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Main Factors Affecting the Performance of Magneto-Rheological Clutches

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By

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STATEMENT

This thesis is submitted as partial fulfillment of M.Sc. degree in Mechanical Engineering, Faculty of Engineering, Ain Shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or qualification at any other scientific entity.

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Thesis Summary

Magneto rheological fluids were first presented in 1949, and recently in 1990's was developed the first MR based device. The magneto rheological fluid is usually denoted by MR fluid or MRF. This fluid belongs to the smart materials family which can be synthesized. MR fluid's viscosity is varied by applying external magnetic field; it can vary from the liquid state to solid or gel like state. MR fluid is mainly consists of carbonyl iron particles (CIP) suspended in a carrier liquid as oils or aqueous liquid. Some additives – as grease – are added to enhance the CIP suspension without affecting the properties or performance of the MR.

In recent two decades, the researchers are more concerned in developing the MR devices and applications as clutches, brakes, dampers, fine machining, etc. These applications made the MR fluids promising in the various industries as automotive, petroleum, and machine tools.

In this study, we are concerned to study the factors affecting the performance of MR clutch. The factors studied were particle size, concentration of CIP and applied magnetic field. For this purpose a test rig was designed and manufactured. The MR clutch design involved four stages to obtain steady and reasonable operation.

It was concerned not only to study the effects of the three factors only, but also if there is interaction between the factors or not. For this purpose we used the factorial design and ANOVA to design the experiment test runs and to analyze the obtained results. The levels of the factors are selected based on previous studies; the magnetic field density (0.2 and 0.4 Tesla), CIP concentration (50% and 86%), and finally the particle size (2.2 and 86 microns). As the previous studies did not study the effect of large particles (which is 86 microns in our study), we involved this size in the study as this is the most available in the local market and get its effect on the MR response.

Finally, the results showed that there is a significant interaction between the particle size and the concentration of the CIP and also the all factors have significant effect on the MR shear strength. But the usage of large particle did not enhance the MR performance.

It is recommended to make further researches on the MR clutch performance taking into considerations the particle size versus the concentration and also, the usage of higher magnetic fields to enhance the transmitted torque by the MR clutch to be applicable in automotive industries. Also, studies may involve changing the gap size and the shape and texture of the clutch plate.

Key Words:

Magnetorheological fluids, MR fluids, MR clutch, iron particle size, MR shear mode

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Abstract

The magneto rheological fluid is denoted by MR fluid or MRF. MR fluid viscosity can be varied by applying external magnetic field. MR fluid consists of carbonyl iron particles (CIP) suspended in a carrier liquid. In this study, we are concerned to study the effect of each factor and the interaction between them on the performance of MR clutch which are particle size, concentration of CIP and applied magnetic field. The study involved using particle size (86 microns), as it is the most available in the local market. The study included execution of MR clutch to obtain results. Finally, the results showed that there is a significant interaction between the particle size and the concentration of the CIP and also all factors have significant effect on the MR shear strength. But the usage of large particle did not enhance the MR performance.

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List of Abbreviations

MRF	Magneto-rheological fluid
ERF	Electro-rheological fluid
T	Transmitted torque (N.m)
μ	Coefficient of friction
F_a	Axial force acting on the clutch plate (N)
D_m	Mean diameter of the clutch (m)
n	Number of contact surfaces in clutch
τ	Total yield shear strength of MR fluid (Pa)
τ_{MR}	Yield stress due to applied magnetic field (Pa)
μ_p	The no field plastic viscosity of MR fluid (Pa.s)
$\dot{\gamma}$	Shear rate (s^{-1})
A	The working surface area of MR clutch (m^2)
N	Number of gaps filled with MR fluid
r	Radial distance from the center (m)
g	Gap width filled with MR fluid (mm)
ω	Angular velocity of the driving disc (rad/s)
T_{MR}	Torque transmitted by MR effect (N.m)