Characterisation of anisotropic porous materials

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Paris, 15 December 2009

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Outline

- Introduction
- Flow resistivity – early results
  - Glass wool
  - Melamine foam
- Conclusions

Introduction

- Conclusions and future work from last WS:
  - Method to identify full anisotropic flow resistivity tensor - tested on fibrous wool and foamed polymer
  - Dependence of flow resistivity on direction if few samples are taken from a larger piece
  - Test the method on different materials

Objectives

- Porous materials are anisotropic (orthotropic)
- On the way to prove reliability of method to measure flow resistivity

Flow resistivity

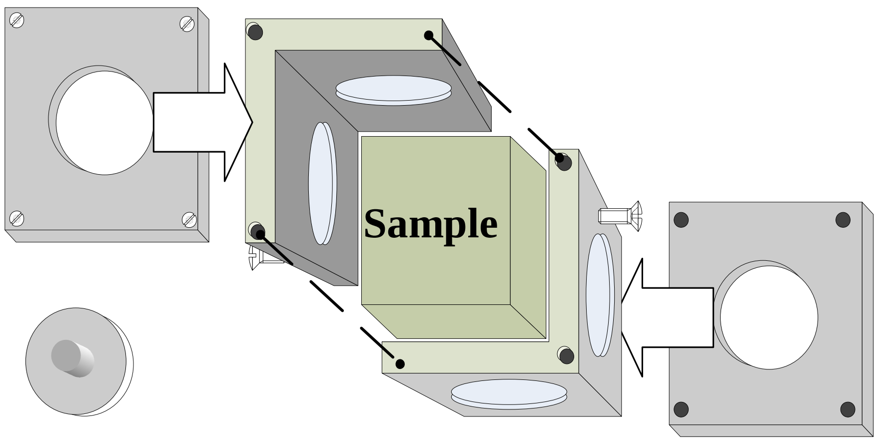
- Darcy's law

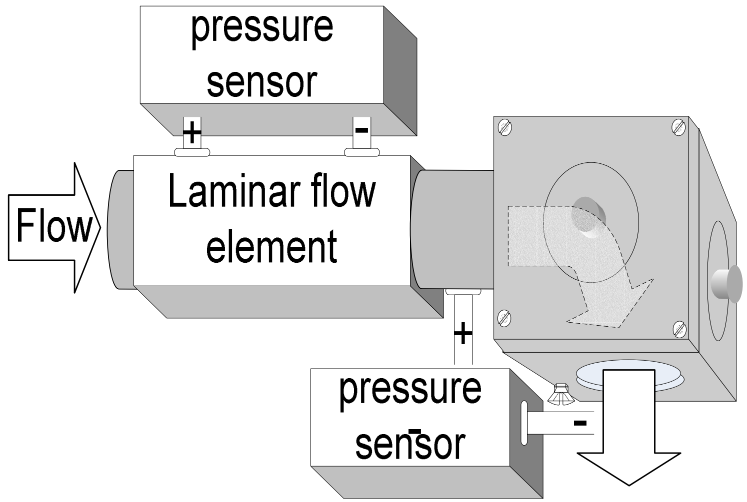
$$-\frac{\boldsymbol{\kappa}}{\eta}\nabla p = \mathbf{v}$$

$$-\boldsymbol{\sigma}^{-1}\nabla p = \mathbf{v}$$

- Second-order permeability tensor $\boldsymbol{\kappa}$
- Dynamic viscosity η
- Second order flow resisitivty tensor $\boldsymbol{\sigma}$

Static flow resistivity



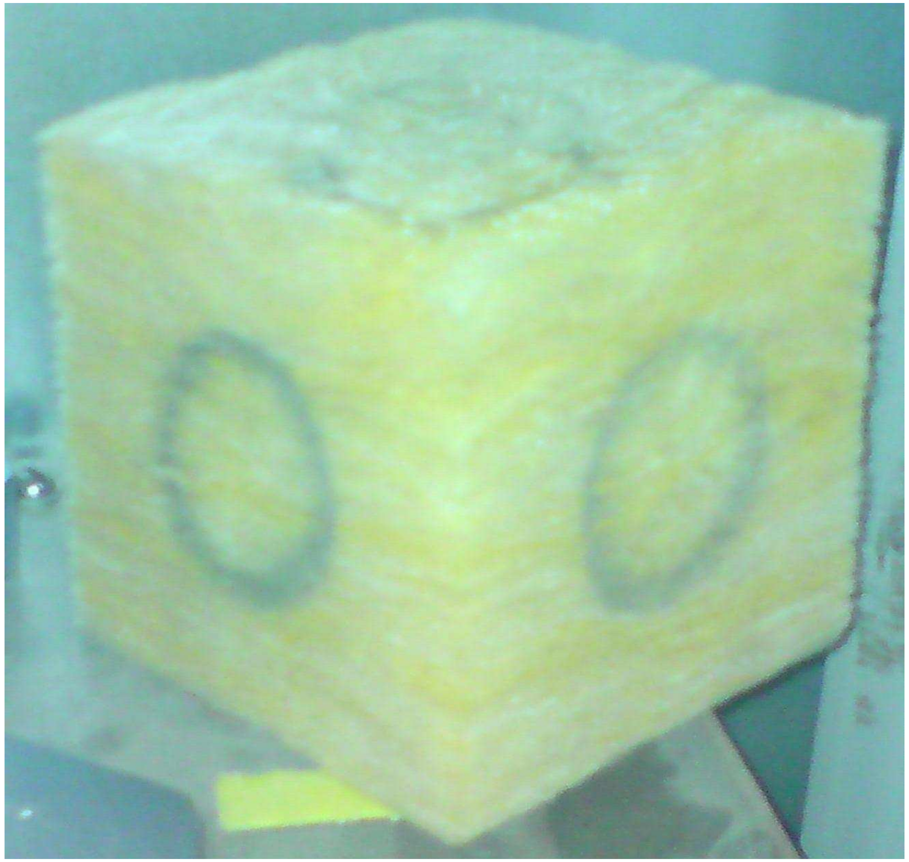


15 exp. values per sample

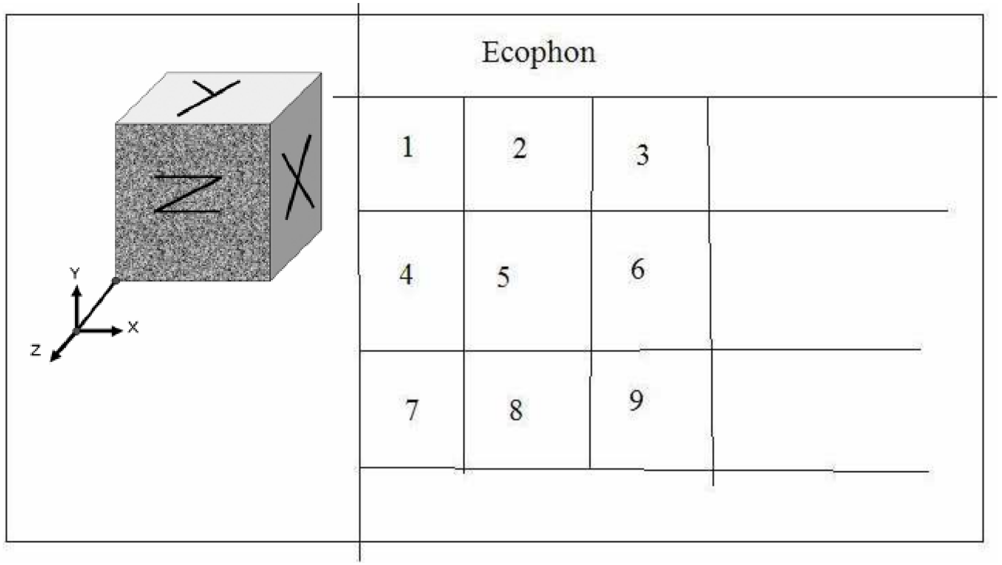
Inverse estimation: FE model compared to $\Delta P_{out} / v_{in}$

Result: FLR matrix

Results: glass wool



Porosity = 1 – $\rho_{foam} / \rho_{bulk}$ = 99%



Results glass wool: Flow Resistivity matrix

All flow resistivity values in Pa*s/m²

FLR = 6500 400 500 400 8400 1500 500 1500 7900 Sample 1	FLR = 6800 400 500 400 9600 1900 500 1900 8700 Sample 2	FLR = 7300 800 700 800 8900 1300 700 1300 7900 Sample 3
FLR = 6100 400 400 400 8600 1200 400 1200 7600 Sample 4	FLR = 6400 800 800 800 8700 1400 800 1400 7000 Sample 5	FLR = 6800 900 800 900 9200 1500 800 1500 7200 Sample 6
FLR = 6400 800 800 800 7600 900 800 900 6300 Sample 7	FLR = 6200 400 400 400 8100 1400 400 1400 7300 Sample 8	FLR = 6600 800 700 800 8400 1000 700 1000 7200 Sample 9

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Results glass wool: principal direction values

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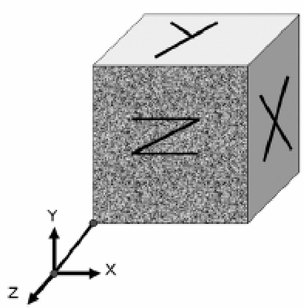
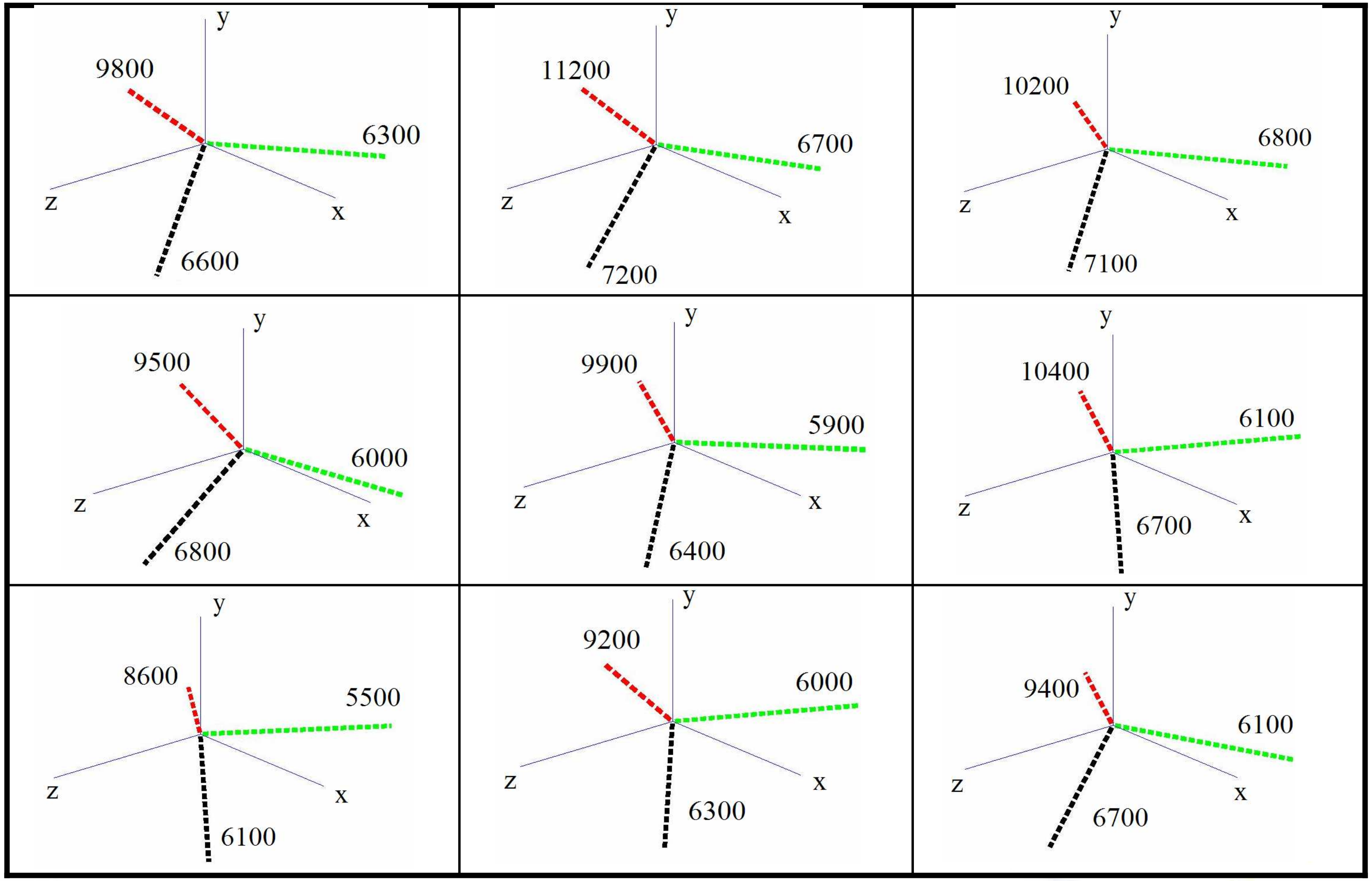
All flow resistivity values in Pa*s/m²

D = $\begin{matrix} 9800 & 0 & 0 \\ 0 & 6300 & 0 \\ 0 & 0 & 6600 \end{matrix}$	D = $\begin{matrix} 11200 & 0 & 0 \\ 0 & 6700 & 0 \\ 0 & 0 & 7200 \end{matrix}$	D = $\begin{matrix} 10200 & 0 & 0 \\ 0 & 6800 & 0 \\ 0 & 0 & 7100 \end{matrix}$
D = $\begin{matrix} 9500 & 0 & 0 \\ 0 & 6000 & 0 \\ 0 & 0 & 6800 \end{matrix}$	D = $\begin{matrix} 9900 & 0 & 0 \\ 0 & 5900 & 0 \\ 0 & 0 & 6400 \end{matrix}$	D = $\begin{matrix} 10400 & 0 & 0 \\ 0 & 6100 & 0 \\ 0 & 0 & 6700 \end{matrix}$
D = $\begin{matrix} 8600 & 0 & 0 \\ 0 & 5500 & 0 \\ 0 & 0 & 6100 \end{matrix}$	D = $\begin{matrix} 9200 & 0 & 0 \\ 0 & 6000 & 0 \\ 0 & 0 & 6300 \end{matrix}$	D = $\begin{matrix} 9400 & 0 & 0 \\ 0 & 6100 & 0 \\ 0 & 0 & 6700 \end{matrix}$

Results glass wool: angles

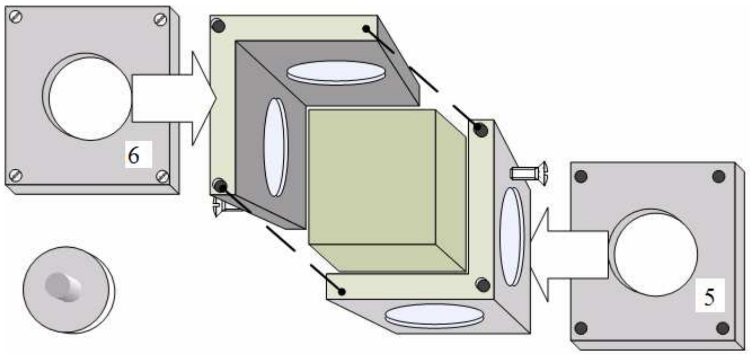




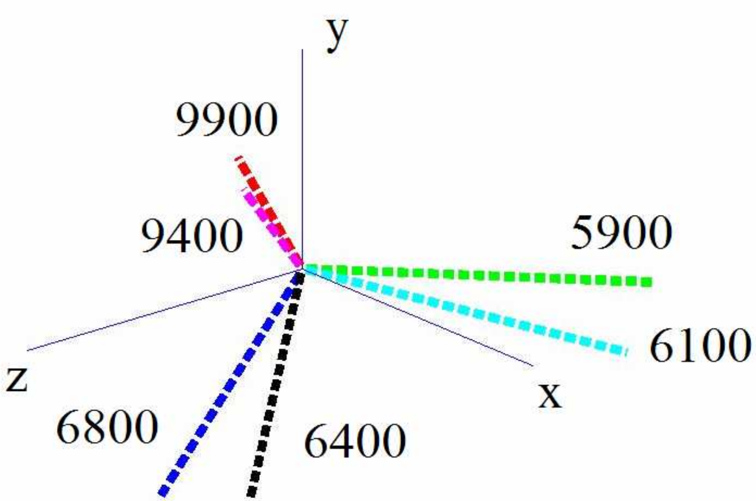
Glass wool: repeatability

All flow resistivity values in Pa*s/m²

Sample 5

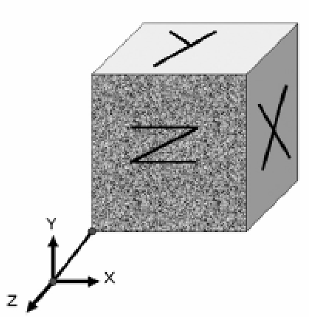


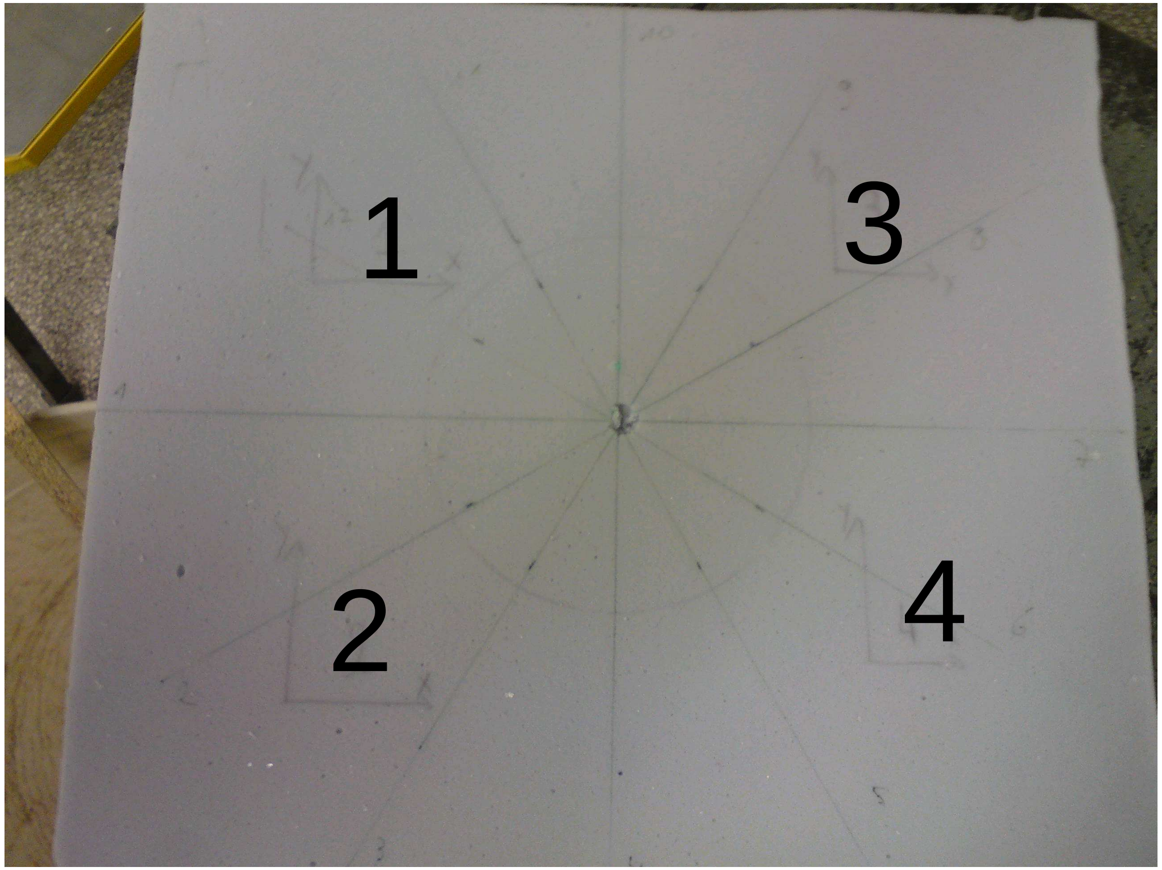
First 5 then 6	First 6 then 5
FLR = 6400 800 800 800 8700 1400 800 1400 7000	FLR = 6700 900 800 900 8200 1000 800 1000 7400
D = 9900 0 0 0 5900 0 0 0 6400	D = 9400 0 0 0 6100 0 0 0 6800



Largest error in principal direction < 6%
→ good repeatability

Results: Melamine





Porosity $= 1 - \rho_{foam} / \rho_{bulk} = 99{,}4\ \%$

Results melamine: Flow Resistivity matrix

All flow resistivity values in Pa*s/m²

Sample 1

FLR =

9100	1200	1000
1200	9800	1100
1000	1100	9600

Sample 3

FLR =

9700	1200	1100
1200	10700	1200
1100	1200	10100

Sample 2

FLR =

10700	1300	1100
1300	11000	100
1100	100	10700

Sample 4

FLR =

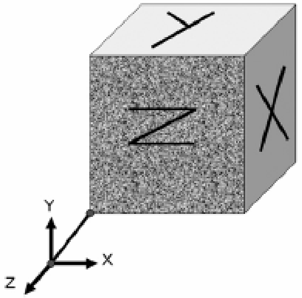
11000	1400	1300
1400	11800	1300
1300	1300	10500

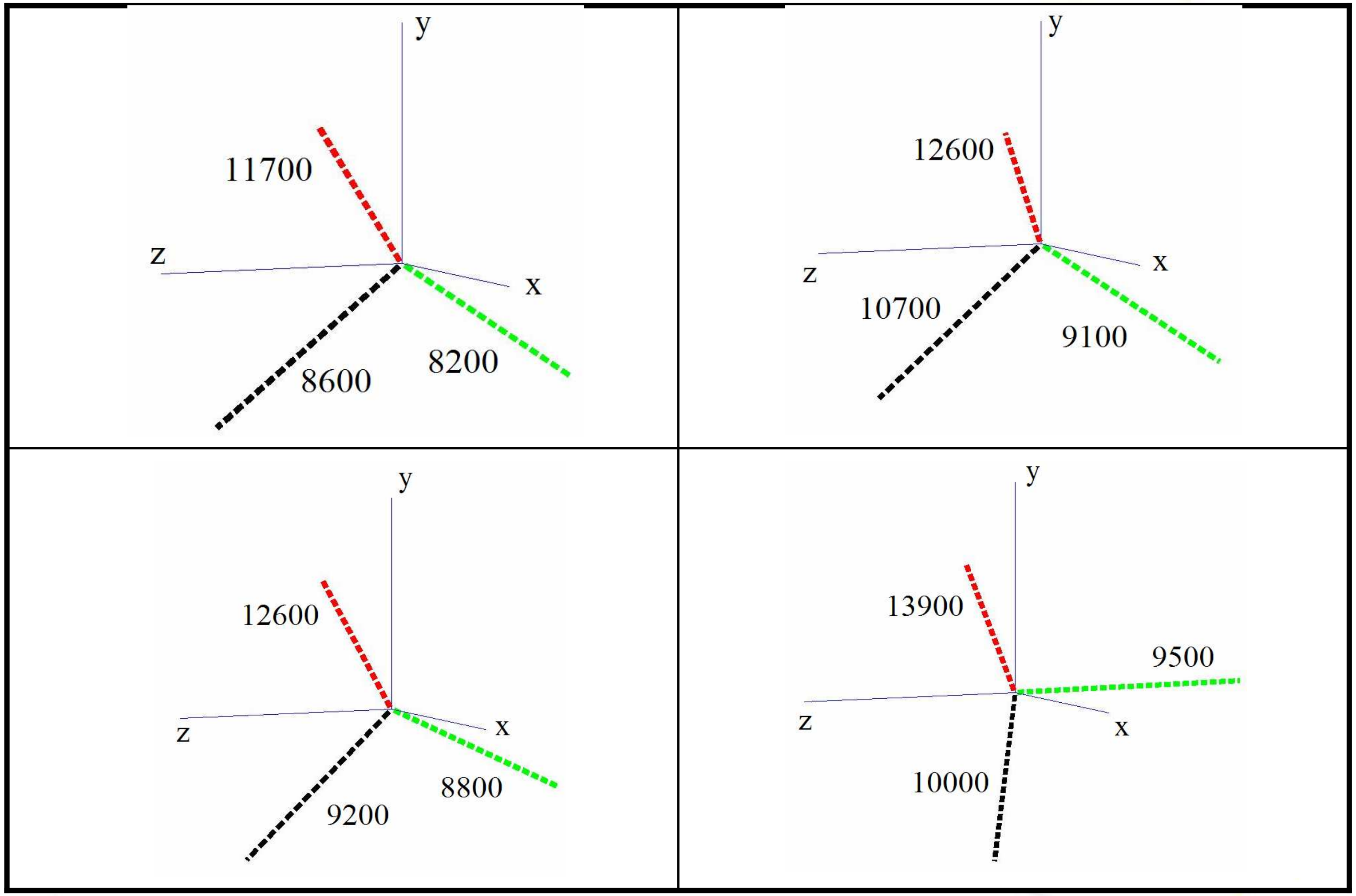
Results melamine: Principal direction values

All flow resistivity values in Pa*s/m²

D = $\begin{matrix} 11700 & 0 & 0 \\ 0 & 8200 & 0 \\ 0 & 0 & 8600 \end{matrix}$	D = $\begin{matrix} 12600 & 0 & 0 \\ 0 & 8800 & 0 \\ 0 & 0 & 9200 \end{matrix}$
D = $\begin{matrix} 12600 & 0 & 0 \\ 0 & 9100 & 0 \\ 0 & 0 & 10700 \end{matrix}$	D = $\begin{matrix} 13900 & 0 & 0 \\ 0 & 9500 & 0 \\ 0 & 0 & 10000 \end{matrix}$

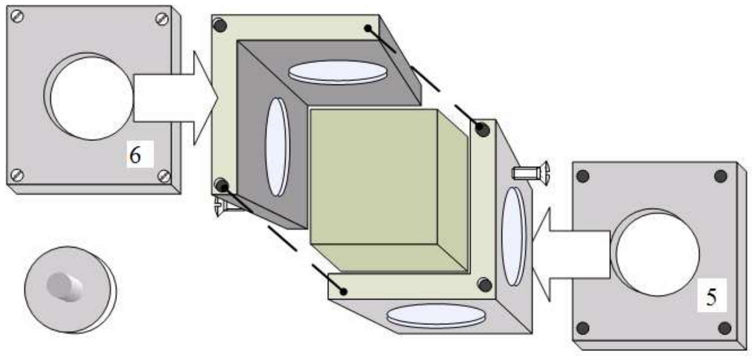
Results melamine: angles

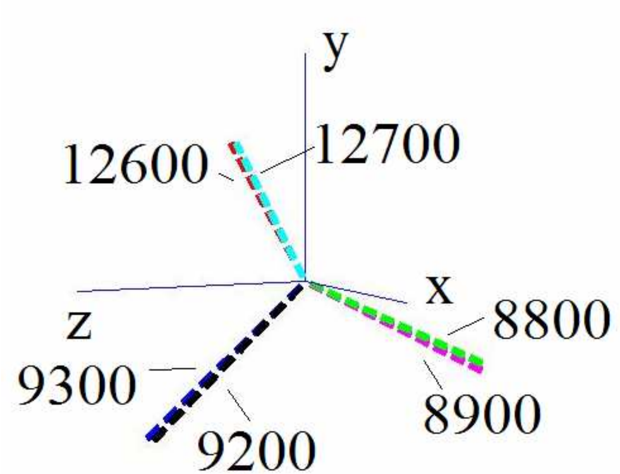




Melamine: repeatability

All flow resistivity values in Pa*s/m²





Sample 2

First 5 then 6	First 6 then 5
FLR = 9700 1200 1100 1200 10700 1200 1100 1200 10100	FLR = 9900 1300 1000 1300 10800 1200 1000 1200 10200
D = 12600 0 0 0 8800 0 0 0 9200	D = 12700 0 0 0 8900 0 0 0 9300

Largest error in principal directions < 3%
→ good repeatability

Conclusions

- Method repeatable
  - Check further reliability
- Glass wool and melamine:
  - Anisotropic material with unique main direction → orthotropic
  - Variation in FLR for samples of same specimen
    - Measurement errors?
    - Estimation errors?
    - Variation in material?
  - Repeatability melamine better than glass wool
    - Stiffer material

Future work

- Measurement method: continue research on estimation and measurement errors
- Glass wool → calculate mean and standard variation out of statistics and find way for error estimation
- Melamine: compare to measurements of ISO 9053

Acknowledgements

- The work presented in this presentation is based on the research performed with the support of Smart Structures (MRTN-CT-2006-035559), which is gratefully acknowledged

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