Wrocław University of Technology

EXPERIMENTAL METHODS IN TESTING OF SMART MAGNETIC MATERIALS

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OUTLINE

- DEFINITION OF SMART MATERIALS
- SMART MAGNETIC MATERIALS - ROLE AND APPLICATIONS
- TESTING OF MAGNETORHEOLOGICAL COMPOSITES (MRC)
  - Creation of magnetorheological composite
  - Examinations of MRC
- TESTING OF MAGNETORHEOLOGICAL ELASTOMERS (MRE)
  - Creation of magnetorheological elastomers
  - Examinations of MRE
- TESTING OF GIANT MAGNETOSTRICTIVE MATERIALS (GMM)
  - Magnetostriction and reverse magnetostriction, GMM
  - Magnetostrictive actuator construction
  - Examinations of GMM
- THE MAGNETOVISION MEASUREMENT SYSTEM
  - Reverse magnetostriction
  - Martensitic transformation detection
- CONCLUSIONS

SMART MATERIALS
DEFINITION

The definition of smart materials has been expanded to materials that receive, transmit, or process a stimulus and respond by producing a useful effect that may include a signal that the material is acting upon it.

J.A. Harwey, 2002 in: Handbook of Materials Selection, edited by M. Kutz., A Wiley-Interscience Publication, John Wiley& Sons, Inc.

SMART MATERIALS
CLASIFICATION

- Piezoceramic (PZT)
- Elektrostrictive (PMN)
- Magnetostrictive (GMM)
- Magnetorheological Fluids (MRF)
- Shape Memory Alloys
  - Temperature Activated (SMA)
  - Magnetic Field Activated (MSMA)
- others

SMART MAGNETIC MATERIALS

CLASIFICATION

- Giant Magnetostrictive
- Magnetic fluids
  - Ferrofluids
  - Magnetorheological fluids
- Magnetorheological Elastomers
- Giant magnetocaloric
- Giant magnetoresistance
- Ferromagnetic shape memory

SMART MAGNETIC MATERIALS
EXAMPLES OF APPLICATIONS

ACTIVE PROSTHESIS

SONARS

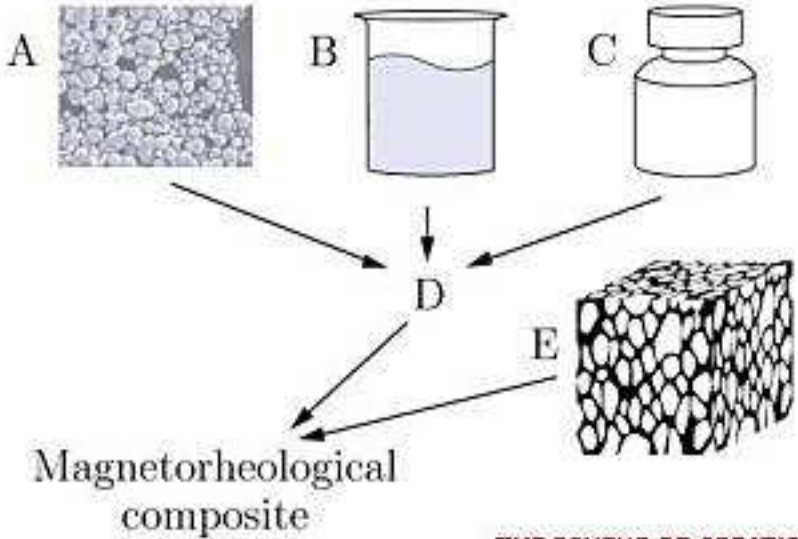
CIVIL ENGINEERING

PETROCHEMIC INDUSTRY

OUR INVESTIGATIONS

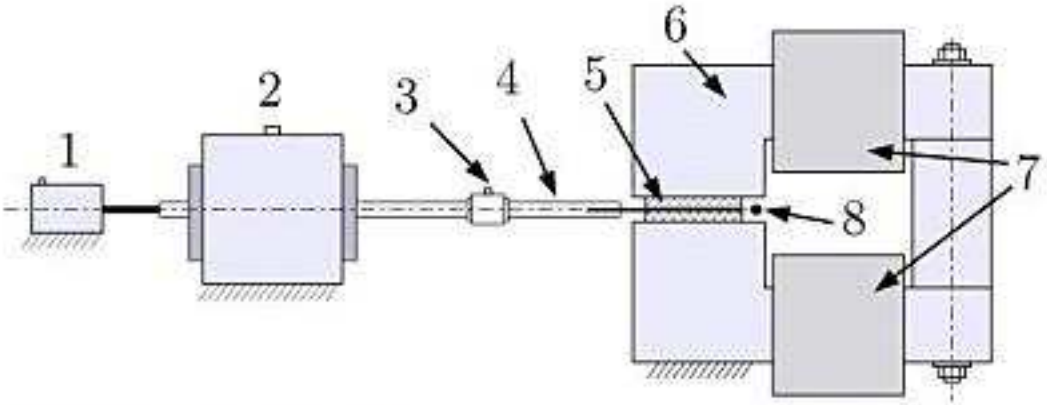
MAGNETORHEOLOGICAL COMPOSITES (FIELD-RESPONSIVE FLUID-IMPREGNATED CELLULAR SOLIDS)

TESTING OF MRC
PREPARATION



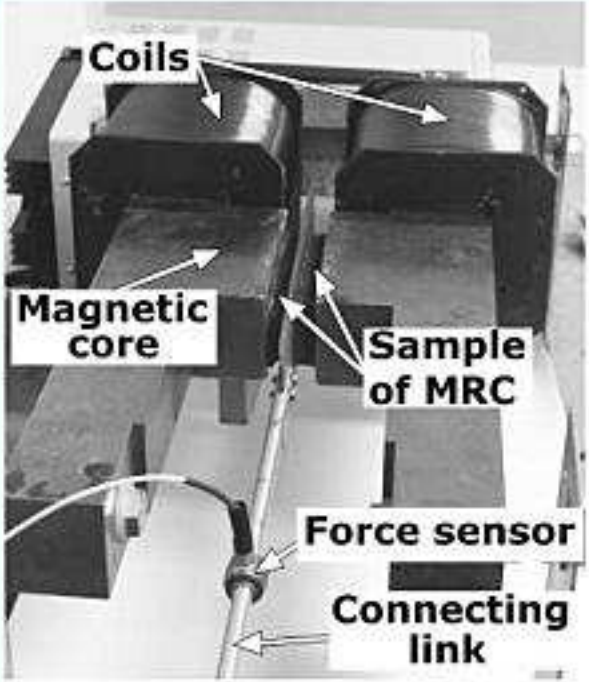
THE SCHEME OF CREATION
MAGNETORHEOLOGICAL COMPOSITE

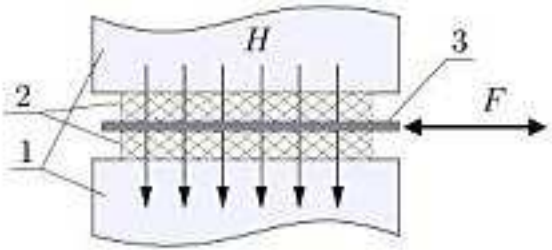
TESTING OF MRC
SCHEME OF SET-UP



EXPERIMENTAL SET-UP USED FOR TESTING DAMPING OF MAGNETORHEOLOGICAL COMPOSITES PROPERTIES

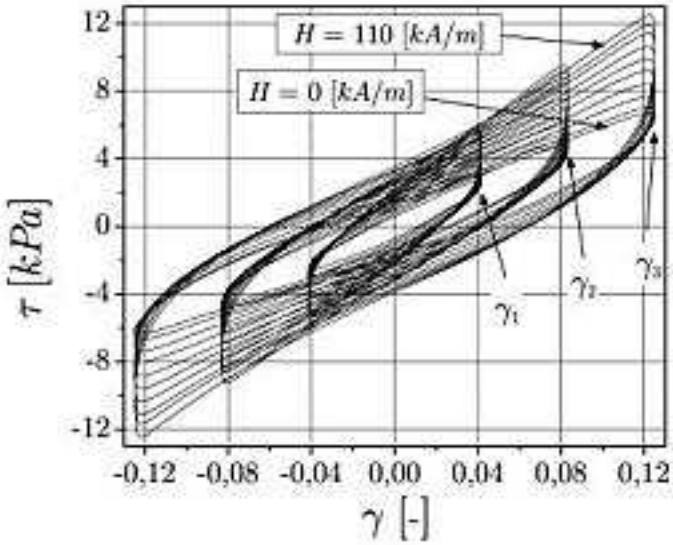
TESTING OF MRC
TEST STAND





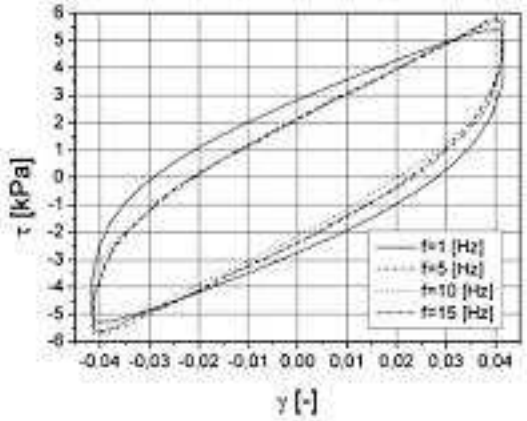
THE SCHEME OF MRC SAMPLE IN MAGNETIC CIRCUIT AND DIRECTION OF APPLIED MAGNETIC FIELD H:
1 - MAGNETIC CORE,
2 - MRC,
3 - CARRYING ELEMENT

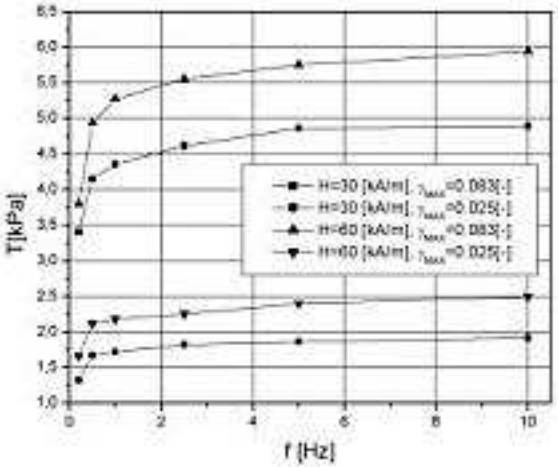
TESTING OF MRC
RESULTS



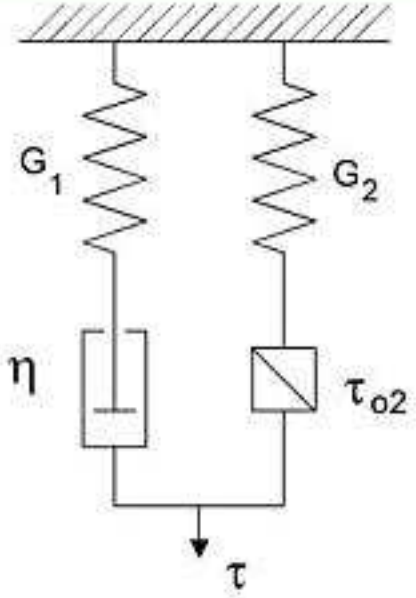
DEPENDENCE OF SHEAR STRESS ON SHEAR STRAIN FOR DIFFERENT VALUES OF STRAIN AMPLITUDE AND DIFFERENT APPLIED MAGNETIC FIELD STRENGTH H

TESTING OF MRC
RESULTS, FREQUENCY INFLUENCE





TESTING OF MRC
VISCO-ELASTIC-PLASTIC MATERIAL MODEL



$$\tau + t_\gamma \dot{\tau} = 2G_2(\gamma + t_\tau \dot{\gamma})$$

$$\tau + t_\gamma \dot{\tau} = 2\eta\dot{\gamma} + \tau_{o2} - 2G_2\gamma_k$$

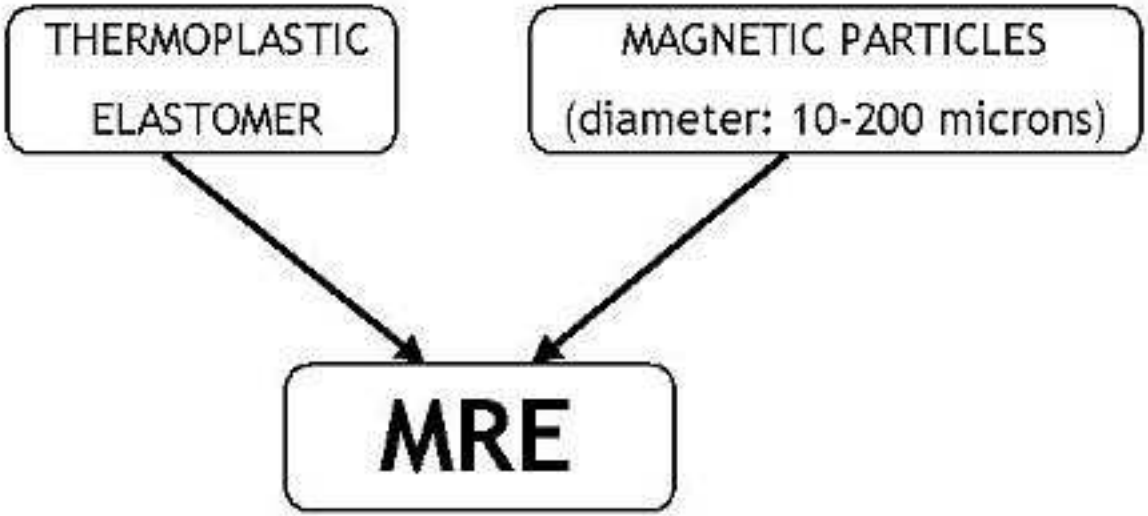
$$t_\gamma(H) = \frac{\eta(H)}{G_1(H)},$$

$$t_\tau(H) = \eta(H)\frac{G_1(H) + G_2(H)}{G_1(H)G_2(H)}$$

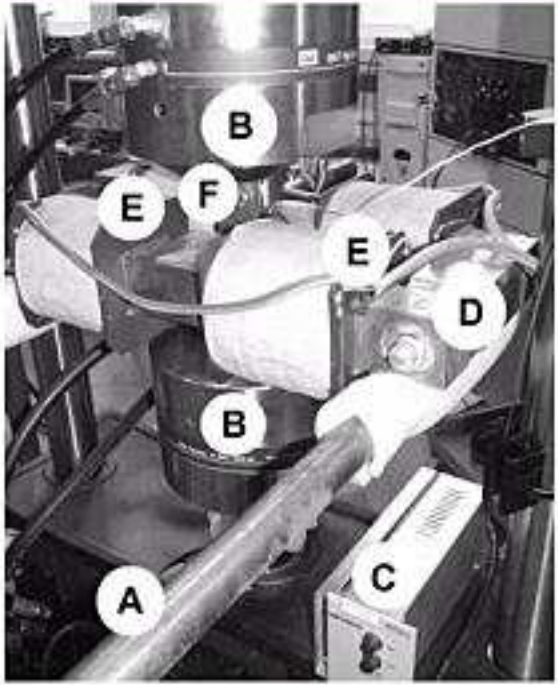
OUR INVESTIGATIONS

MAGNETORHEOLOGICAL ELASTOMERS (MRE)

TESTING OF MRE
PREPARATION



TESTING OF MRE
TEST STAND



THE TEST STAND:

A - CARRYING ELEMENTS,

B - MTS JAWS,

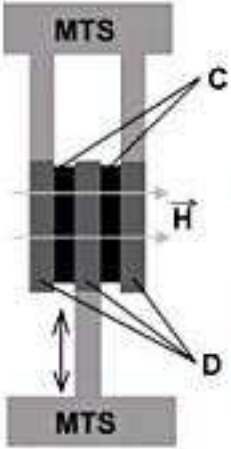
C - POWER SUPPLY FOR MAGNETIC FIELD SENSOR,

D - MAGNETIC CORE,

E - COILS,

F - THE SPECIMEN

TESTING OF MRE
TEST STAND



THE TEST STAND:

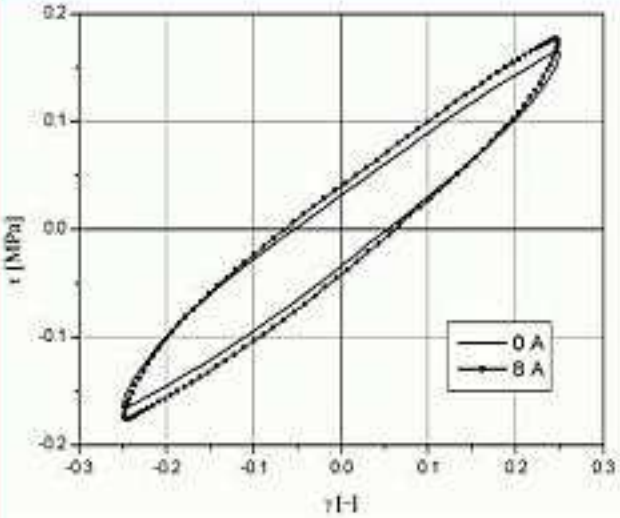
A - PARAMAGNETIC PLATE,

B - MAGNETIC FIELD SENSOR,

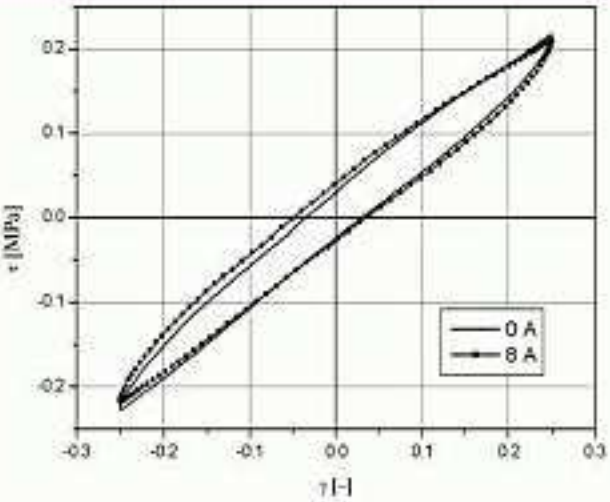
C - SPECIMENS,

D - FERROMAGNETIC PLATE

TESTING OF MRE
RESULTS



MRE with ASC 300 particles



MRE with ABC 100.30 particles

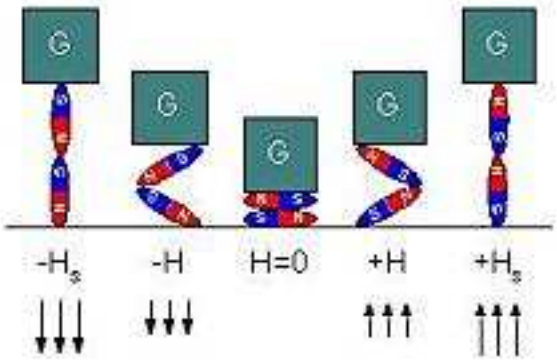
OUR INVESTIGATIONS

GIANT MAGNETOSTRICTIVE MATERIALS - GMM

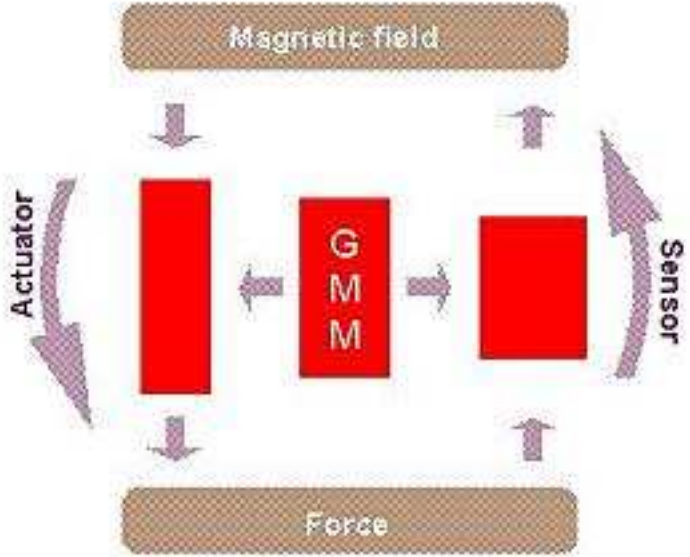
TESTING OF GMM
DEFINITION OF MAGNETOSTRICTION

Magnetostriction is a physical phenomenon that can be described as the deformation of a body in response to a change in its magnetization

- even phenomenon
- exhibits magnetic and thermal hysteresis
- exhibits anisotropy, depends on shape and temperature

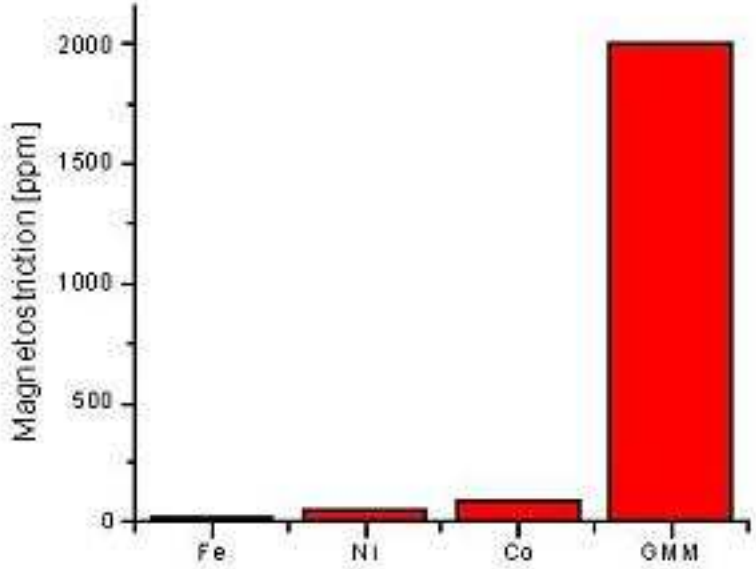


TESTING OF GMM
APPLICATION



TESTING OF GMM

COMPARISION OF CHOSEN MAGNETOSTRICTIVE MATERIALS, TERFENOL-D SPECIMENS



TerFeNOL-D rods

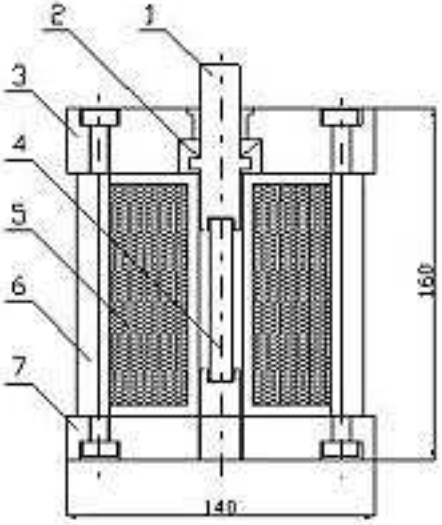
$Tb_xDy_{1-x}Fe_y$

TESTING OF GMM
MAGNETOSTRICTIVE ACTUATOR

http://SMARTsite.immt.pwr.wroc.pl

Rod diam.	10 mm
Rod length	100 mm
Stroke	0.12 mm
Force	2.7 kN
Temp. Range	-15 ÷ 300 ^{0}C
Frequency	>30 kHz

TESTING OF GMM
MAGNETOSTRICTIVE ACTUATOR

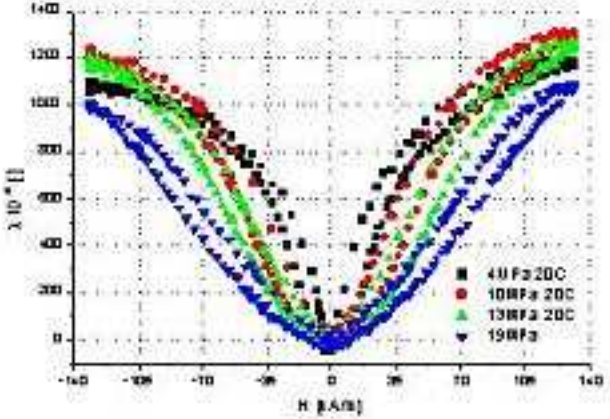


$$\varepsilon = \varepsilon(\sigma, H)$$

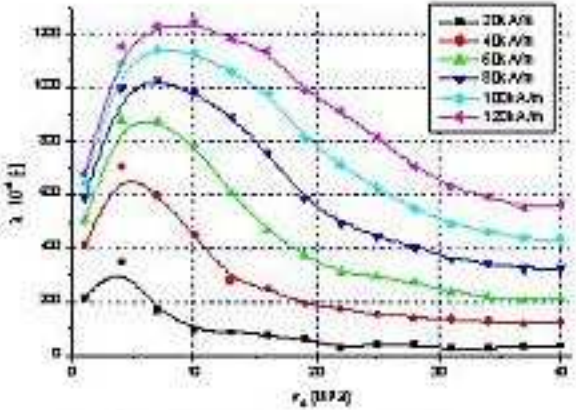
$$B = B(\sigma, H)$$

1 - INSERTED FLEX PIVOT,
2 - PRELOAD WASHER,
3 - UPPER HOUSING,
4 - MAGNETOSTRICTIVE MATERIAL,
5 - FIELD COILS,
6 - HOUSING PIVOT,
7 - BOTTOM HOUSING

TESTING OF GMM
RESULTS, MAGNETOSTRICTION



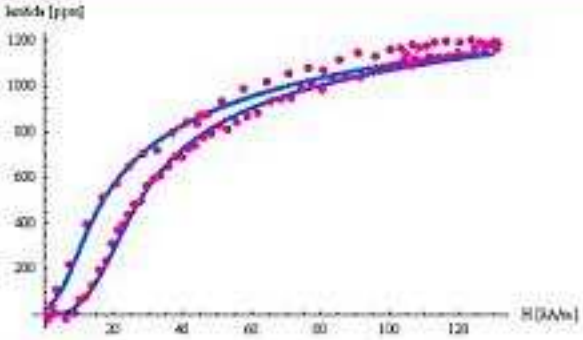
INFLUENCE OF PRESTRESS ON MAGNETOSTRICTION

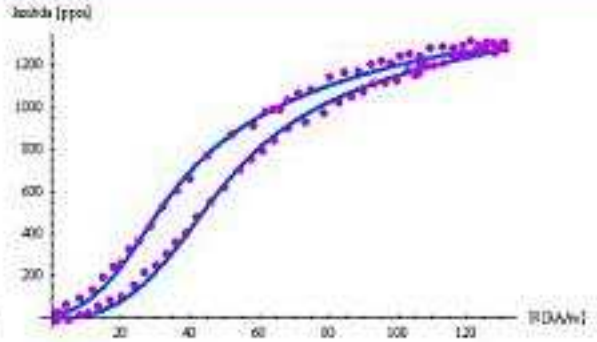


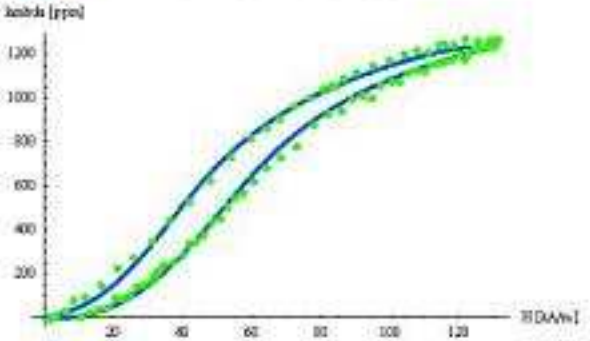
MAGNETOSTRICTION VS. APPLIED PRESTRESS AT DIFFERENT MAGNETIC FIELD INTENSITY

TESTING OF GMM

COMPARISON BETWEEN SIMULATION AND EXPERIMENTAL DATA







continous line - simulation

large dots - experiment

1 ppm = 10^{-6}

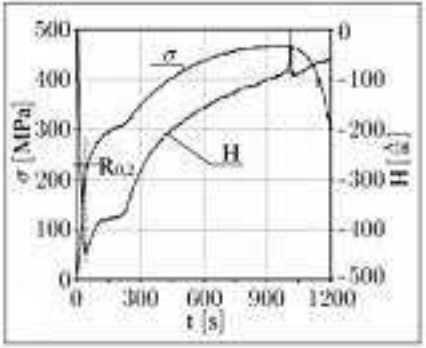
SMM MEASUREMENT
MAGNETOVISION MEASUREMENT SYSTEM

Technical data of Magnetovision Measurement System:

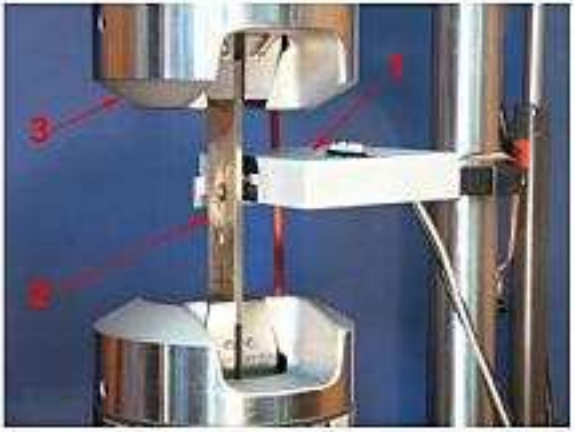
- 48 magnetic field sensors
- 2 axis magnetic field measurement
- range ± 200 A/m (± 530 A/m)
- sensivity 20 mA/m
- dimensions 90x80x100mm
- weight 400g

SMM MEASUREMENT

TEST BENCHES FOR ONE AXIS MAGNETIC FIELD MEASUREMENT

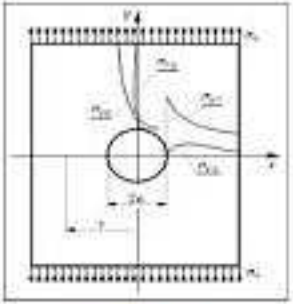


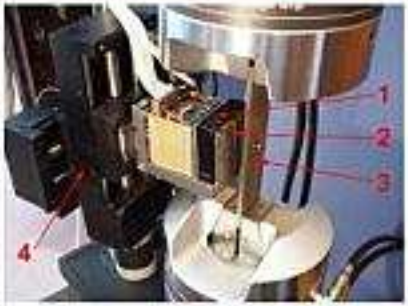
Magnetic analogy of tension curve



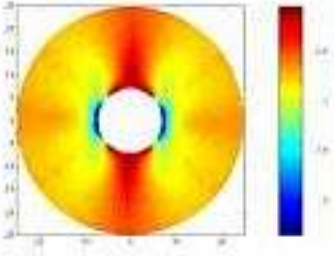
1 - magnetic measuring device, 2 - specimen, 3 - strength machine

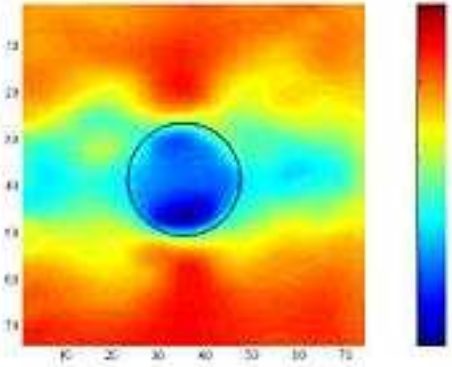
SMM MEASUREMENT
IMAGES FROM MAGNETIC CAMERA





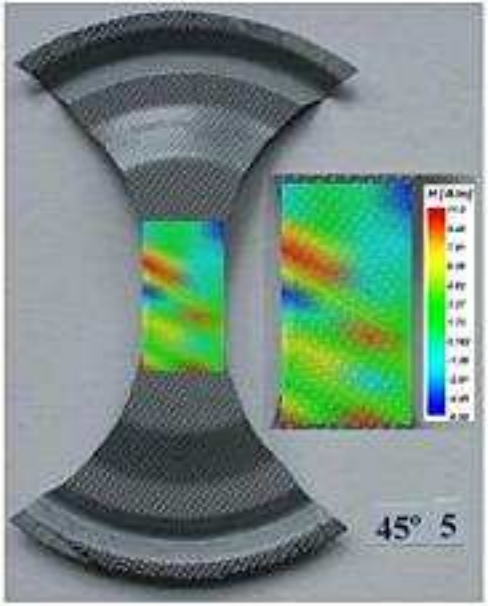
The magnetovision camera; 1 - multisensor head, 2 - magnetic field sensors, 3 - specimen with hole, 4 - positioning system

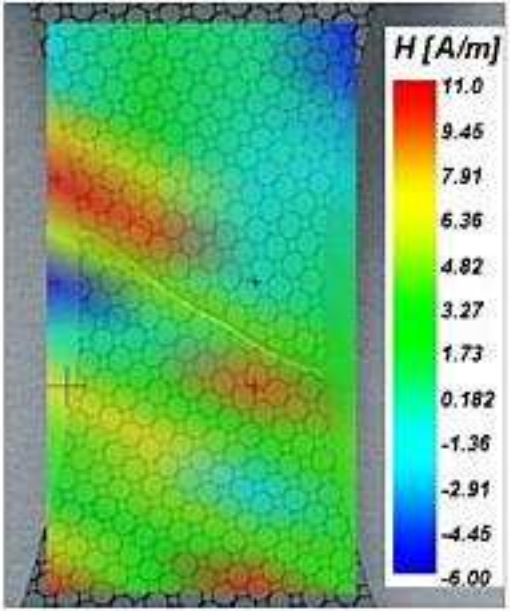




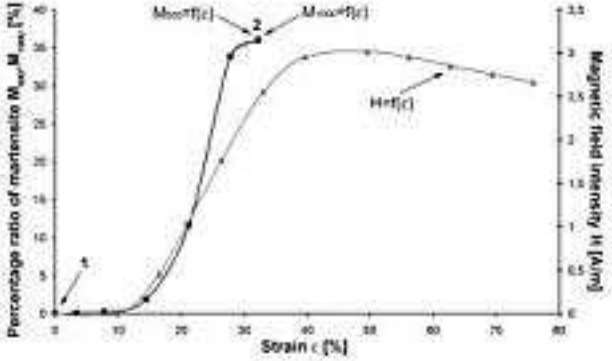
The magnetovision image of the Kirsch specimen under load

SMM MEASUREMENT
FERROMAGNETIC MATERIAL TESTS

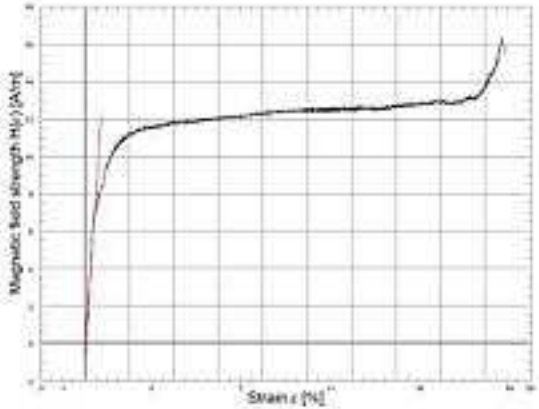




SMM MEASUREMENT
MAGNETORESISTOR SENSOR SYSTEM



Results using austenic foils (shape memory alloy)



Results using ferromagnetic foils

Magnetoresistors as magnetic sensors

CONCLUSIONS

- Experimental stand and measurement methods were created to examine damping in chosen Smart Magnetic Materials under simultaneous mechanical and magnetic loads.
- Damping in MRF, MRC, MRE and GMM materials was determined what enabled identification of constitutive equations.