# PLATE-PLATE MAGNETORHEOMETRY OF MAGNETORHEOLOGICAL FLUIDS – PROGRESS AND CHALLENGES

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Magnetorheological Fluid (MRF) denotes a concentrated suspension of ferromagnetic particles in low viscosity oil. These smart materials are used in automotive vibration damping or clutches and brakes. Submitted to a magnetic field, the magnetised particles form string-like structures parallel to the field lines, thus causing a distinct increase of the suspension yield stress with increasing magnetic flux density. Rheological characterisation is achieved by plate-plate magnetorheometry, the magnetic field being perpendicular to the plane of shear. Starting from the commercial magnetocell MRD 180/1T (Physica/Anton Paar [1]), various modifications were necessary to provide reliable data as required for the design of MR devices over a wide range of magnetic flux densities and shear rates.

Since the transmittable shear stresses also depend on the type of wall material, magnetocell versions for nonmagnetic and also ferromagnetic plates were introduced [2]. The true magnetic flux density in the MRF is determined from the signal of a Hall probe, located in an air gap close to the MRF. Calibration factors stem from validated FEM simulations using Maxwell®2D [3]. It is important to achieve flat radial flux density profiles in the plate-plate gap to prevent particle migration towards the rim, which would cause undesirable time effects.

The conventional single gap magnetocell using ferromagnetic plates (Fig. 1) covers the shear rate range below 1000 $s^{-1}$, while the maximum magnetic flux density is higher than 1 Tesla. At these conditions, a typical Basonetic® MRF, containing 90% by weight Carbonyl Iron Powder (CIP), transmits a shear stress of more than 100 kPa. The concomitant normal force, corrected for magnetostatic forces on the ferromagnetic rotor, is as high as 50 N for 20 mm plate diameter!

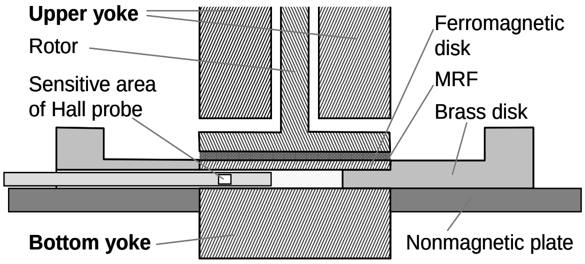


Fig1: Single gap magnetocell (ferromagnetic)

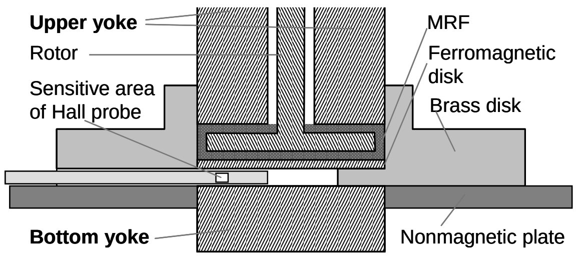


Fig.2: Twin gap magnetocell (ferromagnetic)

This large normal force, increasing the nominal gap height of h = 0.3 mm by roughly 10%, causes a reduction of the actual MRF radius in the gap and also alters the average magnetic flux sensed by the MRF. Pertinent corrections allow taking into account the gap opening effect on the measured shear stress and flux density, respectively. High normal forces may even cause the rheometer to stop because the air bearing limit is met.

In the BASF twin gap magnetocell (Fig.2), MRF normal forces act on both sides of the rotor and compensate each other. Furthermore, the nonmagnetic housing at the rim prevents sample loss at high shear rates and enables shear rates higher than 3000 $s^{-1}$ [4]. A minor drawback is the need to correct for the torque contribution from the additional rim shear gap.

The challenge in magnetorheometry at elevated magnetic flux densities and shear rates remains the control of MRF temperature. The dissipated power per volume is large and heat conductivity in the MRF limited. Furthermore, present magnetocells are not capable to cover the full automotive operation temperature regime, typically -30°C - 150°C, in particular at the low temperatures.

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[2] Laun HM, Gabriel C, Kieburg C "Wall material and roughness effects on transmittable shear stresses of magnetorheological fluids in plate-plate magnetorheometry" Rheol. Acta (2011), in print
[3] Laun HM, Schmidt G, Gabriel C, Kieburg C "Reliable plate-plate MRF magnetorheometry based on validated radial flux density profile simulations" Rheol Acta 47 (2008) 1049-1059
[4] Laun HM, Gabriel C, Kieburg C "Twin gap magnetorheometer using ferromagnetic steel plates – Performance and validation" J. Rheol. 54 (2010) 327-354