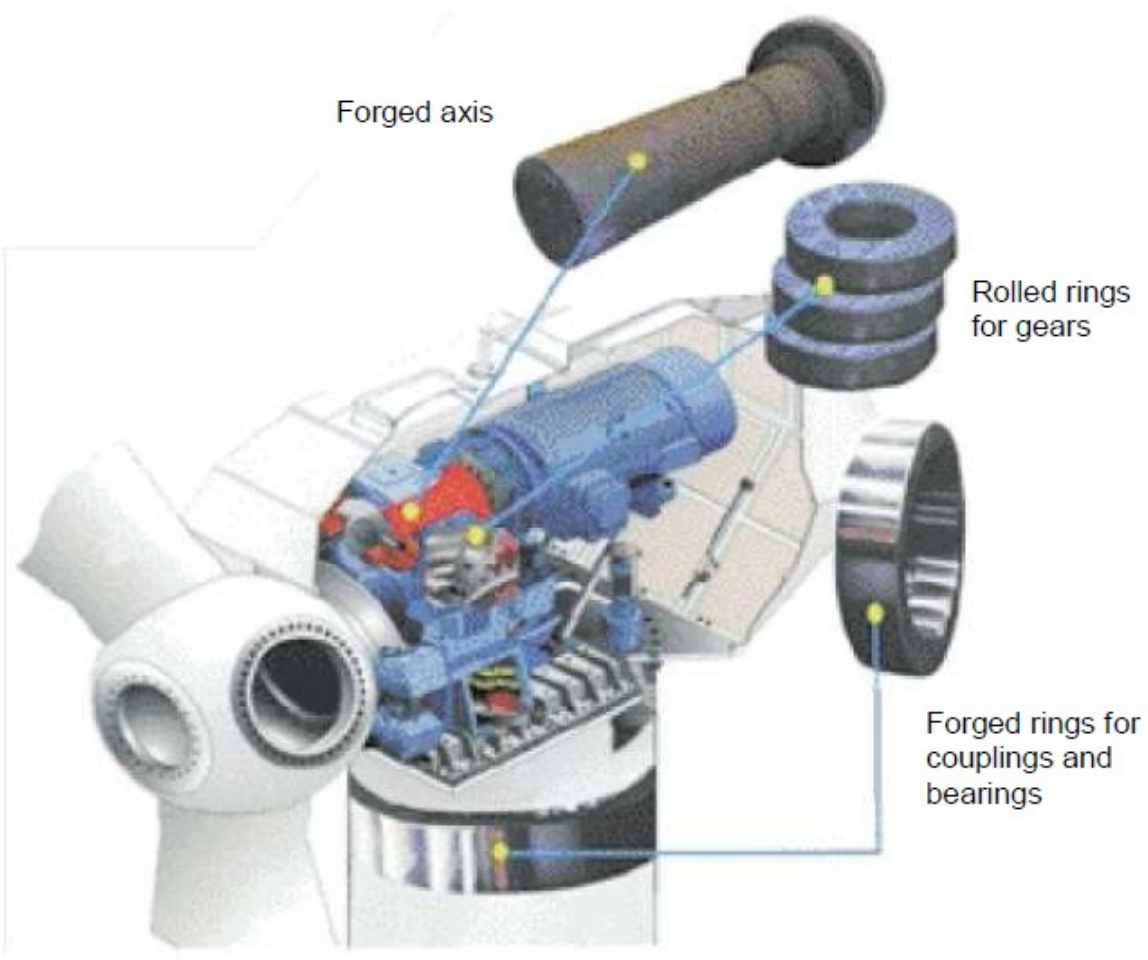
Bragecrim Meeting

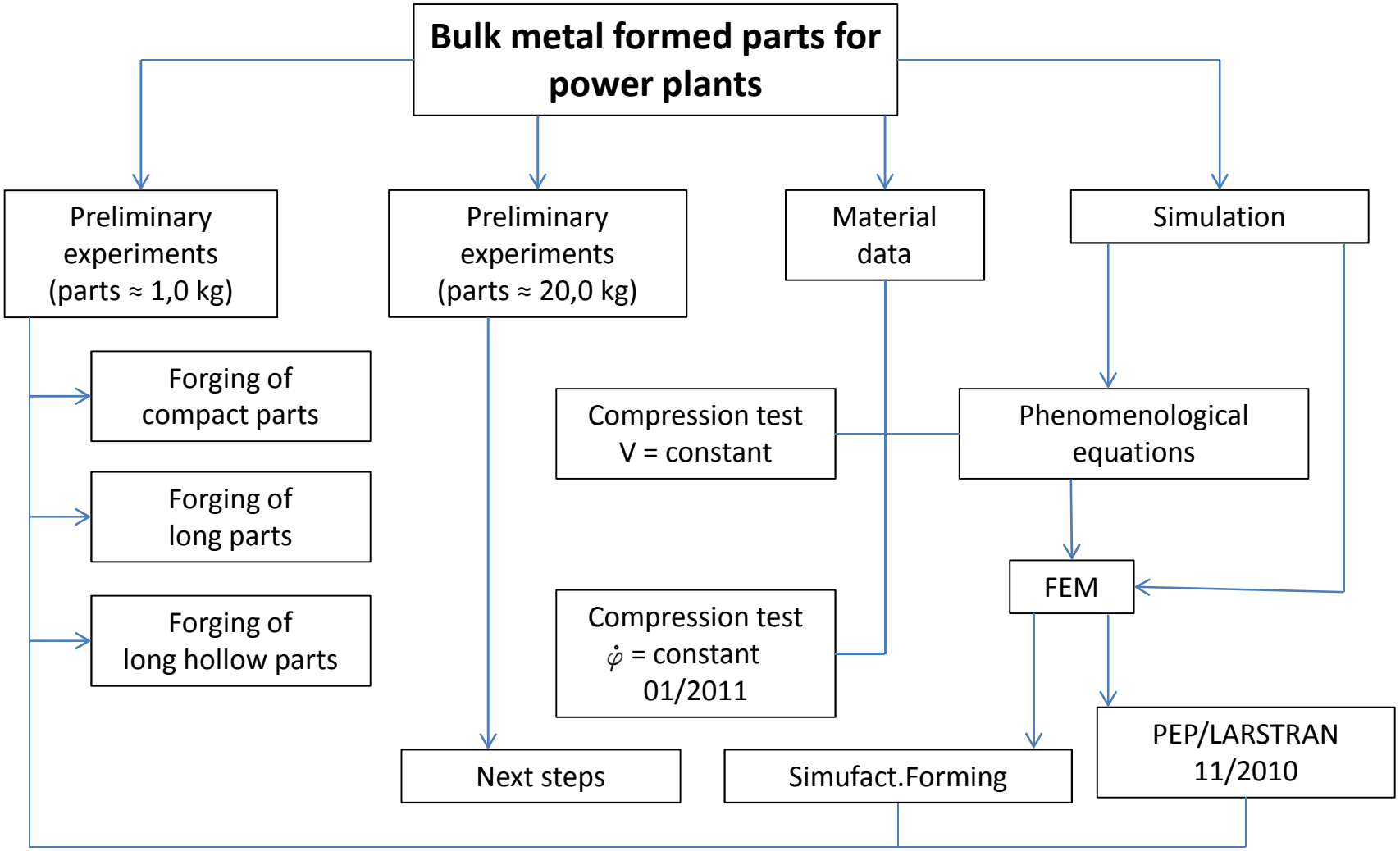
Berlin, October, 2010

Bulk metal formed parts for power plants
Peças forjadas para plantas de energia

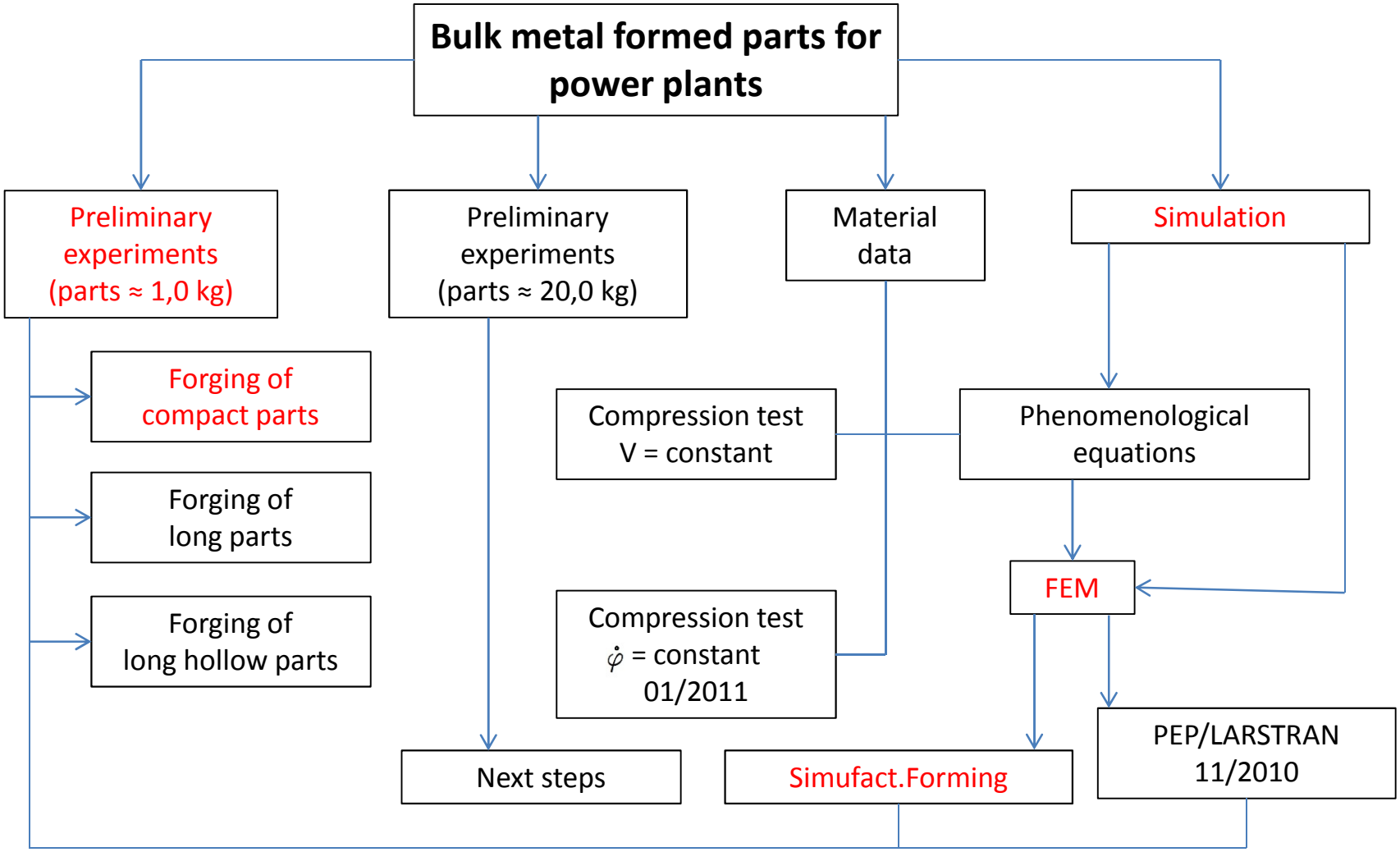
Laboratório de Transformação Mecânica (Metal Forming)
Universidade Federal do Rio Grande do Sul, BRAZIL
Prof. Dr. Ing. Lirio Schaeffer


Forged axis
Rolled rings for gears
Forged rings for couplings and bearings

Research flowchart



Research flowchart



Goals: search the fundamentals of hot open die forging, check microstructural changes that occur during the forging process and compare experimental and numerically simulated results.

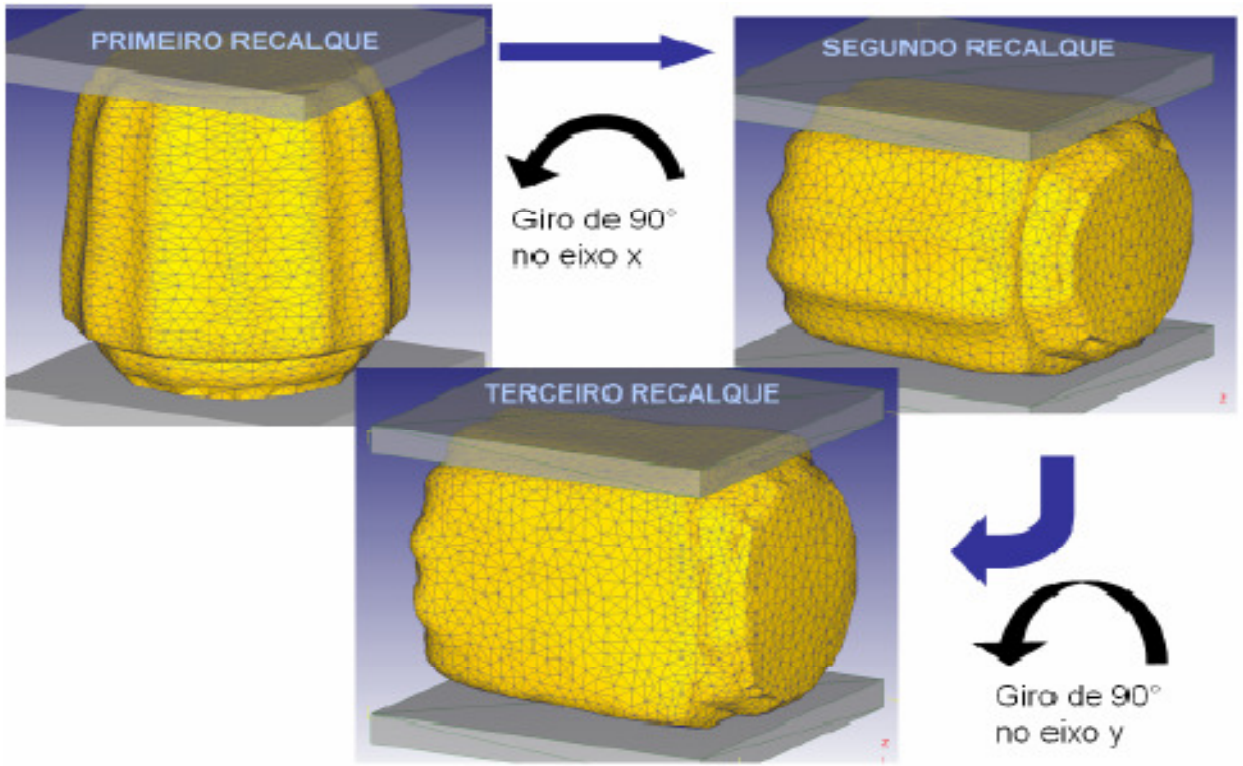
Experimental Procedure:

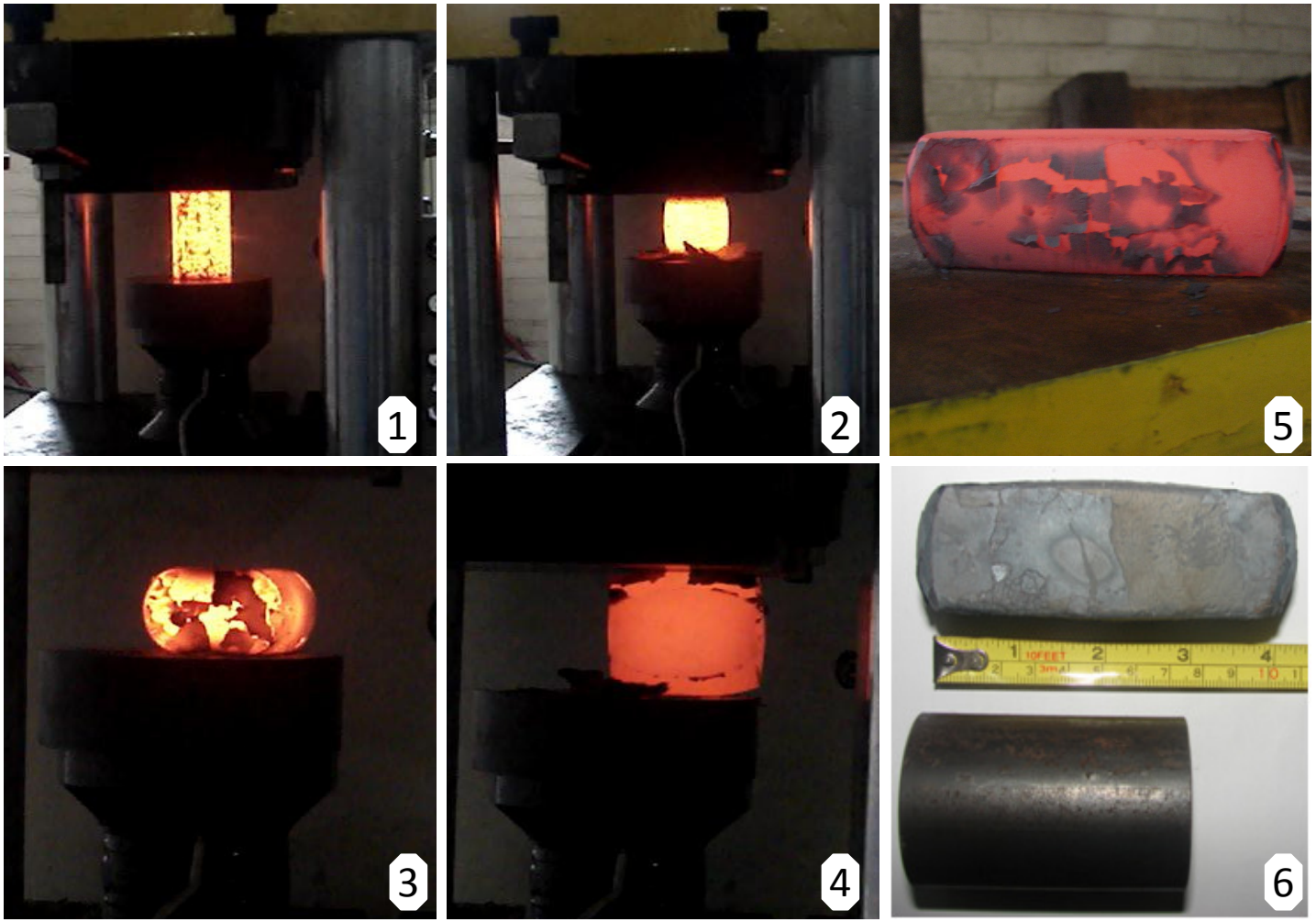
Material: ABNT 4140

H_0 = 75 mm

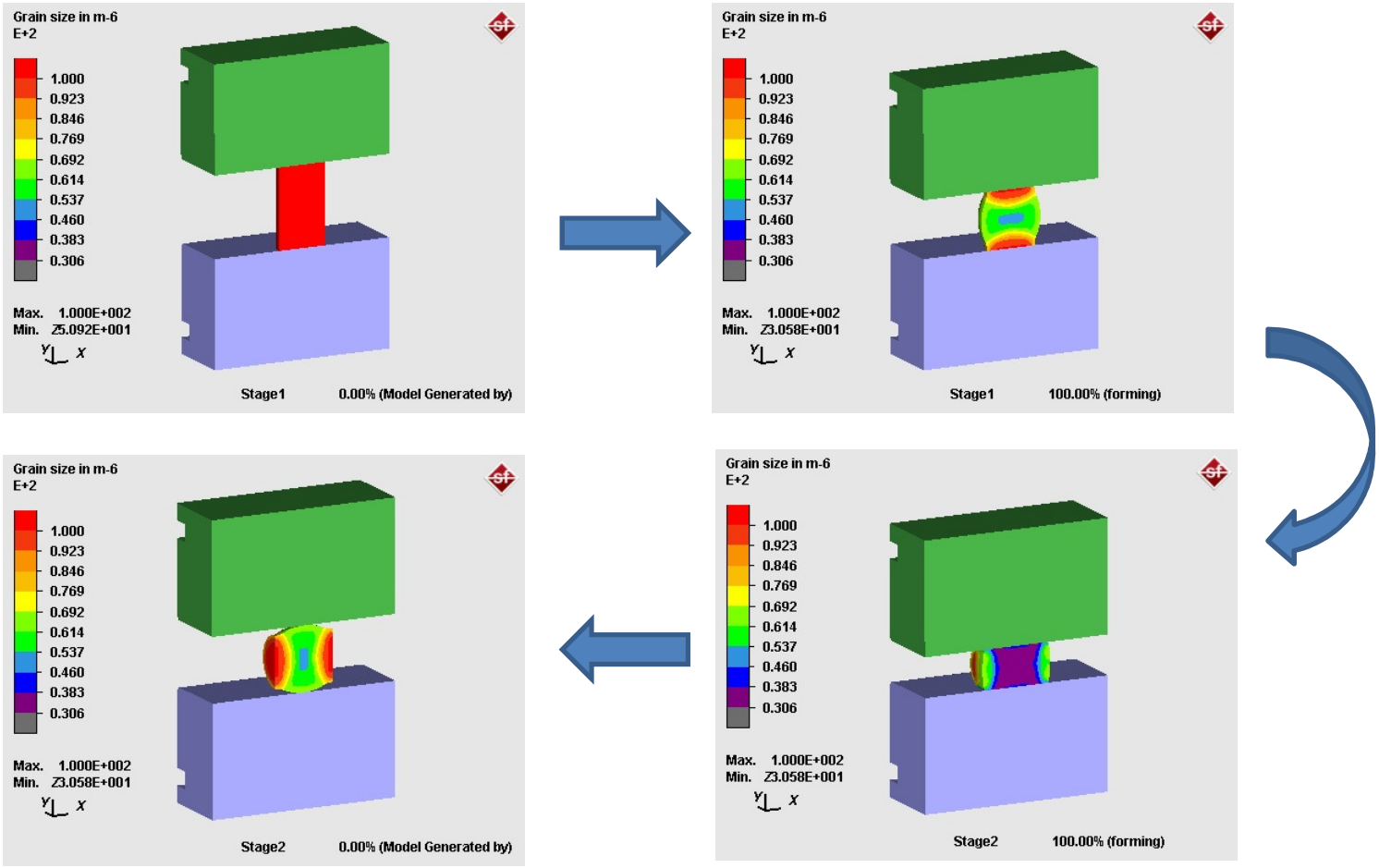
D_0 = 44 mm

υ_o = 1000 °C

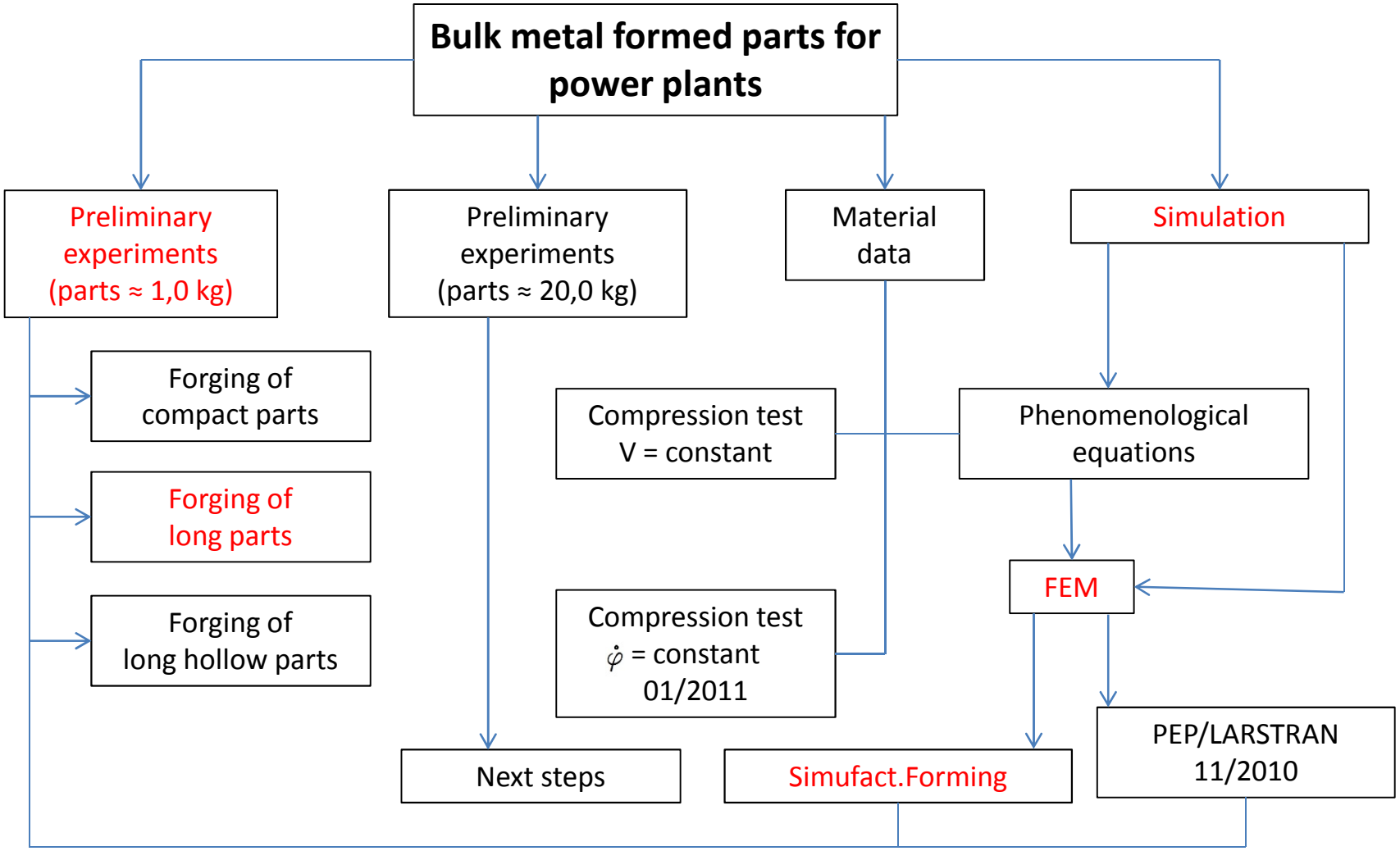



1
2
5
3
4
6

Results: microstructure simulation



Research flowchart

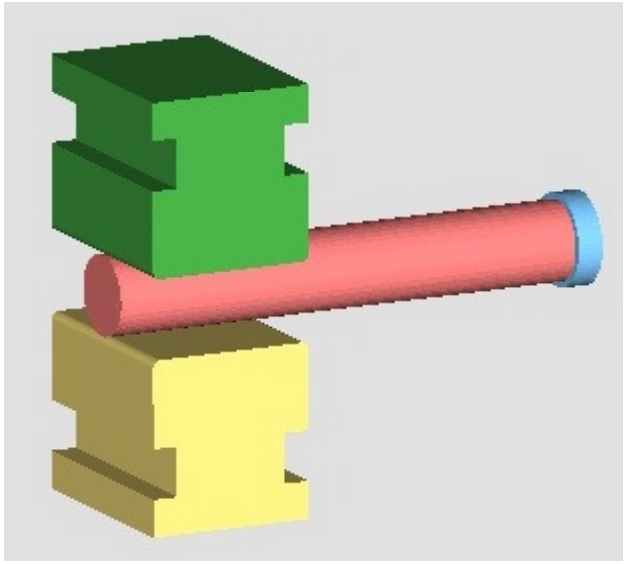


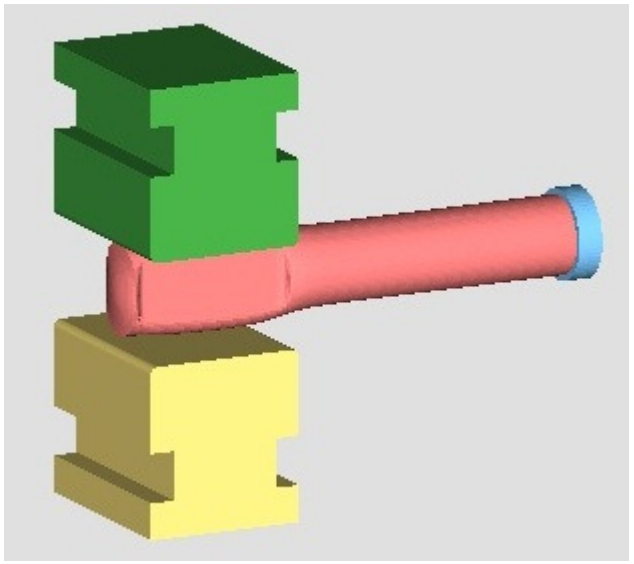
Goals: search the fundamentals of hot open die forging, check microstructural changes that occur during the forging process and compare experimental and numerically simulated results.

Experimental Procedure: Material: ABNT 4140

First step: $L_0 = 200$ mm $D_0 = 32$ mm $H_f = 20$ mm $S_B = 65$mm $\upsilon_o = 1000\ ^oC$

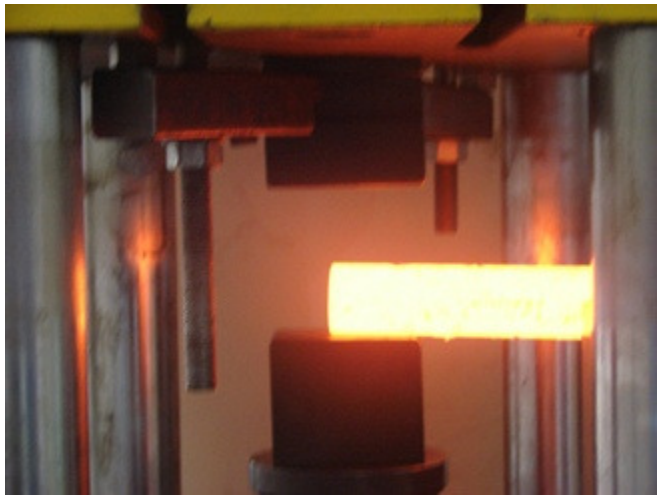
Second step: $H_f = 25$ mm $S_B = 65$mm $\upsilon_o = 1000\ ^oC$

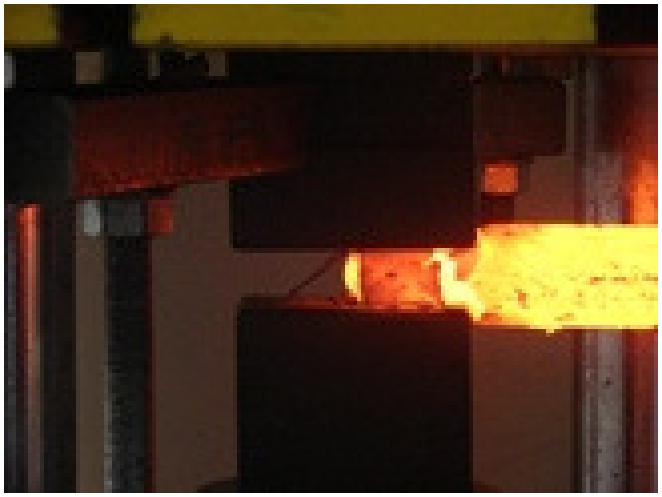




Preliminary experiments (parts ≈ 1,0 kg)/Simulation - forging of long parts

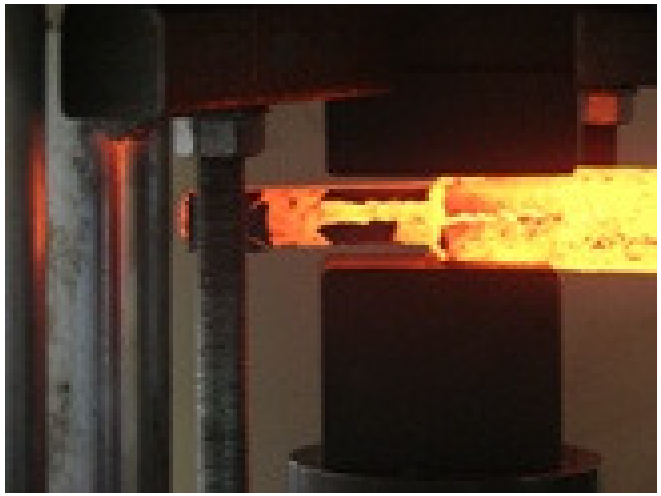
1





2

3

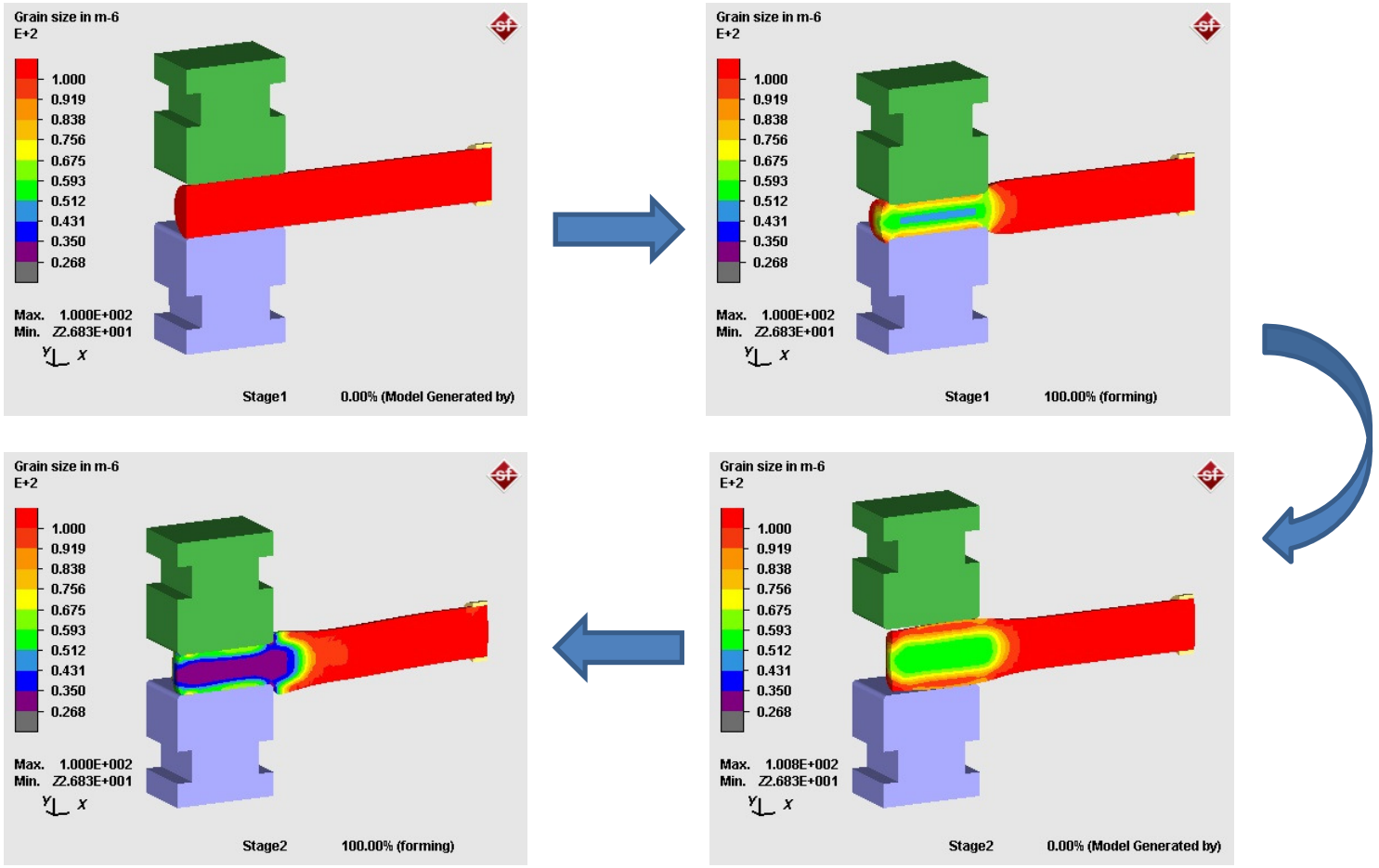


4

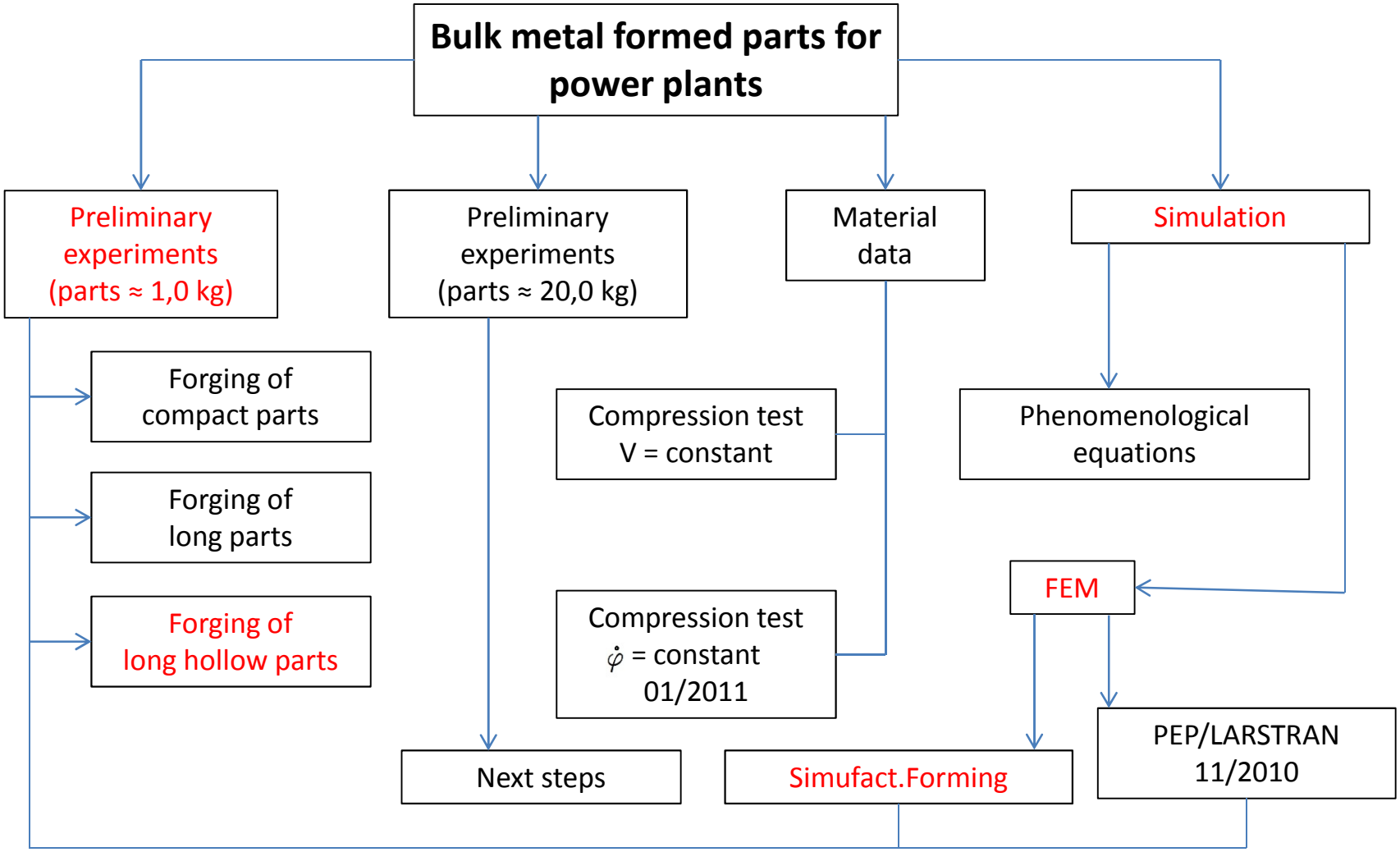
Results: geometry

L_f = 320 mm B_f = 25 mm H_f = 20 mm

Results: microstructure simulation



Research flowchart



Goals: search the fundamentals of hot open die forging, check microstructural changes that occur during the forging process and compare experimental and numerically simulated results.

Experimental Procedure: Material: ABNT 4140

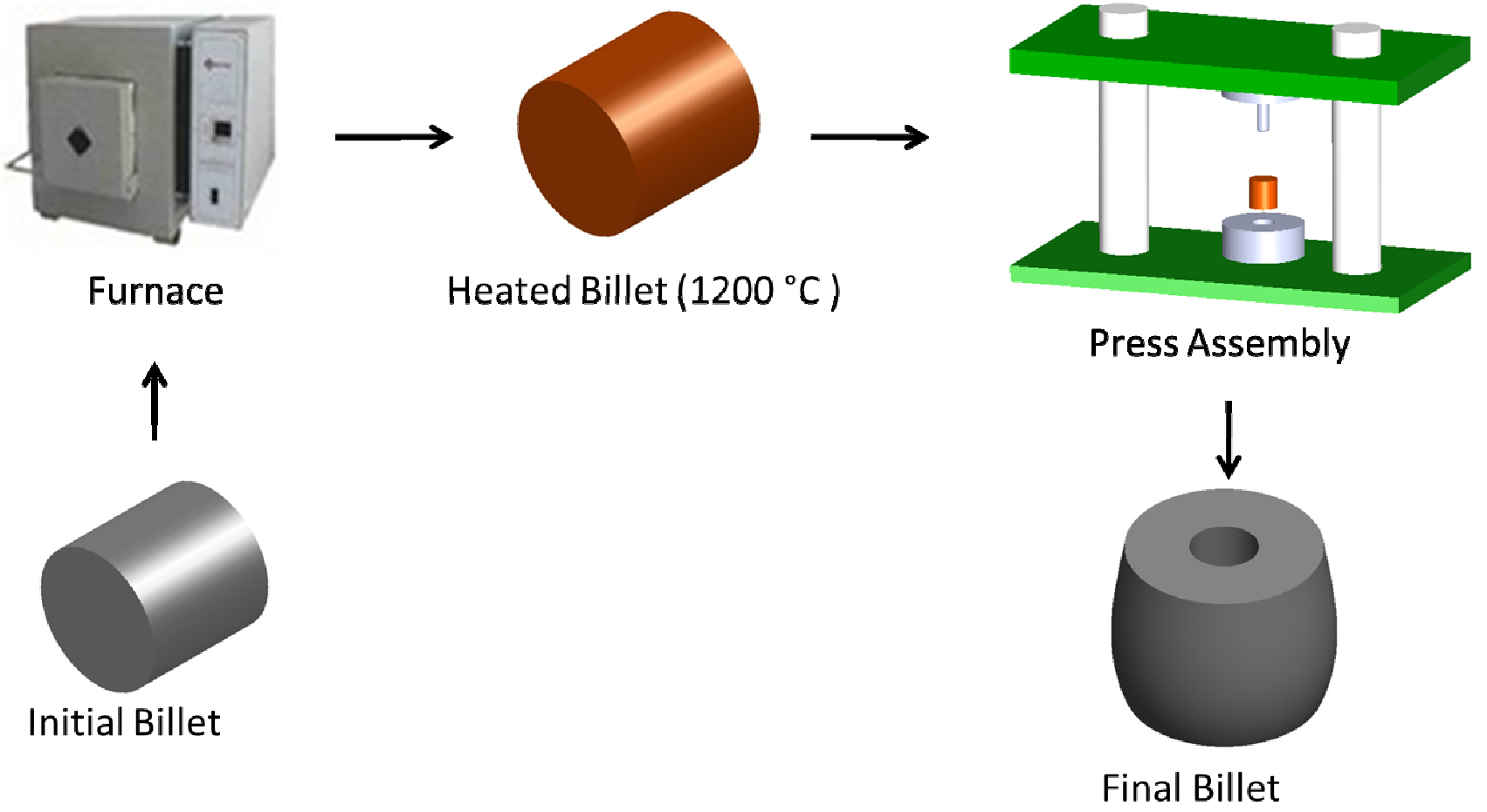
First step: piercing

Billet dimensions: D_0 = 60 mm H_o = 60 mm
Initial temperature: υ_o = 1200 °C
Hole diameter: d = 10 mm
Die speed: V = 4 mm/s
Mass loss by piercing: 15 %

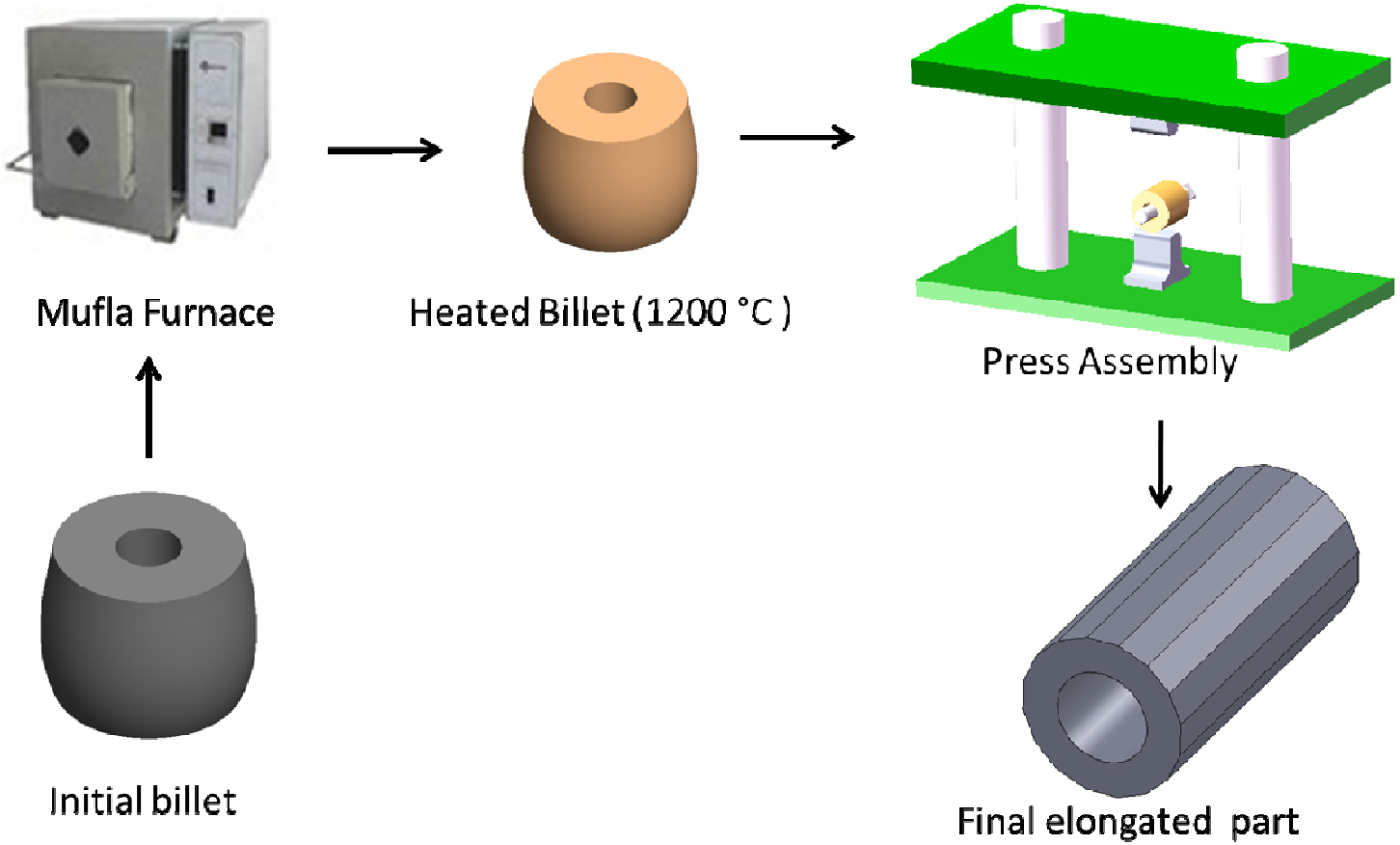
Second step: cogging

Reheating temperature: υ = 1200 °C
Fixed stroke: Δh = 10 mm
End diameter: D_f = 50.4 mm (reduction: 16%)
Final length: L_f = 75 mm (elongation: 25%)

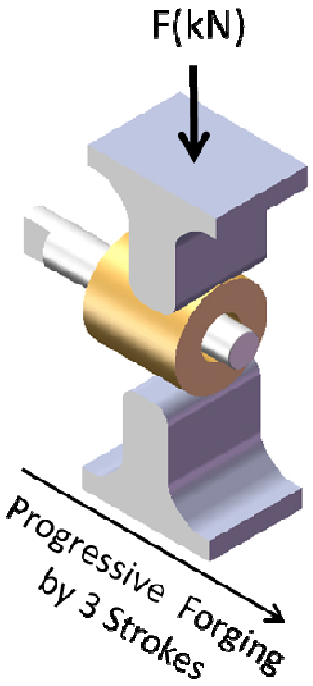
EXPERIMENTAL PROCEDURE - FIRST STEP: PIERCING

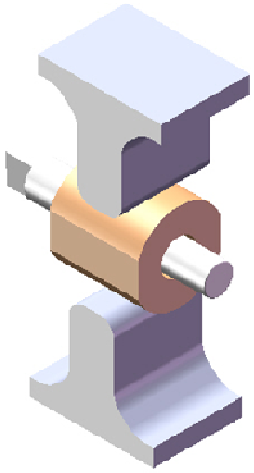


EXPERIMENTAL PROCEDURE - SECOND STEP: COGGING

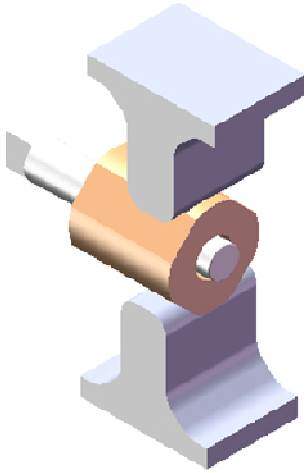


DETAILED SEQUENCE OF COGGING PROCESSE

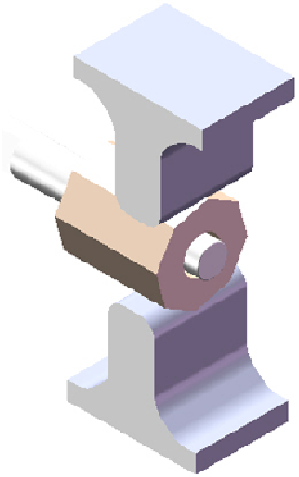




Turned 90 °
From initial
billet position



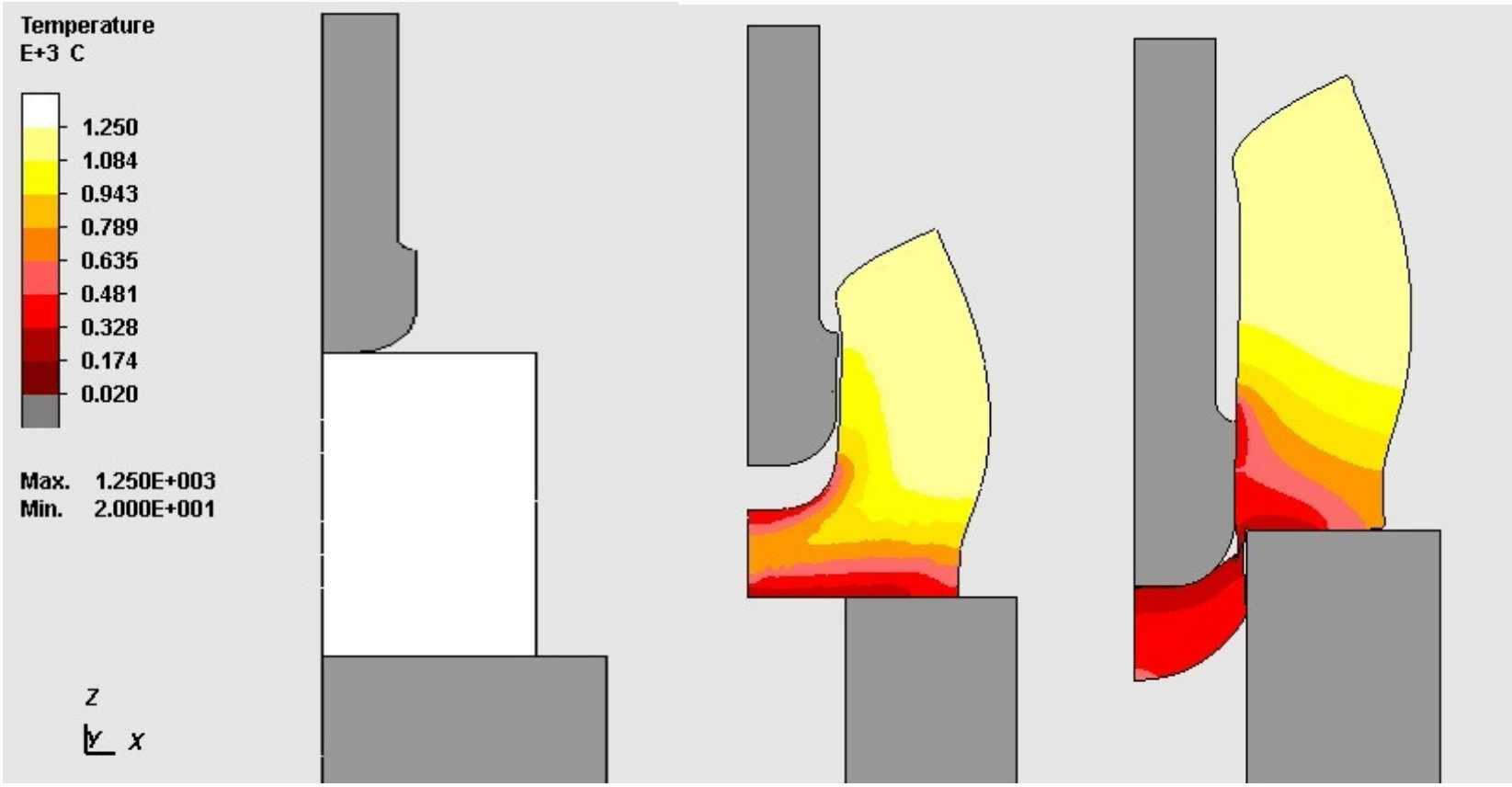
Turned 45°
from previous
position



Turned 15°
from previous
position
(repeated to 8 vertices)

1 **2** **3** **4**

SIMULATION - FIRST STEP: PIERCING



RESULTS - FIRST STEP: PIERCING

Inicial billet

Pre-holed part

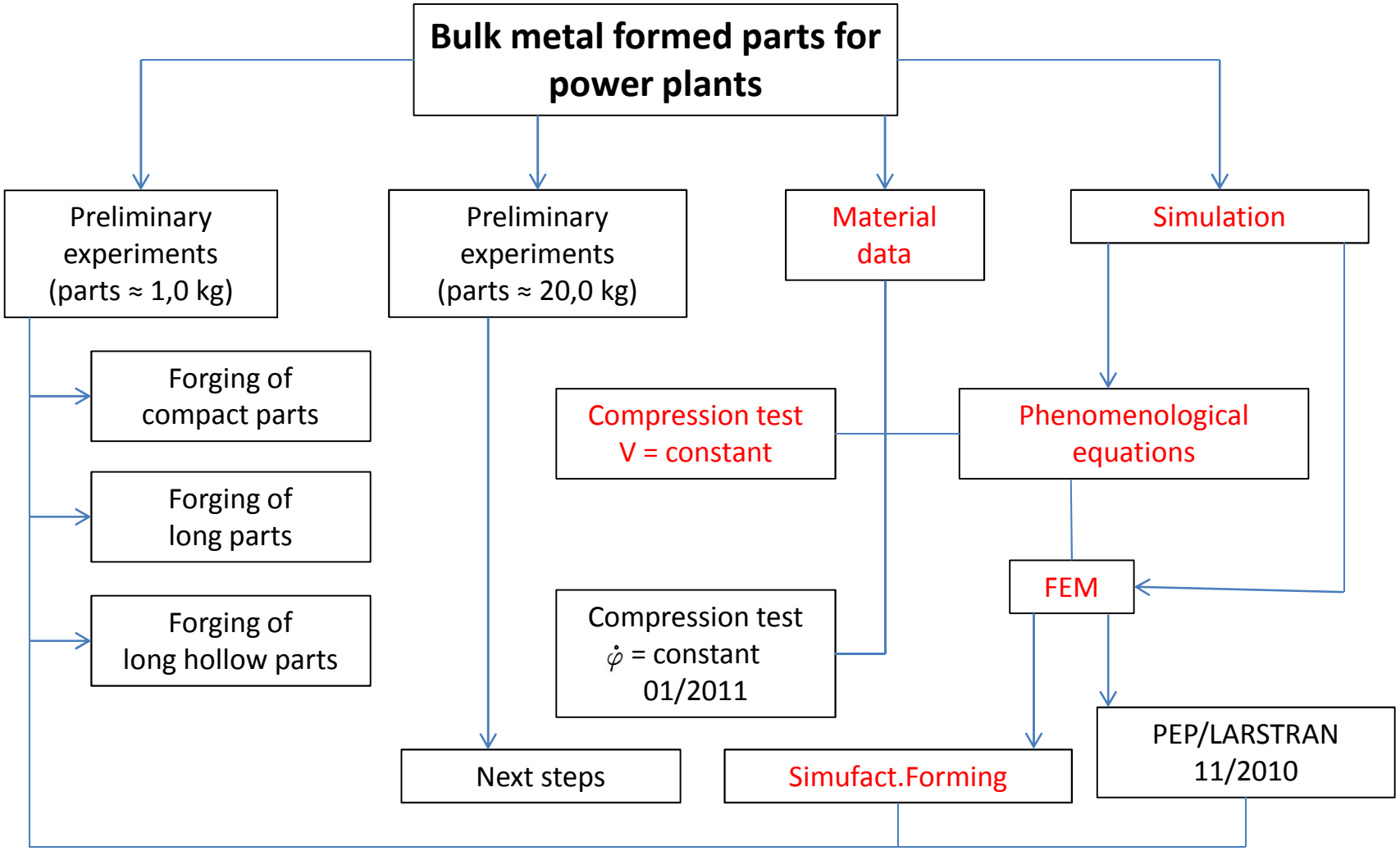
RESULTS - SECOND STEP: COGGING

Hollow Forged

Lateral view

Front view

Research flowchart



DYNAMIC RECRYSTALLISATION

$$Z = \dot{\varepsilon} \cdot \exp\left(\frac{Q_W}{R \cdot T}\right)$$

$$\varepsilon_{peak} = a_1 \cdot d_0^{a_2} \cdot Z^{a_3}$$

$$\varepsilon_{stat} = e_1 \cdot \varepsilon_{peak} + e_2 \cdot d_0^{e_3} \cdot Z^{e_4}$$

$$d_{dyn} = b \cdot k_{fs} = b_1 \cdot Z^{b_2}$$

$$X_{dyn} = 1 - \exp\left(d_1 \cdot \left(\frac{\varepsilon - \varepsilon_{krit}}{\varepsilon_{stat} - \varepsilon_{krit}}\right)^{d_2}\right)$$

$$Z = f_1 \cdot \sinh(f_3 \cdot k_{f\,max})^{f_2}$$

$$C = C_1 \cdot \left(1 - \exp\left(C_2 \cdot (\ln Z)^{C_3}\right)\right)$$

STATIC RECRYSTALLISATION AND GRAIN GROWTH

$$X_{stat} = 1 - \exp\left(c \cdot \left(\frac{W_X}{W_{0.95}}\right)^{g_1}\right)$$

$$t_x = f_1 \cdot d_0^{f_2} \cdot \varepsilon^{f_3} \cdot Z^{f_4} \cdot \exp\left(\frac{-Q_{stat}}{R \cdot T}\right)$$

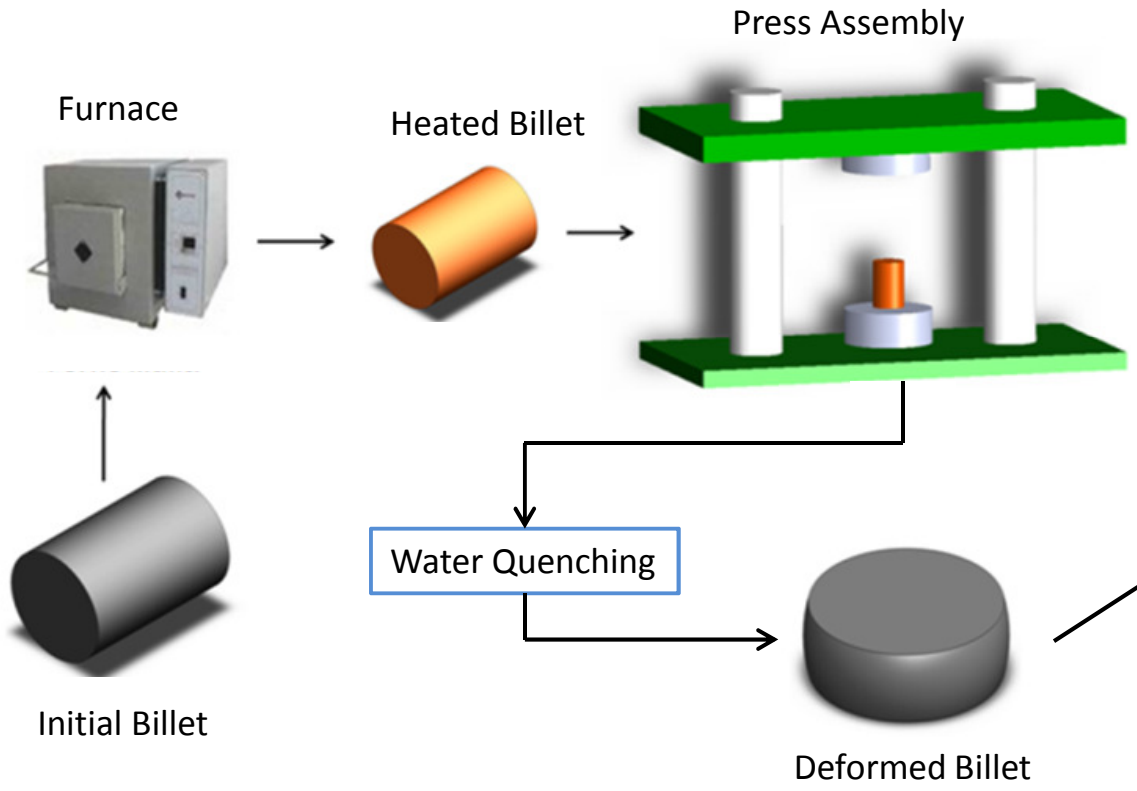
$$W_x = f_1 \cdot d_0^{f_2} \cdot \varepsilon^{f_3} \cdot Z^{f_4}$$

$$d_{KW}^{h_1} = d_0^{h_2} + h_3 \cdot t \cdot \exp\left(\frac{-Q_{KW}}{R \cdot T}\right)$$

$$d_{stat} = c_1 \cdot d_0^{c_2} \cdot \varepsilon^{c_3} \cdot Z^{c_5}$$

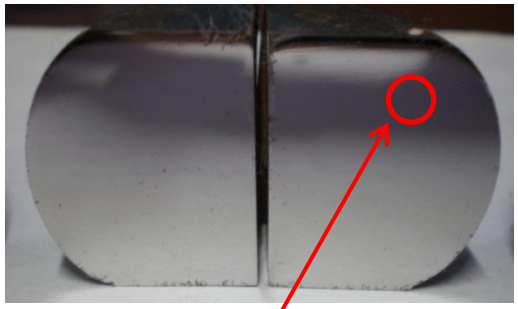
Goals: search microstructural changes that occur during the hot forging process and compare experimental and numerically simulated results.

Experimental Procedure:



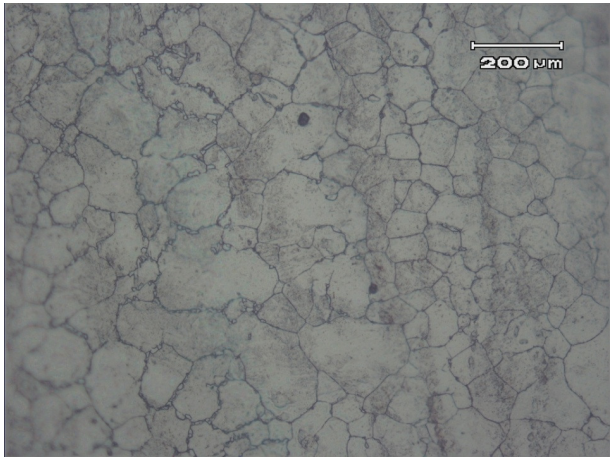
Material: ABNT 4140
H_0 = 50 mm
D_0 = 35 mm
υ_0 = 900, 1100, 1200 °C
ε = 0.5
V = 3.7 mm/s

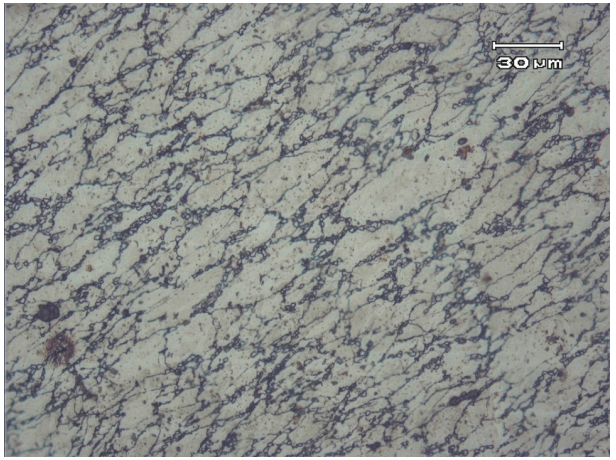
METALLOGRAPHY



RESULTS: Simulation and Experimental (900°C)

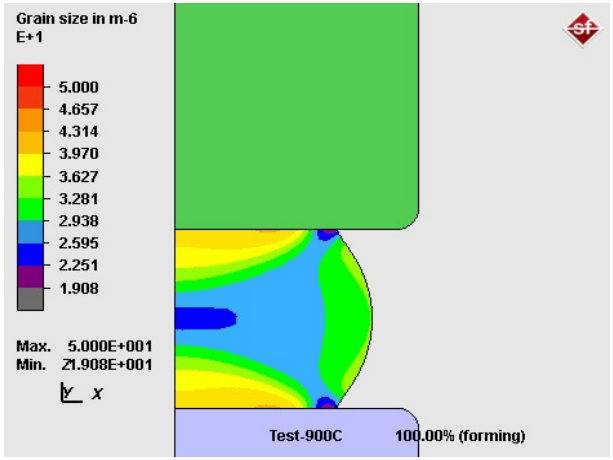
A





B

C



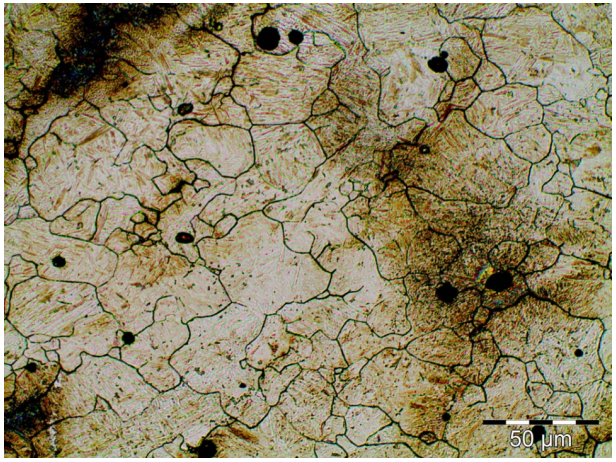
A – Probe heated and quenched (grain size ≈ 50 µm)

B – Probe heated forged and quenched (grain size ≈ 30 µm)

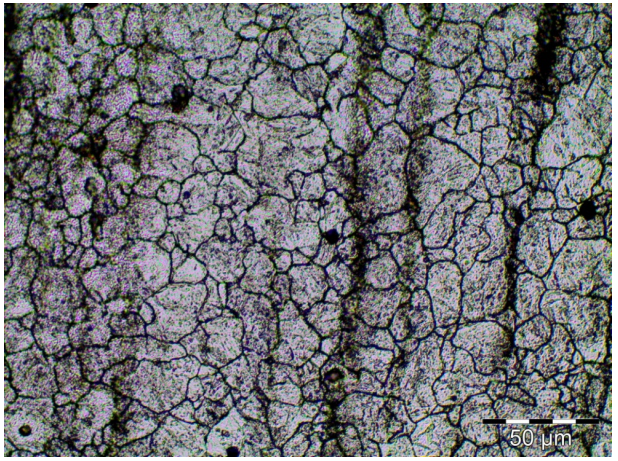
C – Simulation of case B (grain size ≈ 25 to 29 µm)

RESULTS: Simulation and Experimental (1100°C)

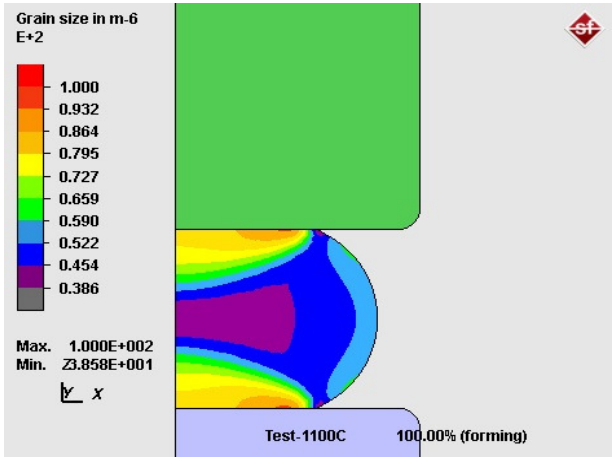
A



B



C



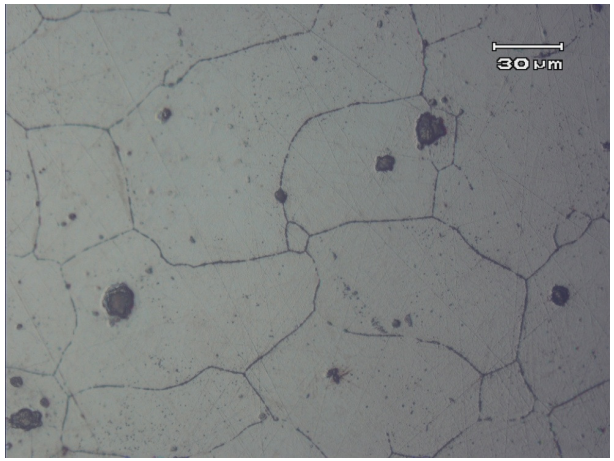
A – Probe heated and quenched (grain size ≈ 100 µm)

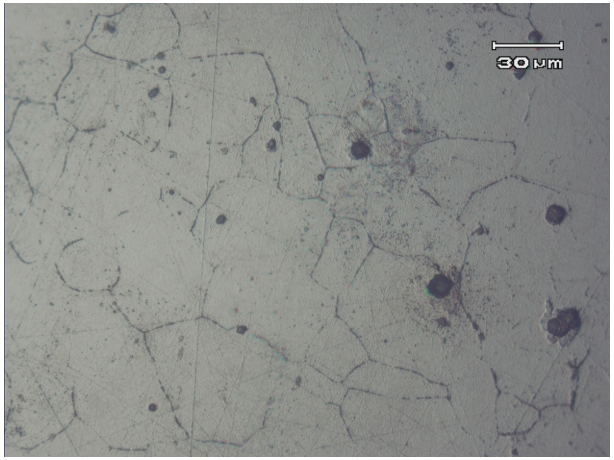
B – Probe heated forged and quenched (grain size ≈ 50 µm)

C – Simulation of case B (grain size ≈ 45 to 52 µm)

RESULTS: Simulation and Experimental (1200°C)

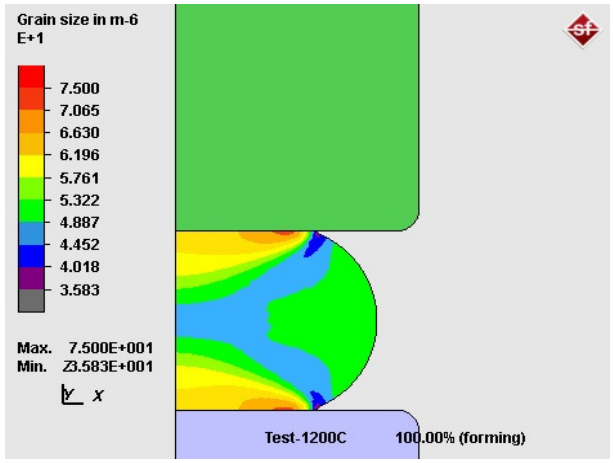
A





B

C



A – Probe heated and quenched (grain size ≈ 100 µm)

B – Probe heated forged and quenched (grain size ≈ 50 µm)

C – Simulation of case B (grain size ≈ 45 to 50 µm)

Forging of compact parts: first step – temperature

Forging of compact parts: second step – temperature

Forging of long parts: first step – temperature

Forging of long parts: seconda step – temperature

Forging of long parts: first step – effective strain

Forging of long parts: seconda step – effective strain

BRAGECRIM TEAM AT LdTM/UFRGS AND CREDITS IN THIS PRESENTATION

Prof. Dr. Ing. Lirio Schaeffer – General coordination

Dr. Eng. Alberto Moreira Guerreiro Brito – Simulation, planning and coordination of experiments, study of the phenomenological equations to microstructural modelling and final edition of this presentation.

Engª Daiana M. Margutti – Preliminary experiments (parts ≈ 1,0 kg) - forging of compact parts.

Engª Christiane Rosado – Preliminary experiments (parts ≈ 1,0 kg) - forging of long parts.

Eng. Gianpaulo Alves Medeiros – Preliminary experiments (parts ≈ 1,0 kg) - forging of long hollow parts; Material data - microstructural transformations in hot forming.

Eng. M.Sc. Alexsandro S. Moraes – Simulations with **Simufact.Forming**.

Est. Diego Lovatel Zollner – Metallography and general support to experiments.

ACKNOWLEDGEMENTS

We want to thank the „**Coordenação de Aperfeiçoamento de Pessoal de Nível Superior** “ and the „ **Conselho Nacional de Desenvolvimento Científico e Tecnológico**“ for the financial support.