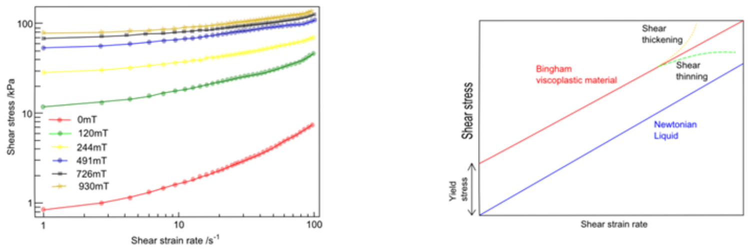
The magnetorheological materials belong to innovative materials due to the functional part, which under influence of the magnetic field can change the state - from fluid to solid state. They can be used in the devices responsible for active dumping of vibrations and the reduction of the effects of impact. There is the necessity to evaluate the constitutive equations and develope numerical simulations to understand better material behaviour in different loading conditions.

The aim of the project is to investigate the behaviour of MR materials under fast dynamic loads and create the new constitutive model of MR material which will be identified and verified by experimental investigations and numerical calculations. To the basic research belong the extension of viscoplasticity Perzyna model to account for the effects of magnetic field strength. Also the studies of new physical mechanisms responsible for dependency of the dynamic yield strength on strain rate in variable magnetic field have fundamental character. The motivation for proposed investigations gives the common application of linear Bingahm model [3], which is not adequate for the description of magnthoreological materials in high strain rates.

$$\tau = \tau_{0H}(H) + \mu\dot{\gamma} \qquad 1)$$

Equation (1) pressents the Bingham model, where: τ shear stress , τ_{0H} quasi-static yield strength under influence of magnetic field H, μ viscosity parameter, $\dot{\gamma}$ shear strain rate

The MR fluid is a material, in which ferroelemetns are stuck together by the magnetic field. This process under fast dynamic loads produces nonlinear relation: dynamic yield strength – strain rate, what can be seen in Fig. 1, [4-5]



a) b)

Figure 1: a) results of experiment [4] and b) theoretical issue [5],

Fig 1a presents the results of dynamical shear tests for magnetorheological gel which consist 30%.of ferroelements.. Fig 1b shows the theoretical behaviuor of viscoplatic material. To describe the behaviour of MR fluid the modified Perzyna viscoplasticity model [6] will be proposed.

The influence of the magnetic field effect is suggested in the form:

$$\dot{e}_{ij} = \frac{1}{2G(H)}\dot{s}_{ij} + \gamma(H)\left\langle \Phi\left(\frac{\sqrt{J_2}}{\varkappa(H)} - 1\right)\right\rangle \frac{s_{ij}}{\sqrt{J_2}} \qquad 2)$$

Where: Φ is nonlinear excess stress function:

$$\langle\Phi\rangle = \begin{cases} \Phi, & \sigma > f(\varepsilon) \\ 0, & \sigma \leq f(\varepsilon) \end{cases}$$

$\sigma = f(\varepsilon)$ material characteristic for quasi-static tension test, ε total nominal strain, $2G(H)$ elastic shear modulus in magnetic field H, $\gamma(H)$ viscosity parameter in magnetic field H, $\varkappa(H)$ is quasi - static yield stress in magnetic field H, s_{ij} deviator of stress tensor $\dot{e}_{ij}$ deviator of strain rate, J_2 second invariant of stress deviator.

The experimental identification of magneto-viscoplatic Perzyna model will be made with use of the specially prepared for testing of MR fluids laboratory set up. The designed set up is based on split Hopkinson pressure bar [7-8, 14-15] with special grip for MR fluid. In the container it will be placed fluid which can change the properties under influence of magnetic field produced by coils.

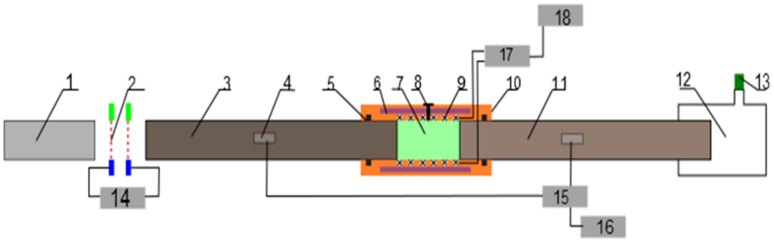


Figure 2:The modified split Hopkinson pressure bar with the grip for MR fluid: 1) striker, 2) sensors to measure velocity of striker, 3) incident bar, 4) strain gauges, 5) seal, 6) water cooling for coils, 7) MR fluid, 8) infusion, 9) coils, 10) sleeve, 11) transmitter bar, 12) gas accumulator, 13)valve, 14) photo diode gates, 15) signal amplifier, 16) data acquisition system, 17) power supply for coils, 18) signal generator for coils controls;

The strength machine Instron with specially prepared grip for MR fluid and electromagnetic coils will be used for performing quasi-static tests.

Based on the results from dynamic and quasi-static tests the modified Perzyna viscoplasticity model will be identified. The numerical simulations of investigated processes will be computed with use of finite element method. During numerical calculations there will be created own UMAT (user subroutine) program, which will be implemented in the commercial program ABAQUS.

The fundamental studies of MR fluid under fast dynamic loads accounting for the effects of magnetic field extend the knowledge of functional materials and are helpful in better understanding of the behaviour of such materials from the point of view of material science and mechanics of materials.