Numerical Analysis of Heat Generation in Ball End Magnetorheological Finishing

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Introduction: Magnetorheological finishing (MRF) is the ultra precision surface finishing operation, MRF fluid utilizes the smart and adaptive behaviour of fluid under magnetic field for polishing. In the presence of the magnetic fluid, It becomes stiff due to magnetic dipole alignment and forming chain like structure. In the Ball End Magneto rheological Finishing, due to heat generation by thermal agitation the effect of MRF finishing reduces and this ultimately hampers the process of the precision finishing and density of MR fluid too, which therefore results in instability of MR fluid. Heat generation in the polishing tool occurs because of the magnetic losses and the current losses. In the proposed work, heating due to current and its variation has been numerically analyzed using transformer oil as coolant.

Computational Methods: Numerical analysis was done using COMSOL Multiphysics by coupling of physics.

- Maxwell's equations:

$$\nabla \times \mathbf{H} = 0$$
$$\nabla . \mathbf{B} = 0$$

- Momentum equation :

$$\rho(\mathbf{u}.\nabla)\mathbf{u} = \nabla\left[-p\mathbf{I} + \mu(\nabla\mathbf{u} + (\nabla u)^T - \frac{2}{3}\mu(\nabla.\mathbf{u})\mathbf{I}\right] + F$$

- Amperes law:

$$\nabla \times (\mu_0^{-1}\mu_r^{-1}\mathbf{B}) - \sigma v \times \mathbf{B} = \mathbf{J}_e$$

- Multi-turn Coil:

$$\mathbf{J}_e = \frac{NI_{coil}}{A} e_{coil}$$

- Heat Transfer In Solid:

$$\rho C_p \mathbf{u} \cdot \nabla T = \nabla \cdot (k\nabla T) + Q$$

Results & Discussions: In this experiment, It was concluded that without use of coolant fluid, the temperature of the polishing tool reaches to 318K and with use of the coolant it is up to 295K. So, it is found that use of coolant reduces agitation of MR fluid.

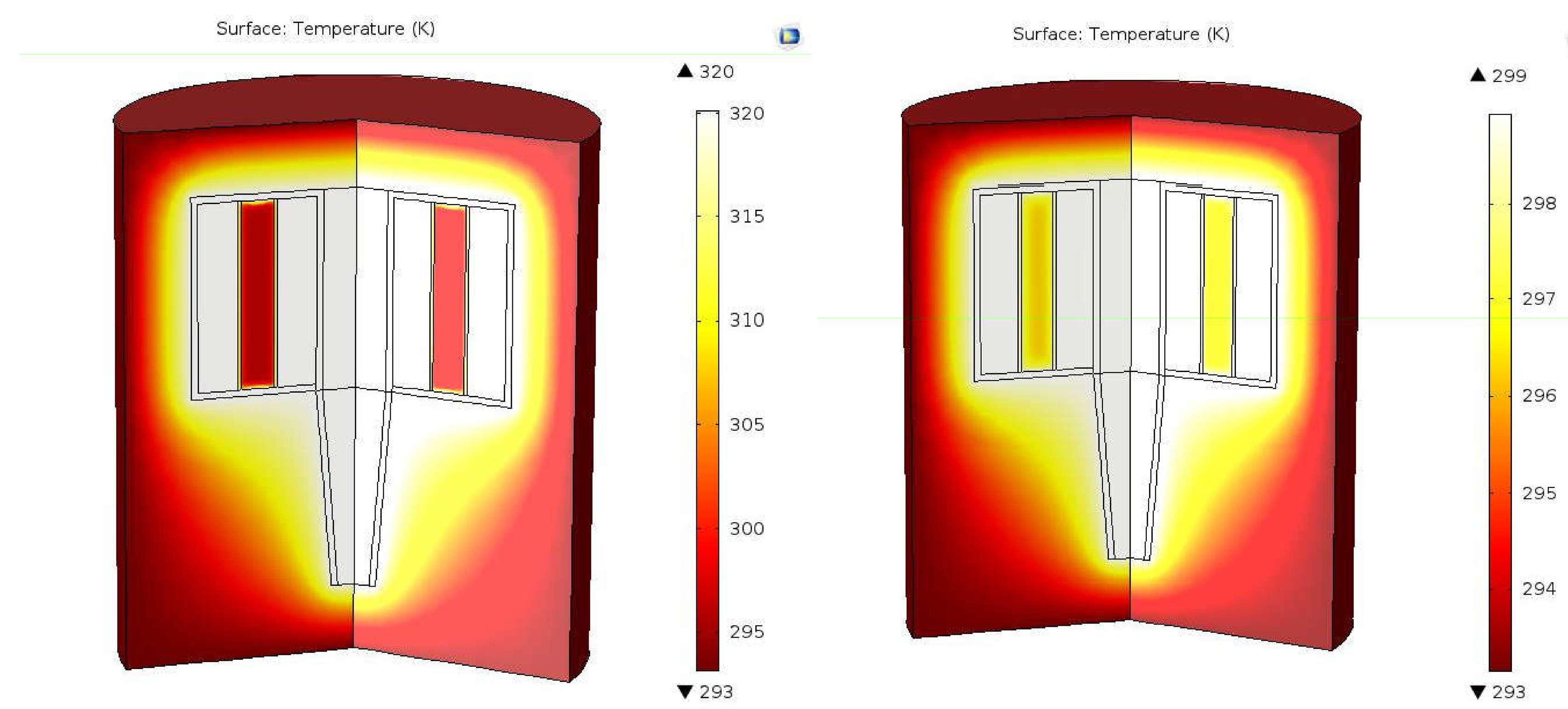

Figure 3. Temperature w/o and With coolant from simulation

Calculating the different values of temperature at wall and fluid, the heat transfer coefficient is calculated at the both conditions.

Table 1. Output parameters

S.No.	Coolant	Temperature at walls (K)	Temperature of Fluid (K)	Heat Transfer Coefficient (W/m^2-K)
1.	Air	312.67	306.4	143.49
2.	Oil	528.51	465.96	28.39

References:

1. Peterson GP, Li CH. Advance Heat Transfer 2006; 39: 275
2. H.Garg, V.S.Negi, A.S.Kharola, R.Sharma, "Effect of Magnetic Field on MR-Fluid in Ball End Magnetorheological Finishing, "COMSOL Conference 2014".
3. A.Roszkowski et al., M.Bogdan, W.Skoczynski, B.Marek, Testing viscosity of MR-fluid in Magnetic field, *Measurment Science review*, 8, 3 (2008).