Hydrodynamic Deep Drawing of Paperboard

TECHNISCHE UNIVERSITÄT DARMSTADT

EFPRO Early Stage Researchers Workshop
Brussels, 2011

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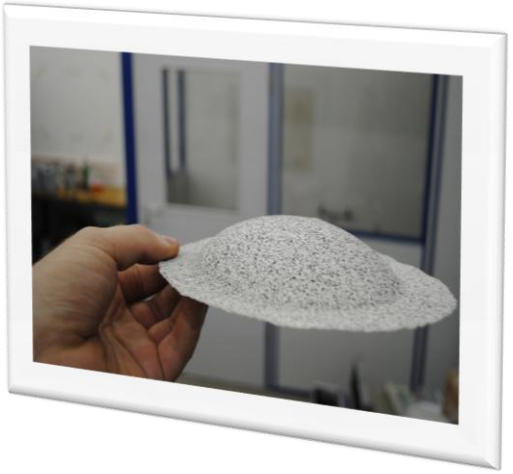
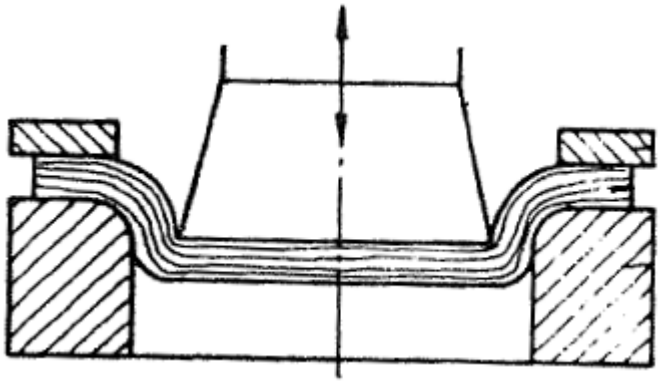


PMV

Conventional deep drawing of paperboard



Paperboard drawing tool
[Tenzer, 1963]

- Special applications
- Rather simple geometries
- Small degrees of deformation
- Product development difficult and expensive
- For decades, machines and processes almost unchanged

Conventional deep drawing of paperboard

Can be made of paper

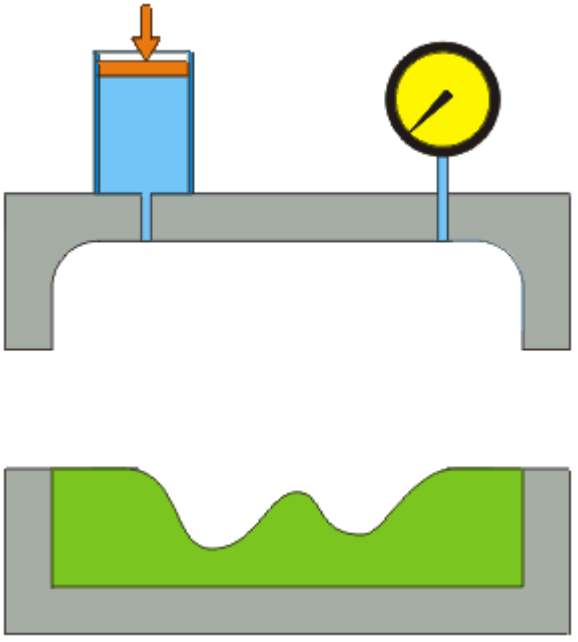
Can‘t be made of paper

Research targets

- **Target 1:** Develop paper optimised for forming processes
- **Target 2:** Develop and simulate forming processes optimised for paper

Hydroforming

- Widespread used in metal forming
  - complex shapes
  - enhanced forming degree

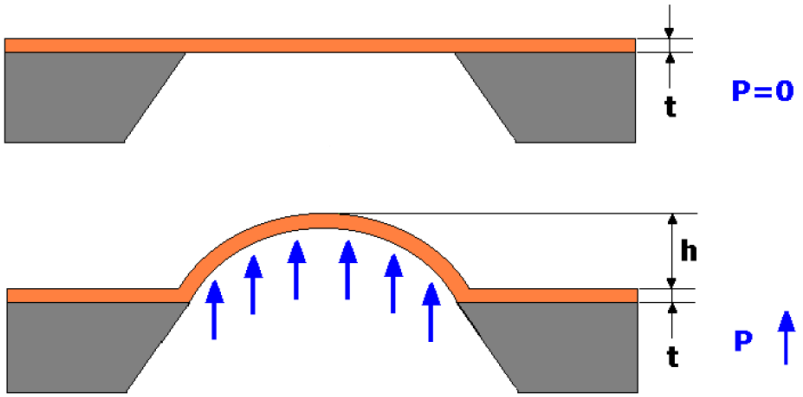


Hydroforming – process visualisation [L. Chiesa]

Is it possible and feasible to adapt this process for paperboard forming?

Test method for hydroformability – bulge test

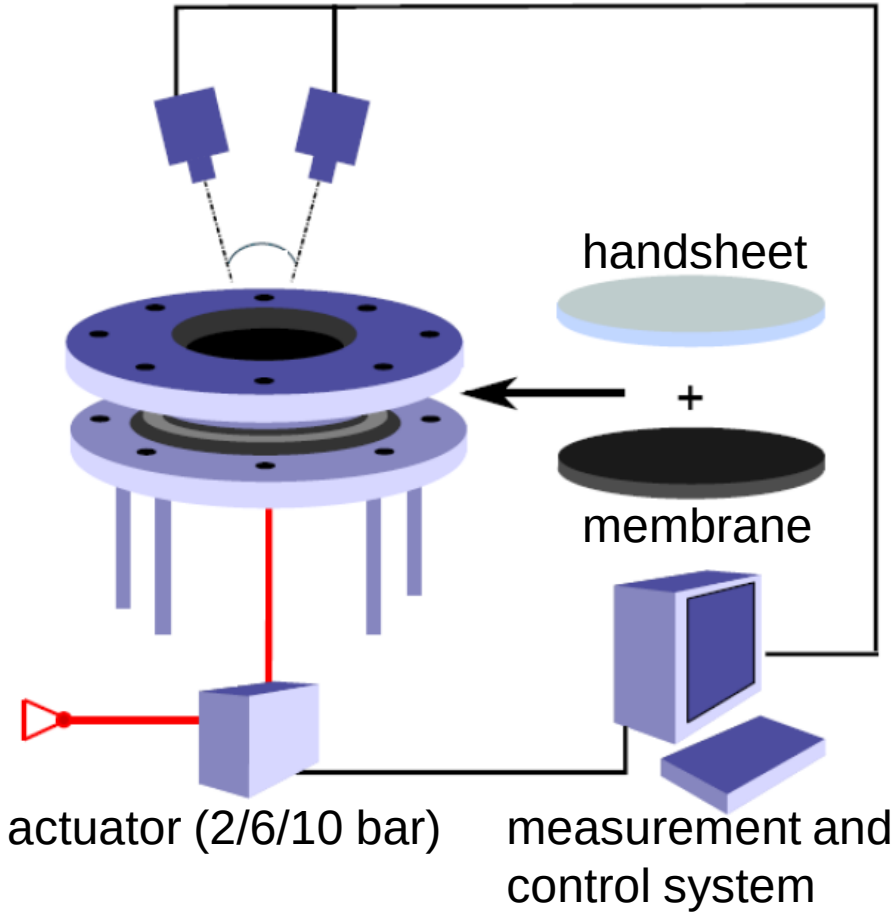
- Hydroforming: Multidimensional state of stress
- State of stress can’t sufficiently be reproduced by standard tensile tests
- Bulge test commonly used test method for metals
- Bulge test allows better predictability of the (metal) forming results



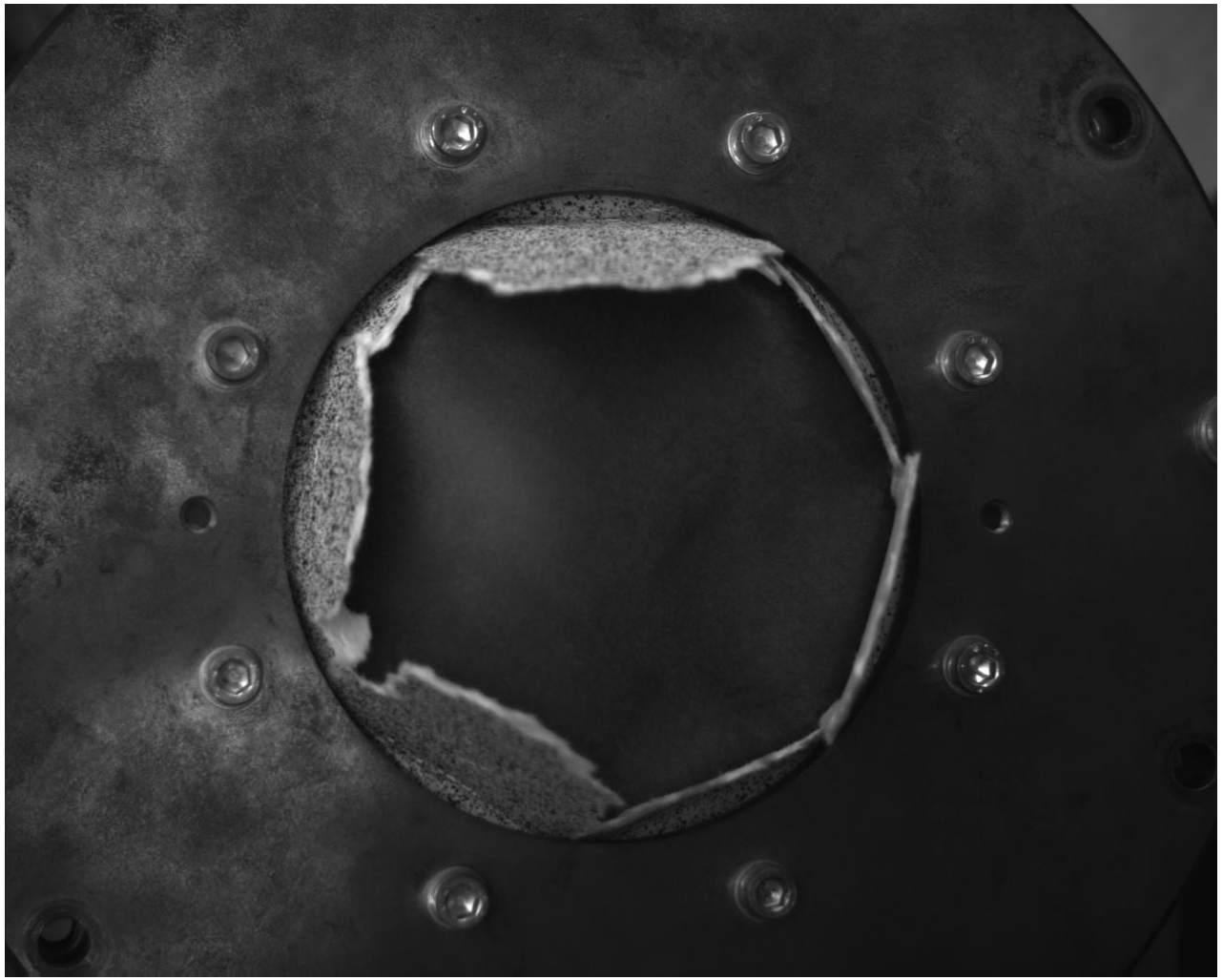
Schematic of bulge test [Xiang et al., 2002]

Paperboard bulge test

- **Membrane** separates **pressurised air** and test sample
- optical 3D extensometer (GOM ARAMIS)
- Optional tools for forming experiments
- Two pressure cycles (clamping/blank holder + bulge/forming pressure)



Paperboard bulge test

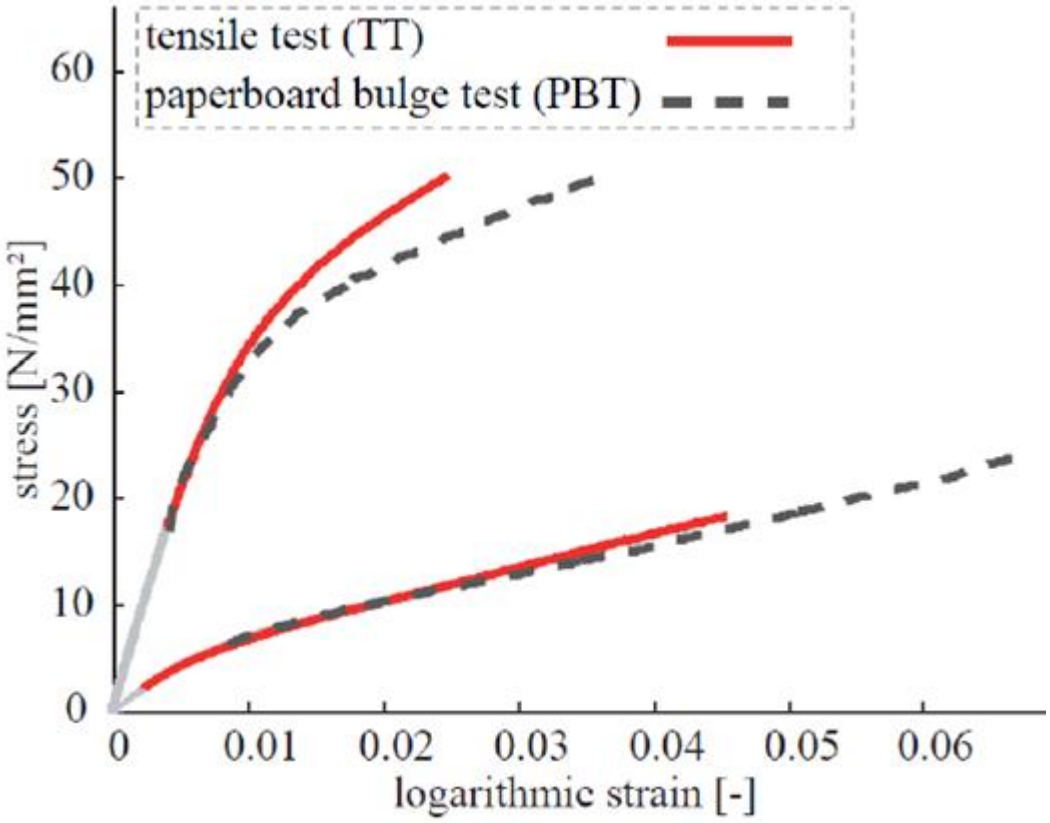


Test programme

- Variables changed:
  - Type of fibre
  - Freeness
  - Grammage
  - Fibre length
  - Moisture content
  - Fibre curl
  - Shrinkage

- 75 different material conditions tested in bulge and tensile tests

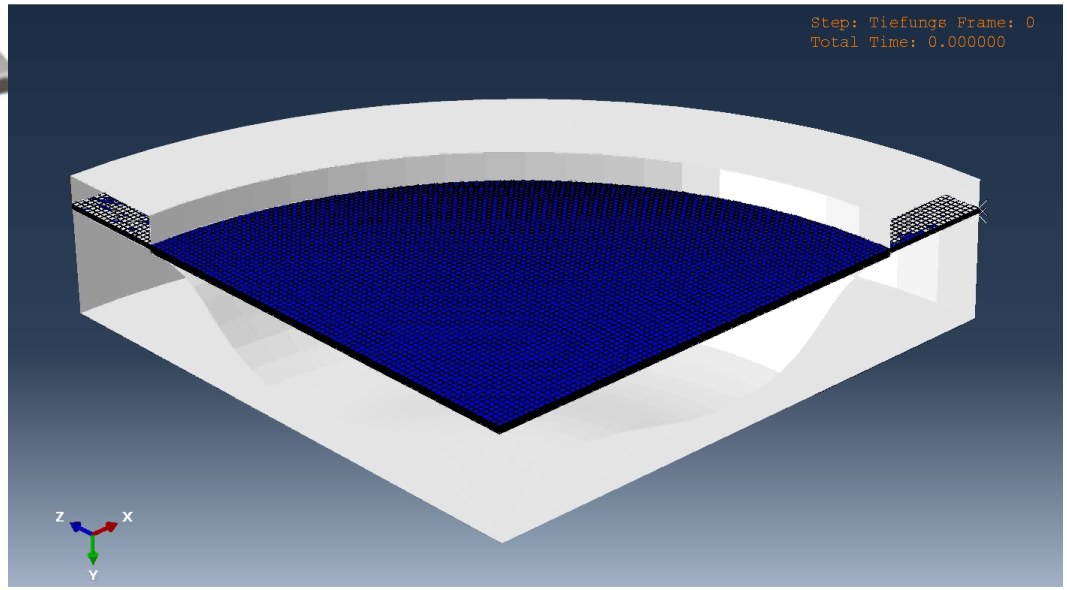
Results



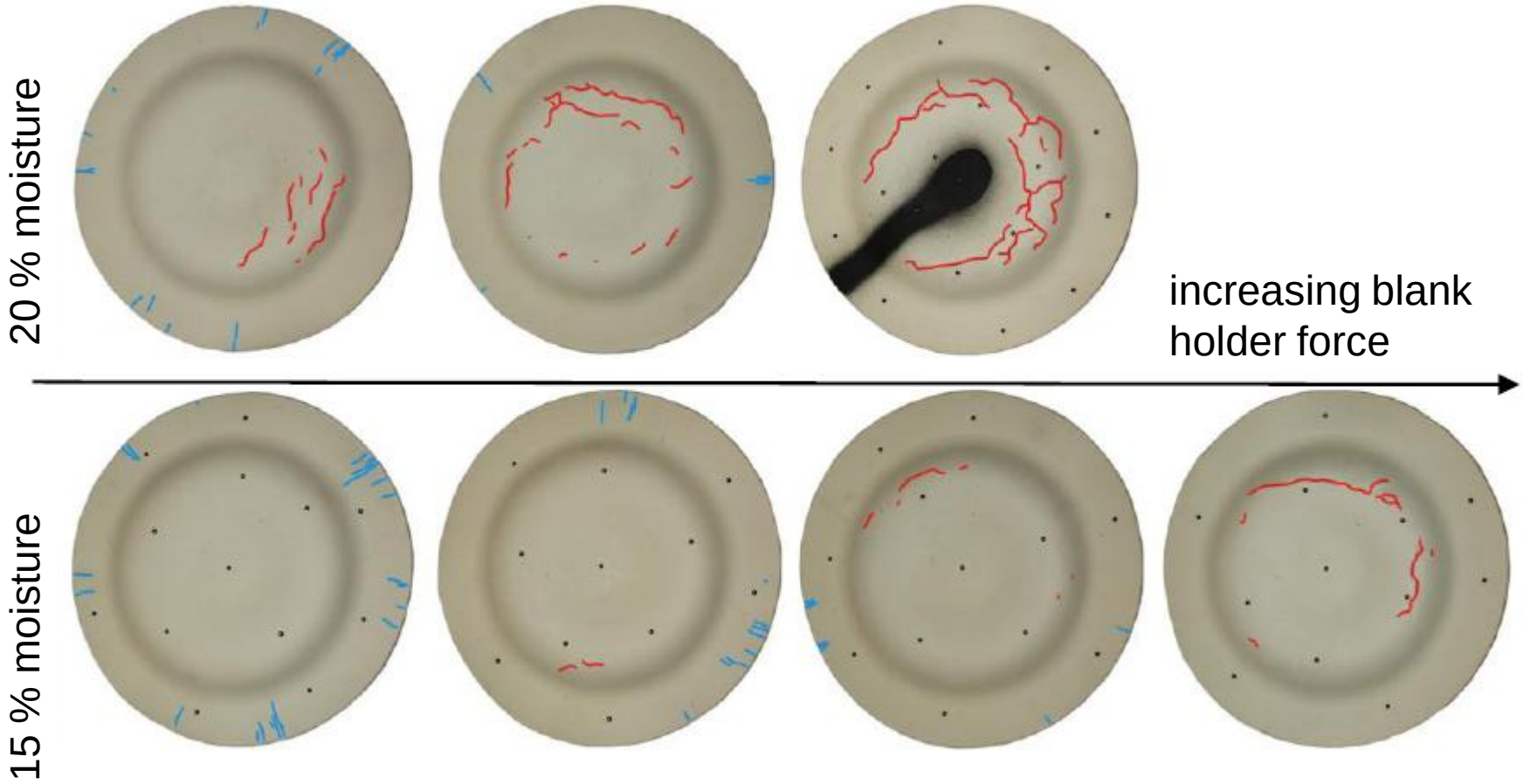
Flow curves of 25 SR softwood pulp handsheets, 7 % and 20 % moisture

- Fracture strain in bulge test was in every case the same or higher than in tensile test.
- Breaking stresses did not show a completely unified picture.
- PBT and TT showed very good correlation when breaking stress was low.
- Some deviations in cases of high breaking stresses.

Forming tests



Influence of moisture content and blank holder force on forming results



Conclusion

- Paperboard bulge test proved to be an appropriate test procedure for evaluation of the material behaviour of paperboard under multiaxial load.
- Multiaxial load led to higher fracture strain.
- Maximum elongation is not the only material parameter which affects the forming behaviour.
- Best overall results: wet, beaten, curled kraft pulp handsheets.
- Highest elongation at break: freely shrunken handsheets.

Perspectives

- Further improvement of the material properties
- Drying procedure/ shrinkage
- Temperature, friction, surface finish
- Optimised FEA modeling

Acknowledgement

- The authors would like to thank the German Research Foundation (DFG) for its financial support of the project GR 1818/37-1.