SPF SIMULATIONS

Performed at Aircraft Manufacturing Technologies Research and Virtual Simulation Laboratory
by requests of Patrick Romilly and Guillaume Sana (ACB)

Irkutsk State Technical University

Brief task description

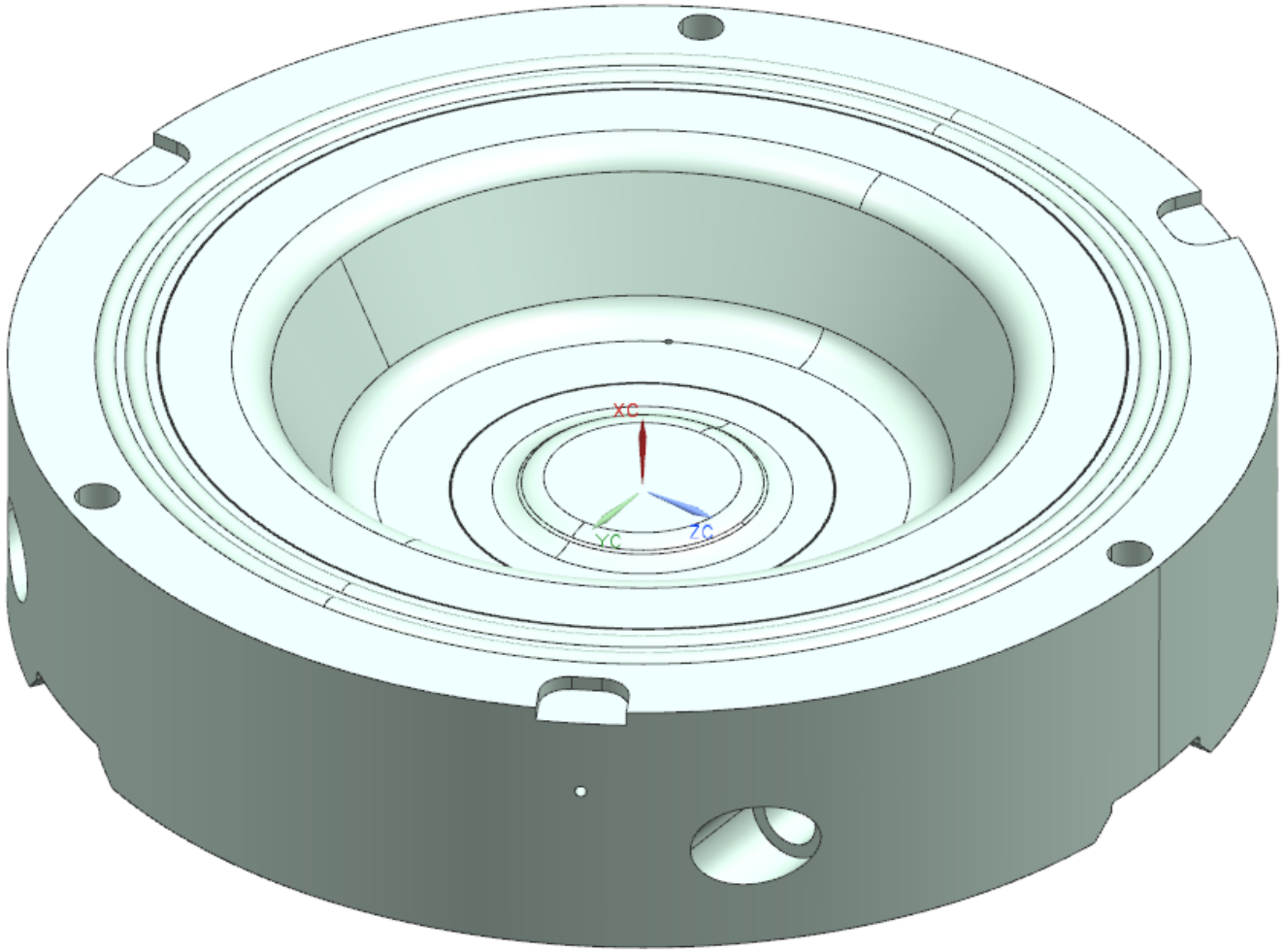
- Initial data provided:
  - tool geometry
  - initial blank thickness
  - material superplastic behavior properties (2 cases with different strain rates, strain rate sensitivities and according flow stresses)
  - friction property (friction coefficient)

- Requested information:
  - forming pressure law (pressure-time dependence)
  - fields of thickness reduction, stresses and strains
  - finite element model and simulation details

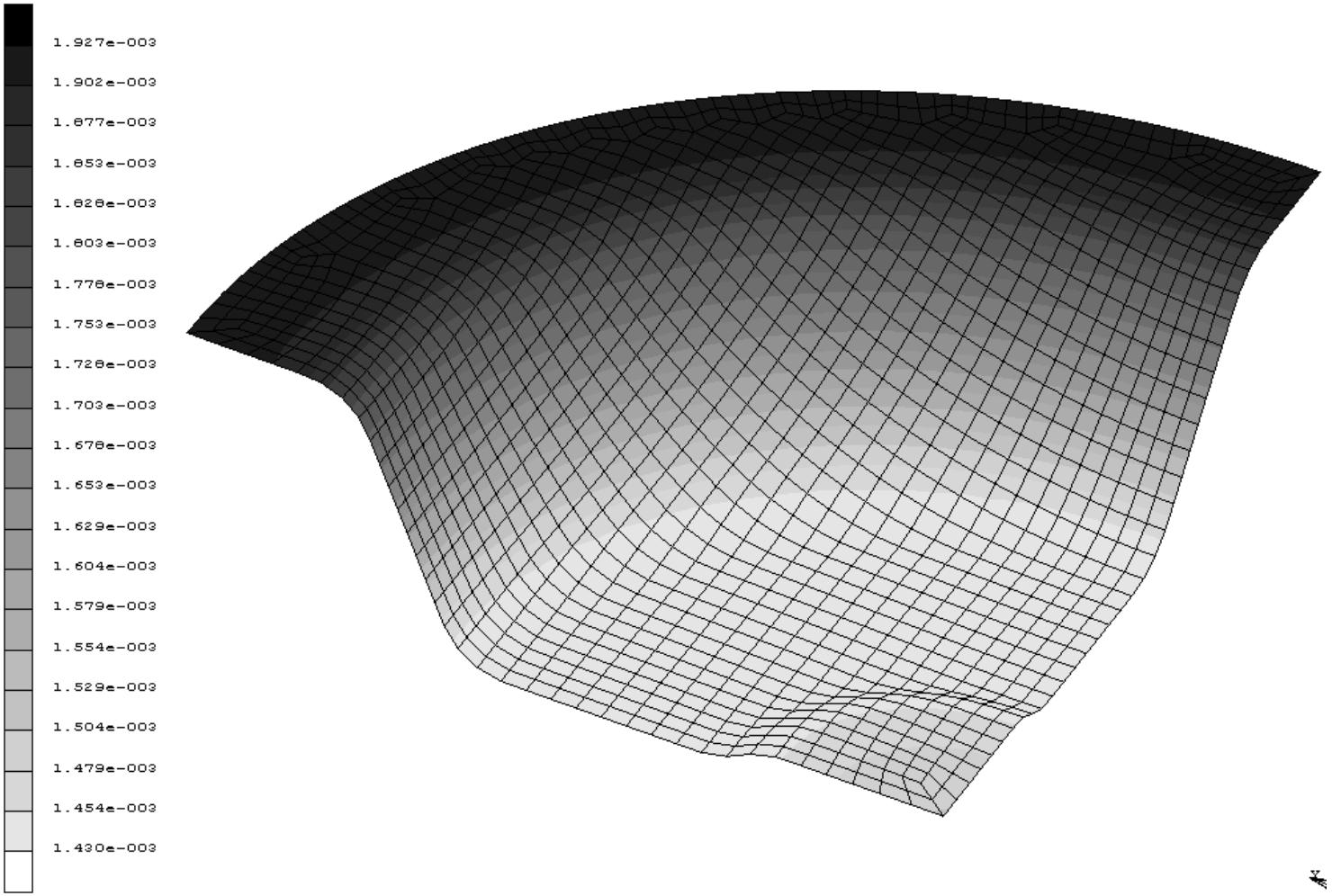
Brief task description (continued) Simulation cases

- Case 1:
  - strain rate sensitivity coefficient 0.5
  - maximum strain rate set to $4 \cdot 10^{-4}\ s^{-1}$
  - superplastic flow stress at strain rate $3 \cdot 10^{-4}\ s^{-1}$ is 8MPa
- Case 2:
  - strain rate sensitivity coefficient 0.37
  - maximum strain rate is $3{,}3 \cdot 10^{-4}\ s^{-1}$
  - superplastic flow equation coefficient $A=400 \cdot 10^{6}$
  - additional check of minimum thickness at the end of forming is requested, minimum thickness is expected to be 1.52 mm

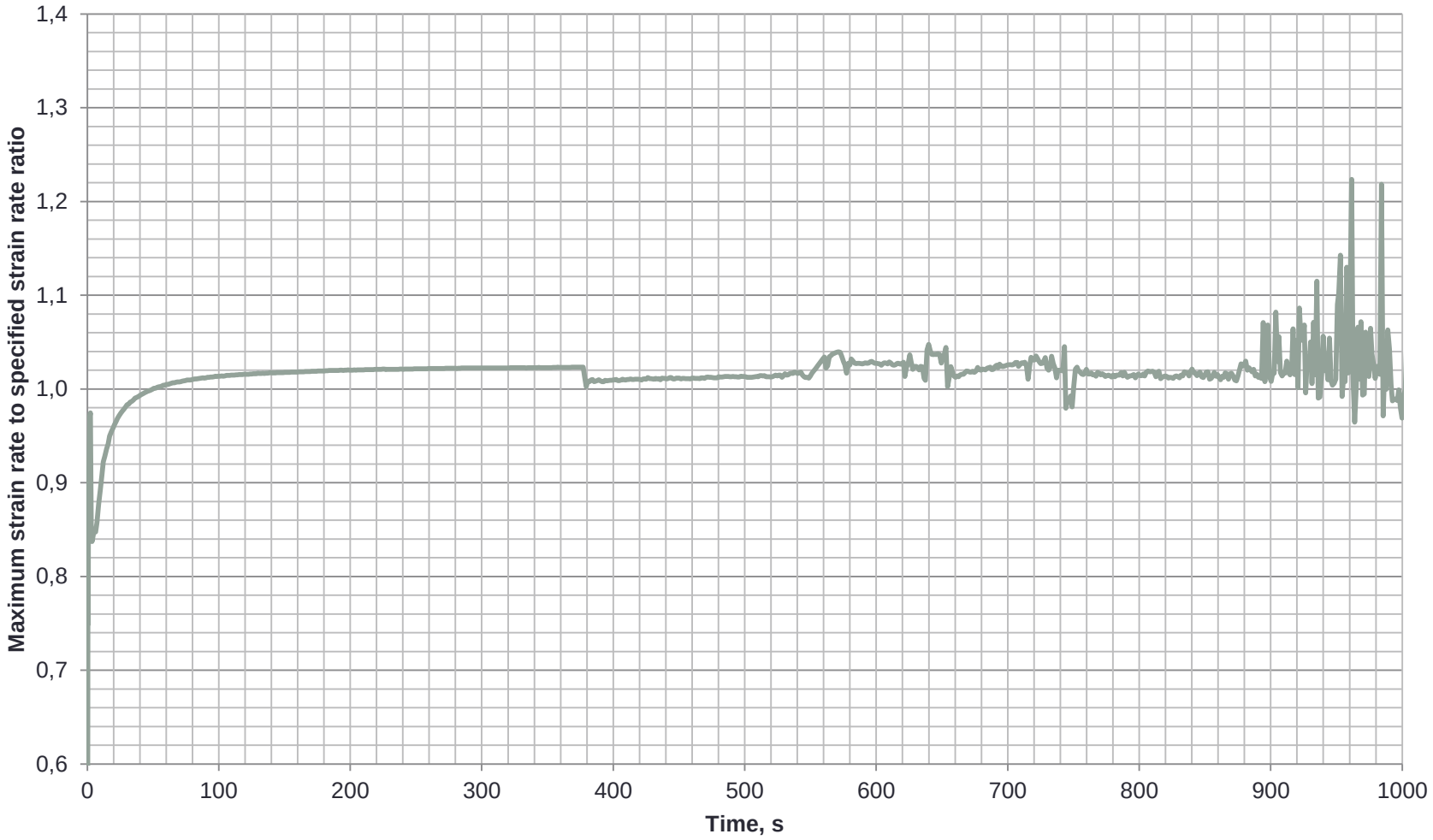
Tool geometry



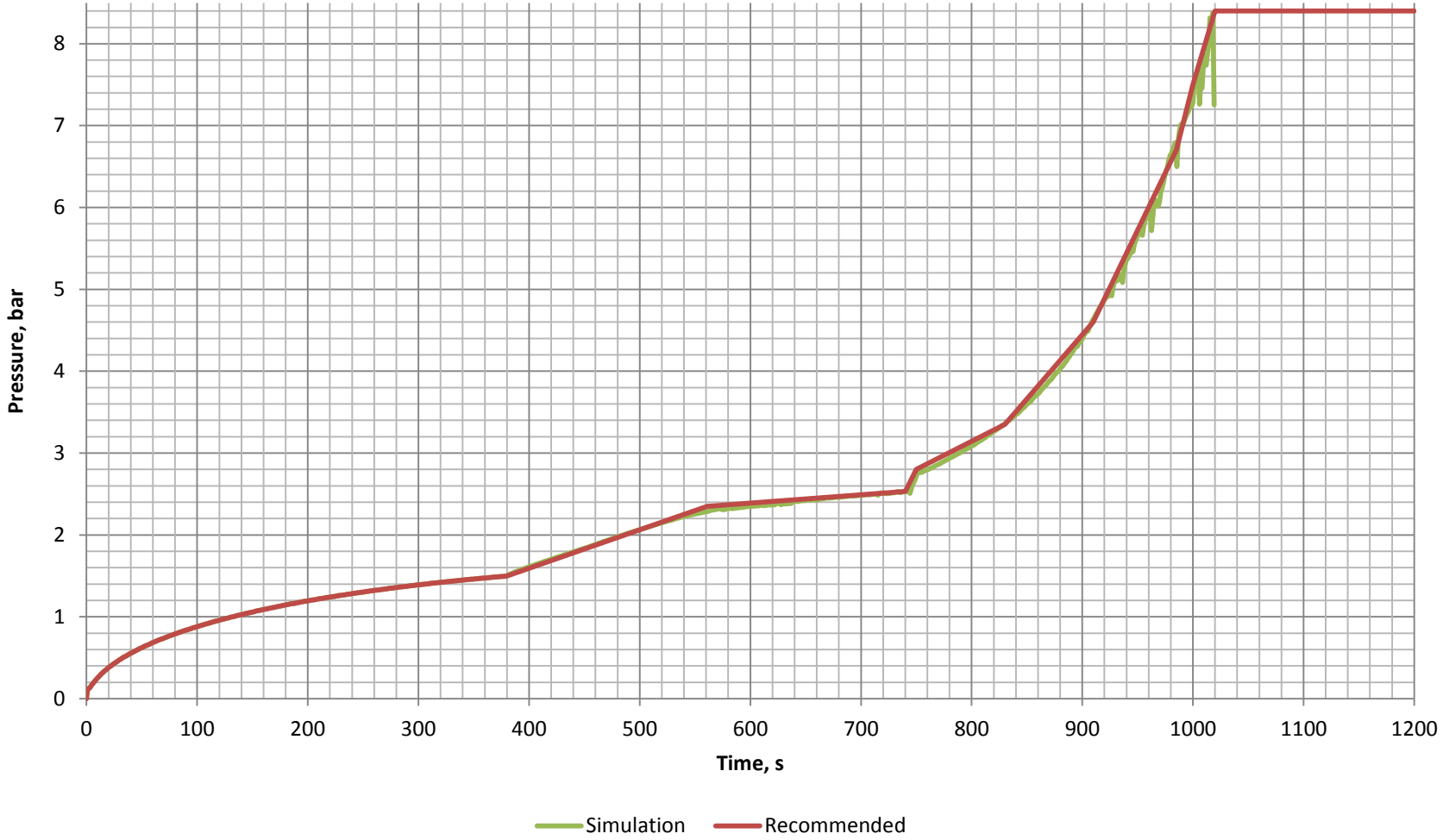
Simulation results, case 1
Field of thickness at the end of simulation



Simulation results, case 1
Maximum strain rate to desired strain rate ratio during simulation



Simulation results, case 1
Pressure-time dependence curve

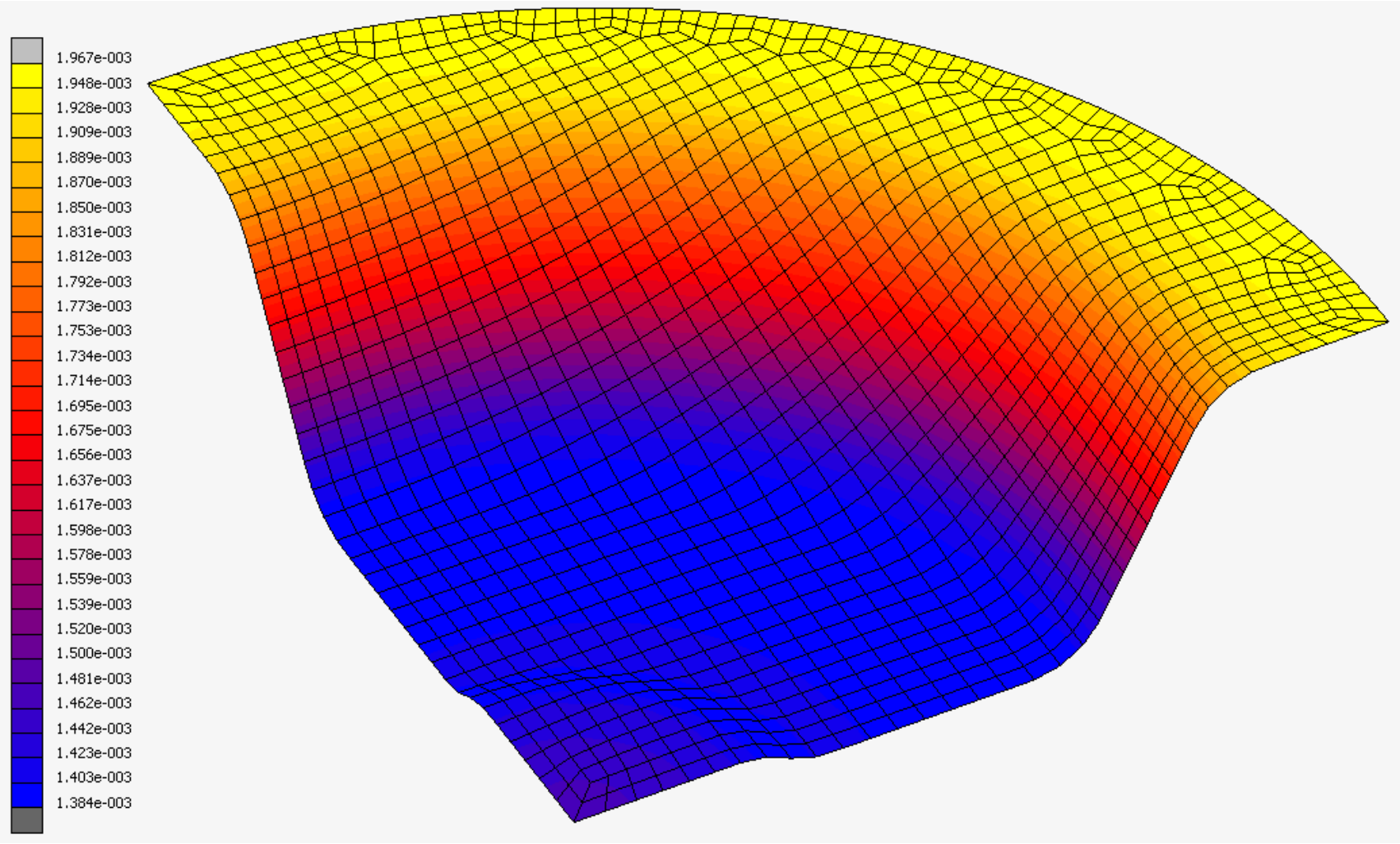


Recommended pressure-time dependence curve is also given, smoothed and supplemented with a constant pressure final calibration stage

Simulation results, case 1 Summary

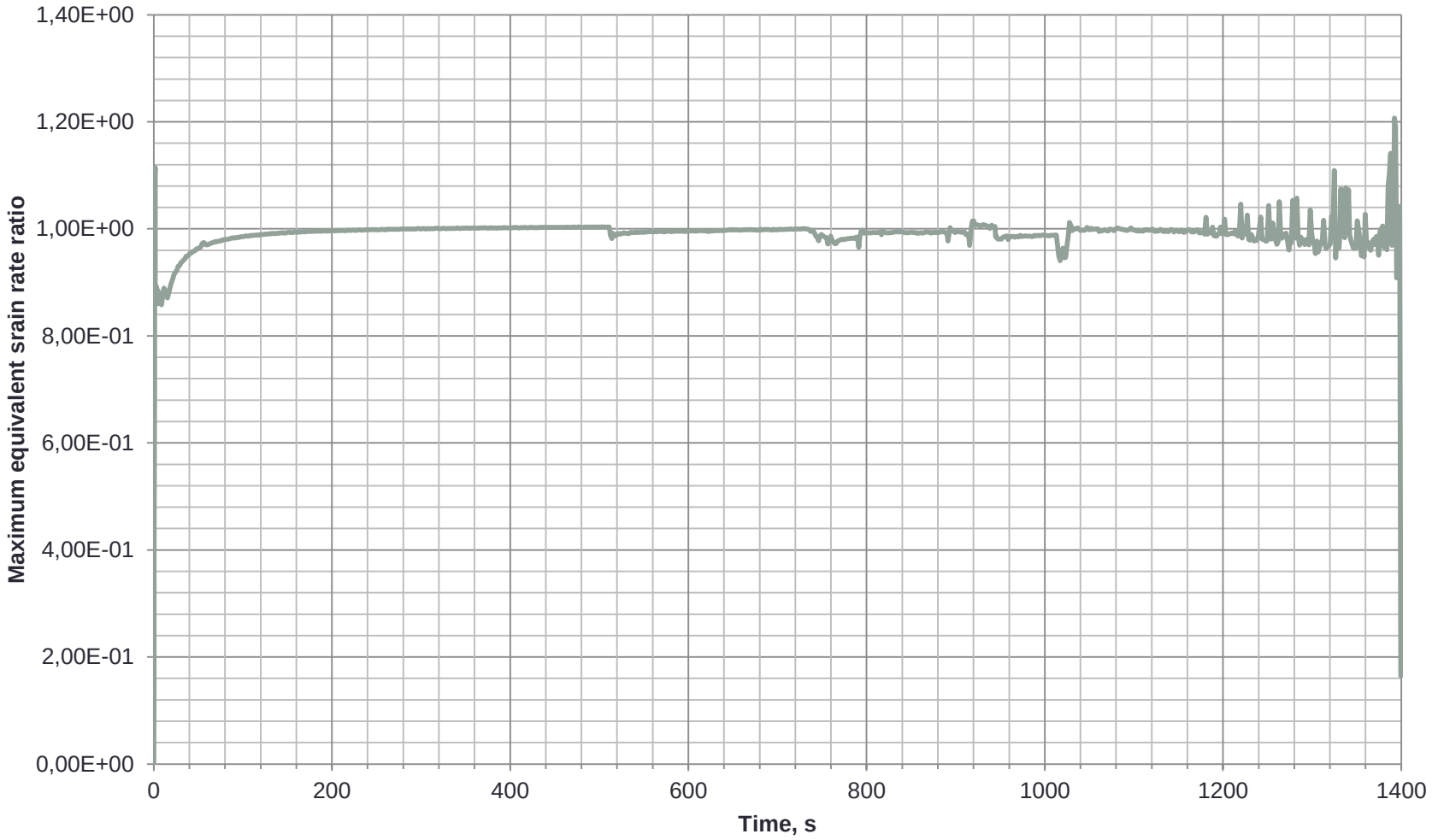
- Forming time (not including pressure unload stage): 1020 seconds
- Maximum required pressure: 8.4 bar
- Maximum plastic strain: 36.1%
- Minimum thickness at the end of simulation: 1.43 mm

Simulation results, case 2
Field of thickness at the end of simulation

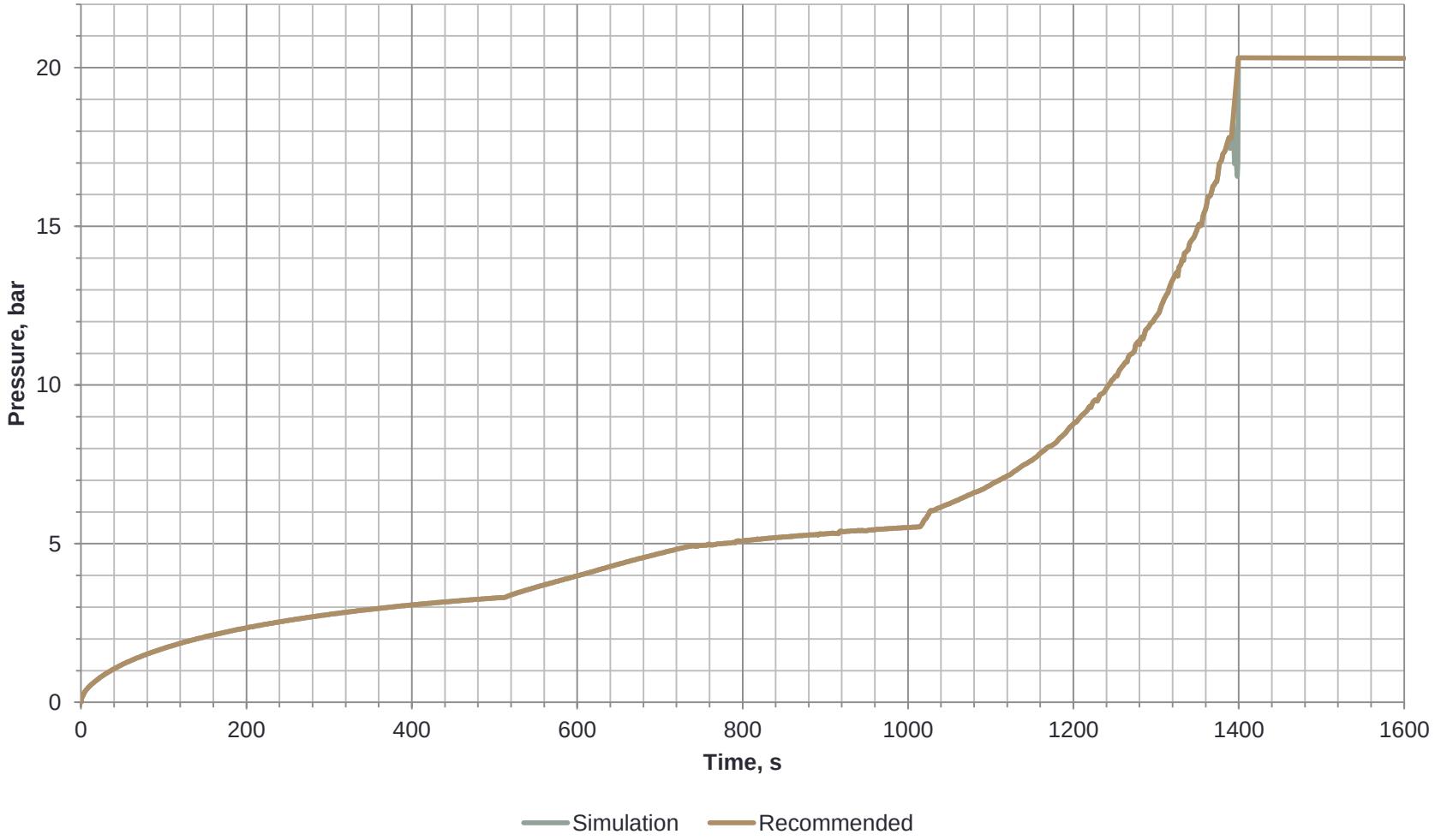


Simulation results, case 2

Maximum strain rate to desired strain rate ratio during simulation



Simulation results, case 2
Pressure-time dependence curve



Recommended pressure-time dependence curve is also given, smoothed and supplemented with a constant pressure final calibration stage

Simulation results, case 2 Summary

- Forming time (not including calibration and pressure unload stages): 1400 seconds
- Maximum required pressure: 20.3 bar
- Maximum plastic strain: 39.4%
- Minimum thickness at the end of simulation: 1.38 mm

- Minimum thickness is different from specified (1.52 mm), additional check was performed (see next)

Simulations results
Additional minimum thickness check

- Simulation case 1 minimum thickness: 1.43 mm
- Simulation case 1 minimum thickness: 1.38 mm

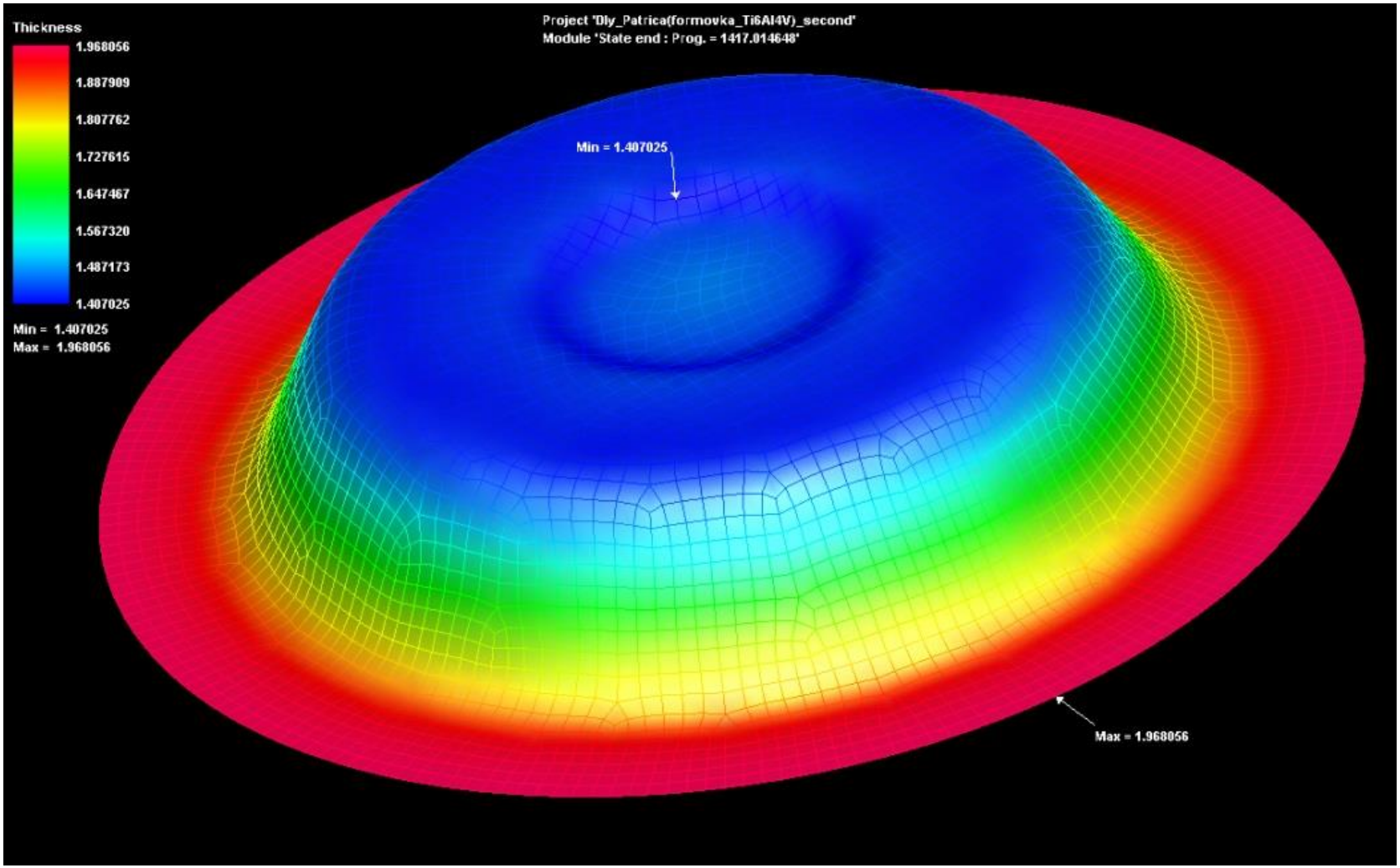
- Expected minimum thickness: 1.52 mm

- Decision: perform control simulation using different CAE software

Control simulation case

- Same initial data as in simulation case 2
- Different CAE software – ESI PAM-STAMP instead of previously used MSC.Marc
- Different FE model:
  - different finite element density
  - different contact formulation
  - different model simplification (more complex model used)

Simulation results, control case
Field of thickness at the end of simulation



Simulation results, control case Summary

- Forming time (not including calibration and pressure unload stages): 1417 seconds
- Maximum plastic strain: 37.8%
- Minimum thickness at the end of simulation: 1.41 mm

- Minimum thickness showed by control simulation is very close to results of cases 1 and 2. Simulation cases may be precise enough.

Summary and conclusion

Case	Strain rate	Forming time	Max. plastic strain	Min. thickness
Case 1	$4 \cdot 10^{-4}\ s^{-1}$	1020	36.1%	1.43 mm
Case 2	$3.3 \cdot 10^{-4}\ s^{-1}$	1400	39.4%	1.38 mm
Control case	$3.3 \cdot 10^{-4}\ s^{-1}$	1417	37.8%	1.41 mm

Minimum thickness showed by control simulation is very close to results of cases 1 and 2. Simulation cases are believed to be of good precision.

If necessary, additional FE-study can be performed using more complex FE-models with finite elements, taking bending strains and stresses into account. This approach can possibly give results of better precision.

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Aircraft Manufacturing Technologies Research and Virtual Simulation Laboratory

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  - Strength studies
  - Fatigue studies