Viscoplastic deformation of magnethoreological solids

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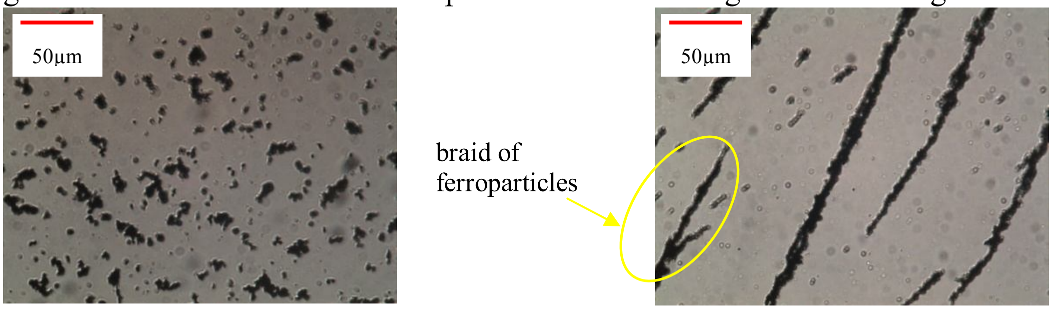
1. Introduction

The microsized (~10μm) ferroelements build the structure of magenthoreological (MR) fluid. This two phase material in neutral state behaves as a fluid but in magnetic field becomes a solid and has properties of elasto-viscoplastic material. This is due to the skeleton made by ferrolements connected into braids. The aim of the paper is to identify the physical mechanisms of deformation of such a structure with use of own set up for *in situ* microscopic observations.

2. The rearregment of the ferroelements

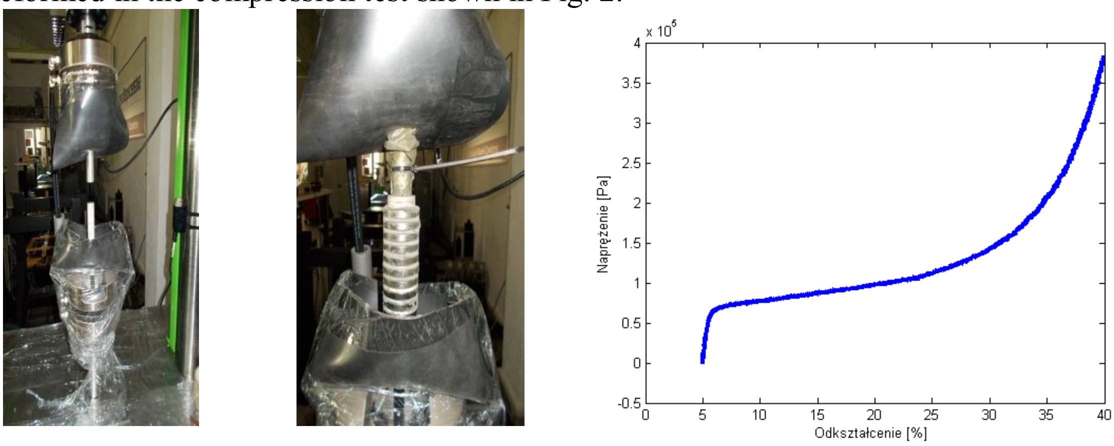
Magneto active ferroelements are the particles connected together in the magnetic field.



a) b)

Fig. 1: The ferroelements in a neutral state (a) and under the influence of magnetic field (b).

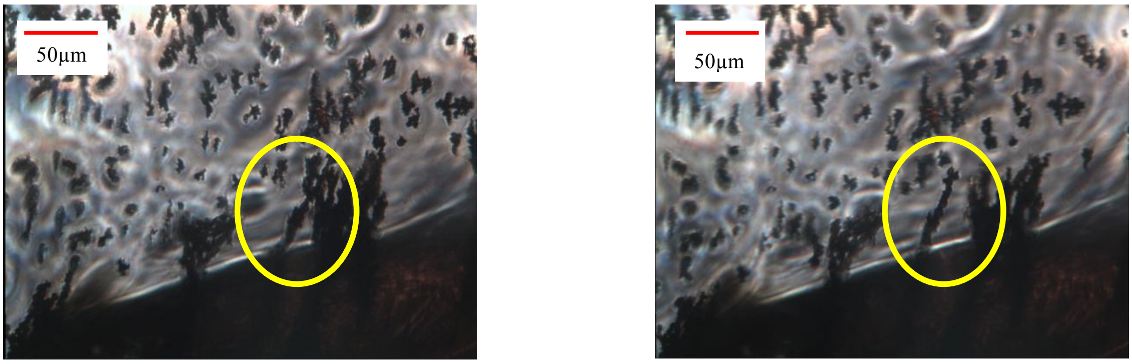
The particles are immersed in the carrying fluid (e.g oil) and they are connected together if the magnetic field is strong enough. The specimens with the structure created by magnetic field can be deformed in the compression test shown in Fig. 2.



a) b) c)

Fig. 2: The MR fluid during the compression test (a), magnets and the specimen placed in set up (b) and an example of the results (c)

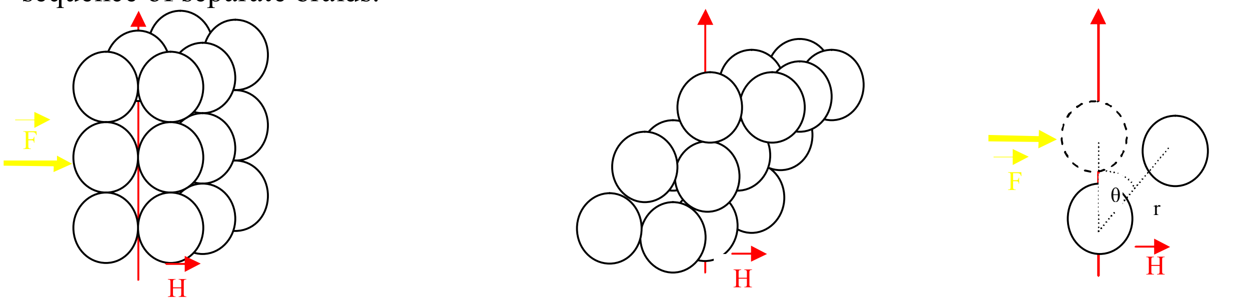
The MR fluid structure can be deformed inside the rubber hose placed inside concentric magnetic field. The investigation are presented on Fig. 2 c).



a) b)

Figure 3: The deformation mechanism of the structure of ferroelements: a) position of the observed braid, (b) picture of the separated braid due to deformation of MR volume

The presented in the Fig 3 pictures show the rearregment of the structure during deformation process. In case of influence of external force, the braid of ferroelements is ripped off the group. The deformation of the structure can be described by analogy as shear banding mechanism that is observed in metallic solids [1]. In our case, the structure is deformed in course of taking off the sequence of separate braids.



The rearregment of ferrorelements under the external force tends to swap the neighboring element. The particle is shifted and produce shear angle is increasing. The interaction energy of two particles is given as follows [2]:

$$E_{12} = \frac{|m^2|(1 - 3cos^2\theta)}{4\pi\mu_1\mu_0 r^3}$$

where m is mass of the particle, θ corresponds to the angle of shear, r denotes distance between particles and μ_1 is relative permeability. The shift of a single ferroelement produces the migration of the braid.

3. Conclusions

The presented experimental observations make a basis for the formulation of theoretical descriptopn of elastic-viscoplastic deformation of MR fluids under the influence of magnetic field.

4. References

[1] R.B. Pęcherski, Macroscopic effects of micro-shear banding in plasticity of metals, *Acta Mechanica*, 131, 203-224, [1998].

[2] Mark R. Jolly, J. David Carlson, Beth C. Munoz, A model of the behaviour of magnetorheological materials, *Smart Mater. Struct. 5* 607-614, 1996.