STUDY OF MAGNETO RHEOLOGICAL GRIPPER IN BORE-WELL RESCUE OPERATION

D.LAVANYA, K.SARAN, S.VIGNESH, D.RAMESH

Abstract— **This paper deals with the optimization of bore-well rescue operation by introducing MRFT (Magneto-Rheological Fluid Technology) in already designed bore-well rescue robot. The proposal is given such that the already existing mechanical gripper was replaced with magneto rheological gripper. Main objective of this paper is to avoid major injury and to assure the safety of trapped baby while rescuing the baby in bore-well with the help of MRF. Magneto rheological fluid (MRF) is a smart fluid whose properties can be controlled with the help of metal particles and magnetic field. These fluids have the ability to transmit force in a controlled manner with the help of magnetic field, thus improving their performance especially in areas where controlled fluid motion is required. Some applications of magneto rheological fluid technology are in dampers, brakes, journal bearings, pneumatic artificial muscles, optics finishing, fluid clutches, aerospace etc. where we give electrical inputs and get the mechanical output comparatively faster and in a controlled manner. Thus the paper explains the basic nature of magneto rheological fluid and its application in our proposed bore-well rescue robot gripper.**

Index Terms— **Rheological fluid, MR properties, bore-well robot, gripper.**

I. INTRODUCTION

In the present era, the advancement in the field of automation along with the mechanical design has a great impact on the society. There were so many child deaths due to the open Bore-wells. The children fell into the open Bore-well and the rescue operation was almost end with failure. The current conventional method was very difficult because of costly process as well as more time consuming even in terms of days. The project of design and analysis of a "Bore-well rescue robot" (to rescue a trapped child/object from Bore-well) embedded with computerized control is done. This project includes series of process development from hand drawn sketches to computer generated design followed by analysis. In this paper the proposal is given such that the already existing mechanical gripper was replaced with magneto rheological gripper. The problem of mud and dust over child/object was taken into consideration and a vacuum pump system will be implemented in this proposal project. In addition to this, modern equipment's were implemented for various parts of the machine, since the machine performs a life rescue activity. The light weight servo motors were implemented for the gripper operations. The essential components of MRFT are MR fluid and a magnetic field to control the viscous property of the fluid. The basic principle of MRFT is that very small suspended particles having magnetizing properties are introduced in the base fluid. When a magnetic fluid is applied to this fluid, these particles form a chain aligned in the direction of the field which creates a resistance to the fluid flow. Resulting, an increase in the fluid viscosity takes place. Thus in the presence of magnetic field the MR fluid converts into a semi solid with an increase in its yield strength. This work phenomenon takes only milliseconds to occur. MR fluids thus act similar to Bingham fluids used in many engineering applications. In the absence of magnetic field, the MR fluid behaves like newtanion fluids.

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II. LITERATURE REVIEW

Authors name	Title of the paper	Published journal/ conference	Objective of paper	Drawbacks
Prof.Sridhar Palaniswamy Karpagam University, Coimbatore.	LIFE SAVING MACHINE	Inter disciplinary Research and Development Conference at Thailand, **June 2011.**	The proposed a system that will easily rescue the baby within two hours of time without any major injury.	it has practical difficulties to rescue the baby
Prof.J.P.Ajith Kumar, John Jose Pattery, Jittu Varghese Kurian, Noble K John, Amal Jyoti College of Engineering, Kerala.	ROBOT FOR BOREWELL RESCUE	Report in **2012.**	The prototype consists of 4 separate mechanisms driven by motors and an air compressor is operated to pump air to the bladder attached to the end of the lifting rod through an air tube. bladder provides a safe seating to the child	It may cause major injury to the victim
Prof.Marlon Jones Louis, K.Saran, S.Vignesh GCE, Salem	BORE WELL RESCUE ROBOT	International Journal of Research in Aeronautical and Mechanical Engineering in **APRIL, 2014.**	The light weight servo motors were implemented for the machine operations. A safety balloon was introduced in order to provide extra safety	Mechanical hand is not flexible. And there may be a chance of slip while rescue the baby
G. Nithin, G.Gowtham, G.Venkatachalam, S.Narayanan VIT University	DESIGN AND SIMULATION OF BORE WELL RESCUE ROBOT –ADVANCED	ARPN Journal of Engineering and Applied Science in **May 2014.**	This Project deals with extreme Safe Handling of the victim. The handling system is made in such a way that the baby/victim never gets hurt and the robot itself provides some pretreatment to make the baby survive till the end of operation.	This robot require large gap between the side of bore-well and trapped baby

This project proposal aims to overcome above mentioned difficulties by implementing Magneto-Rheological gripper in the bore-well rescue robot.

III. MR FLUID COMPONENTS

Magneto rheological (MR) fluids are basically non-colloidal suspensions of micro sized magnetisable particles in an inert base fluid along with some additives. A magneto rheological fluid (MR fluid) is a type of smart fluid in a carrier fluid, usually a type of oil. When subjected to a magnetic field, the fluid greatly increases its apparent viscosity, to the point of becoming a viscoelastic solid.

Thus there are basically three components in an MR fluid.

A. Base fluid,
B. Metal particles and
C. Stabilizing additives.

A. Base fluid

The base fluid is an inert or non magnetic carrier fluid in which the metal particles are suspended. The base fluid should have natural lubrication and damping features. For better implementation of MRF technology the base fluid should have a low viscosity and it should not vary with temperature. This is necessary so that MRF effect i.e. variation of viscosity due to magnetic field becomes dominant as compared to the natural viscosity variation. Due to the presence of suspended particles base fluid becomes thicker. Commonly used base fluids are hydrocarbon oils, mineral oils and Silicon oils.

B. Metal particles

For proper utilization of this technology we need such type of particles which can magnetized easily and quickly therefore we use metal particles. Metal particles used in the MR- technology are very small. Size of the particle is approximate of the order of 1µm to 7µm. Commonly used metal particles are carbonyl iron, powder iron and iron cobalt alloys. Metal particles of these materials have the property to achieve high magnetic saturation due to which they are able to form a strong magnetizing chain. The concentration of magnetic particles in base fluid can go up to 50%. (approx.). 20 to 40 percent of the fluid is made of these soft iron particles that are just 3 to 5 micrometers in diameter. A package of dry carbonyl iron particles looks like black flour because the particles are so fine.

C. Additives

It is necessary to add certain additives to MR fluid for controlling its properties. These additives include stabilizers and surfactants [7]. Surfactants serve to decrease the rate of settling of the metal particles. While the functions of additives are to control the viscosity of the fluid, maintain friction between the metal particles and to reduce the rate of thickening of the fluid due to long term use of the fluid thus additives also increase the life of the MR fluid. Commonly used additives are ferrous oleate and lithium stearate. All the three components of an MR fluid define its magneto rheological behavior. Changing any one component will result in change in the Rheological and magneto rheological properties of the MR fluid. An optimum combination of all the three components is necessary to achieve the desirable properties of an MR fluid.

IV. WORKING PRINCIPLE OF MR FLUID TECHNOLOGY

MR fluid is a smart fluid whose properties can be controlled in the presence of magnetic field. In the absence of magnetic field, the rheological properties of the MR fluid are similar to that of base fluid. In the absence of magnetic field, these metal particles align themselves along the direction of flow.

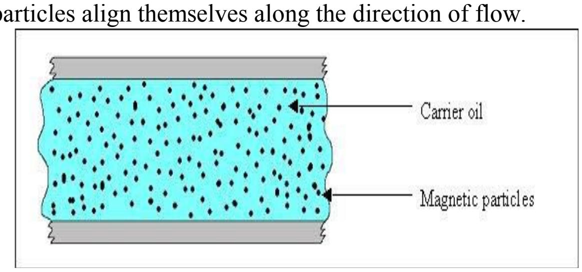


Fig 1. MR fluid in the absence of magnetic field.

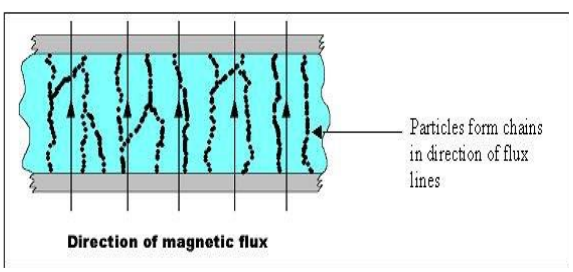


Fig 2. MR fluid in the presence of magnetic field

However when a magnetic field is applied each metal particles becomes a dipole aligning itself along the direction of magnetic field. Thus a chain like structure is formed along the line of magnetic flux which offers mechanical resistance to the flow resulting in an increase in the viscosity of fluid .This mechanical resistance created due to the chain column imparts yield strength to the fluid, making it stiff like a semi-solid. This stiffness and hence the yield strength depends on the strength of the magnetic field and also the quality and quantity of metal particles. The MR effect is reversible. When the magnetic field is removed the fluid returns to its original condition. The MR fluids with their controllable properties are found to be useful in the implementation of smart fluid concept. Where the fluid motion is controlled by varying its viscosity with the help of magnetization .The simpleness of MR fluid technology, the controllability and the quick response of the rheological properties makes it a smart fluid with application areas where fluid motion is controlled by varying the viscosity.

V. RHEOLOGY OF THE MR FLUID

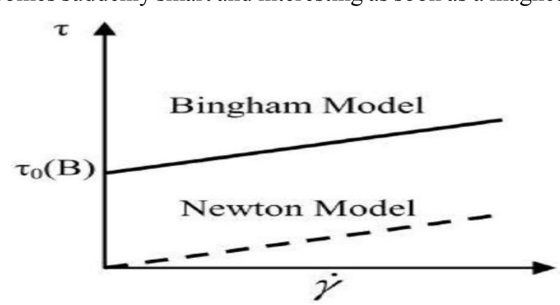
Rheology is the study of the deformation and the flow of the liquid. Basically three factors viscosity, shear stress and rate of strain are considered in the study of flow and deformation. In most of the fluid applications viscosity is an important property. In case of general fluids, viscosity changes with change in other physical properties such as shear stress, temperature etc. In most applications these physical properties cannot be controlled as they are governed by the working environment and hence the viscosity also cannot be controlled. In the case of MR fluid, the viscosity can be controlled with the help of magnetic field. Rheologically the MR fluid can change from a liquid state to a solid state by varying the strength of the magnetic field and this change is reversible.

VI. PROPERTIES OF MAGNETORHEOLOGICAL FLUIDS

Magneto rheological (MR) fluids are smart and controllable materials, even though at the first glance they do not look so impressive. They are a non colloidal mixture of ferromagnetic particles randomly dispersed in oil or water, plus some surfactants useful to avoid the settling of the suspended particles. The overall aspect is like a greasy quite heavy mud, since MR fluids density is more than three times the density of water. This material

Fig 3. Bingham model of MR fluid

becomes suddenly smart and interesting as soon as a magnetic



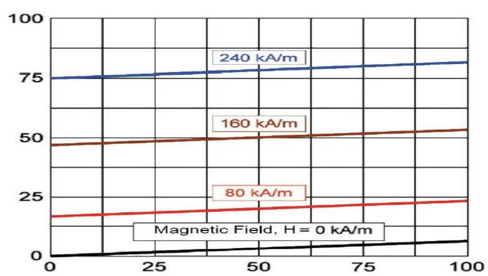
field passes through it. The ferromagnetic particles feel the induction field and acquire a magnetic bipolar, then they move and redesign their arrangement start to flow and to form chains and linear structures. These microscopic chains have the macroscopic effect to change the apparent viscosity of the fluid. The size of the particles is around 10 micron. While the applications of MR fluids are relevant for engineers and can be used in many damping devices

The yield shear stress is the main figure of merit of a MR fluid and derives from the non Newtonian behavior of these fluids. The MR fluid behaves following so called Bingham law, which means that it exhibits a non-zero shear stress value for a zero shear rate, behaving more like a solid than like a liquid. The value of the shear stress at no shear rate is called yield stress of the MR fluid and is controlled by the applied magnetic field. Larger the field, higher the yield stress. The higher the yield stress the higher the force the material can withstand without flowing. Bearing a load is possible only because MR fluids can modify their aggregations states changing from a viscous free-flow liquid to a quasi solid state.

Fig 4. effect of the magnetic field on the yield stress.

In order to exploit MR fluids properties there are three main way envisioned in current engineering applications:

a) Flow mode



b) Shear mode

c) Squeeze mode

Flow mode, also called valve mode, exploits the fluid between two fixed walls, the magnetic field is normal to the flow directions and is typical for linear damper applications. Shear mode is mainly used in rotary application such as brakes and clutches and the fluid is constrained between two walls which are in relative motion with the magnetic field normal to the wall direction. Squeeze mode is used mainly for bearing applications, is able to provide high forces and low displacements having the magnetic field normal to walls directions. In all the above mentioned cases the working principle is the same. The applied magnetic field regulates the yield stress of the fluid and changes its apparent viscosity. So the amount of dissipated energy of the system is simply controllable by acting on the coil current and the system can provide semi-active behavior

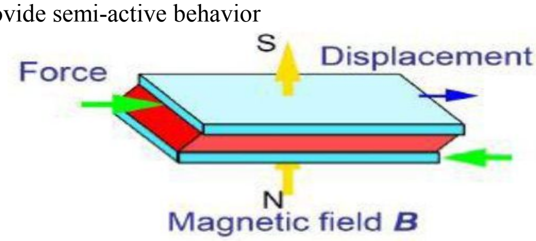
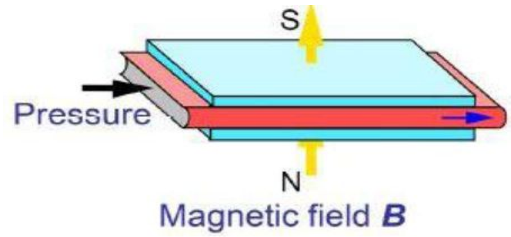


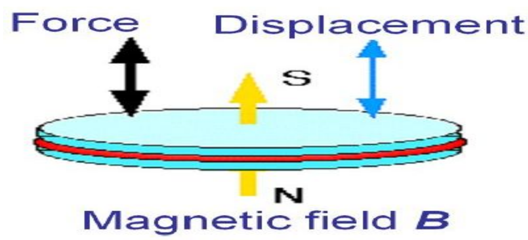
Fig 5. Flow mode

Fig 6.: Shear mode

Fig 7: Squeeze mode.



VII. APPLICATIONS OF MAGNETORHEOLOGICAL FLUIDS



The sudden change in the MR behavior (few milliseconds) due to the magnetic field application makes this material attractive for damping and dissipative devices. The MR fluids can be used to build integral, silent, quick mechanical systems enhanced by means of electronic controls. The MR applications in the field of are semi-active control devices which offer the flexibility and versatility of the active systems and the reliability of the passive ones. The main applications are damper, braking, clutch, prosthetic legs etc.

The main application exploits the MR fluid in shear mode to realize a sort of hydraulic brakes and clutches with MR fluids. The aim is to obtain a precise control of the braking torque (in case of brakes) or transmitted torque (in case of clutches) with no moving parts by simply varying the current in the coils. In braking the magnetic flux path passes through the chassis and the rotating disk and the fluid is sheared between these elements. The braking force depends on the yield stress of the fluid making the system controllable. The MR based clutch is ideally described by Fig., the fluid is between the input disk and the output disk and the amount of transmitted torque is proportional to the yield stress of the fluid. No moving part is used to change the transmitted torque and the torque value can be smoothly controlled through the coil current. Even though multidisc applications can be used to increase the output torque, the typical application of rotary MR fluid devices is in the high precision and low power range. For example the Rheoknee, developed by Ossur is the first prosthetic knee which allows the amputee to have a normal leg motion even in case of stairs. The MR knee exhibits a very low torque when is not active enabling the leg to move forward freely and in a few millisecond the MR is able to carry all the human weight to complete the step. The overall performance is outstanding and shows how the smartness of MR fluid can improve human condition.

VIII. PROPOSED APPLICATION OF MR FLUID

The MR fluid used has

Base fluid : castor oil.
Metal particle : Carbonyl iron particle.
Additive : Aerosol.
Mode : Shear mode.

The iron particle is around 3 to 10 microns. It is spherical shaped which will prolong the time of settling down of iron particle. The additive also helps in reducing settling time. The shear mode is chosen since the shearing action during rescue will be predominant.
The magneto Rheological fluid was used in the gripper attached to the bore-well rescue robot.

We used Pro-e wildfire 5 software to draw the complete 3D model of our rescue robot. The hand portion was modified to accommodate MR fluid.

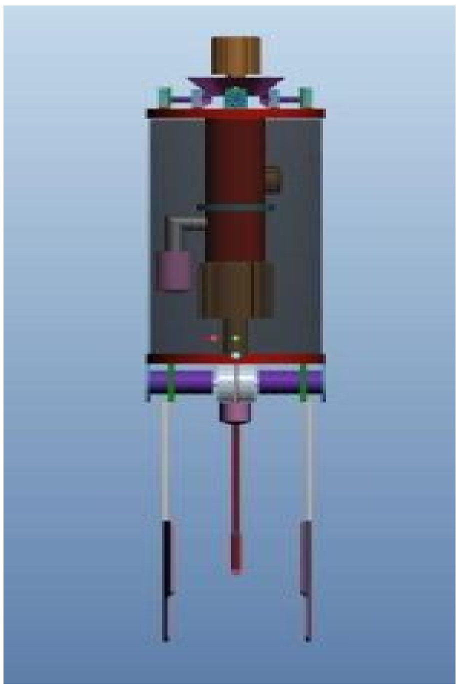


Fig 8.

Rescue robot with ordinary hands

The hand was covered with rubber pouch. The pouch was filled with MR fluid. The electro magnet was attached to the back side of gripper to actuate the MR fluid whenever required.

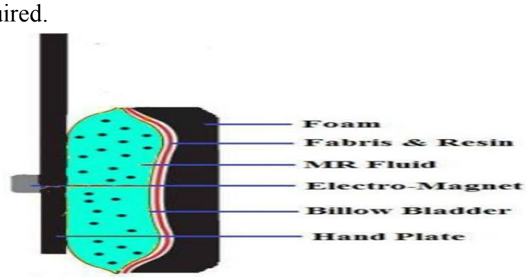
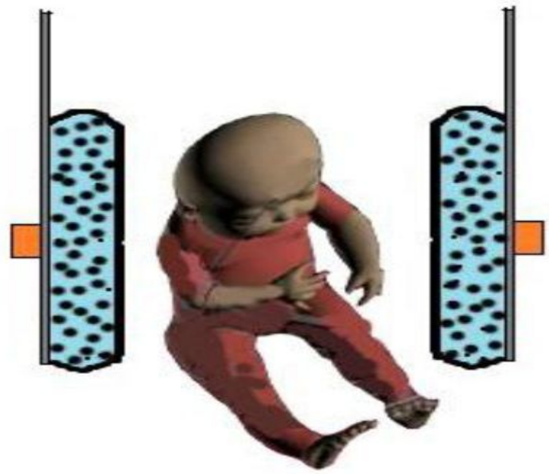


Fig 9. Modified hand with pouch

IX. PROCEDURE FOR USING MRF GRIPPER

The detailed procedure steps to rescue the baby/object are explained in BORE-WELL RESCUE ROBOT journal published in IJRAME. Here only concentrated on the MRF GRIPPER handling procedure.
Step 1:
Inserting the MRF gripper using servo motor control such a way that the baby is in middle of the gripper hands. Initially the pouches have MR fluid without magnetic field is in liquid form. So it is easy to inserting the gripper hand without damage the baby skin. Linear motion of the gripper is controlled by servo motor separately.

Fig 10: Initial posture



Step 2:
After inserting the gripper in correct position, grasp the baby by gripper hand controlled separately with the help of servo motor. Till now it is in the liquid form, so the flexible pouch which has MRF deformed with respect to the baby position. The pouch lining was connected with pressure sensor to know the grasping pressure while rescue the baby. The grasping pressure maintained by LABVIEW software.

Fig 11: Grasped posture without magnetic field

Step 3:
After grasping, the electro magnet activated by using computer control. Now the magnetic field created, so the iron particles are arranged as a chain. It makes the MRF liquid state into the semi-solid state. This phase change increases the friction between the baby and billow pouch. This reduces the slip of the baby from gripper.

Fig 12: Grasped posture with magnetic field

X. MECHANICAL GRIPPER Vs MRF GRIPPER

PROPERTY	MECHANICAL GRIPPER	MRF GRIPPER
Friction on contact	Friction between the baby and hand is low. So there may be a chance of slip	After change as a semi solid, the friction will increase. It reduces the slip.
Handling	Not flexible	Flexible
Pressure sensor	Pressure sensing difficult	pressure sensing easy
Accessories	Need not required any extra accessories	Electro-magnet, pouches are required
Thickness of hand	Thickness is slim	High thickness due to pouch system

CONCLUSION

Based on this study, a design of the rescue machine was formulated and so the hand drafted design was created especially for magneto-rheological gripper. The MR fluid has many advantages particularly its grasping tendency and response time. Thus implementing MR gripper surely increases the level of safety during rescue operation. Since it is a life rescue machine, focus on necessary additional components/devices to be included in the machine was mandatory. So, a study on the necessary of such components and selection was carried out based upon requirement and safety.

FUTURE WORKS

The design which is already done is to be modified to adopt the magneto rheological hand and to provide necessary design calculations. The final design will be analyzed to determine structural properties, stresses, strains and other properties. The servo motor power calculation and controlling techniques will be introduced.

A new magneto rheological gripper fluid is to be prepared and tested to determine the response capability of the fluid by using FEMM software. The software and its importance in the project are

CREOPARAMETRIC - 3D Modeling
ANSYS - Simulation
FEMM - MR fluid simulation

To implement obstacle remover technique with the help of a vacuum pump to remove mud and dust over child/object.

REFERENCES

[1] K.Saran, S.Vignesh, Marlon Jones Louis, “bore-well rescue robot,” International journal of research in aeronautical and mechanical engineering, Vol.2 Issue.4,pgs: 61-80.

[2] A.Spaggiari, “Properties and applications of Magneto rheological fluids,” Scilla 2012 - The Italian research on smart materials and MEMS.

[3] R. Turczyn , M. Kciuk , “Preparation and study of model magnetorheological fluids,” Journal of Achievements in Materials and Manufacturing Engineering, Volume 27, Issue 2, April 2008.

[4] Md. Sadak Ali Khan, A.Suresh, N.Seetha Ramaiah, “Analysis of Magneto Rheological Fluid Damper with Various Piston Profiles,” International Journal of Engineering and Advanced Technology (IJEAT), Volume-2, Issue-2, December 2012.

[5] A.Grunwald, A. G. Olabi, “Design of magneto-rheological (MR) valve,” Dublin City University, School of Mechanical and Manufacturing Engineering, Glasnevin, Dublin 9, Ireland.

[6] Deepak Baranwal1, Dr. T.S. Deshmukh, “MR-Fluid Technology and Its Application- A Review,” International Journal of Emerging Technology and Advanced Engineering, Volume 2, Issue 12, December 2012.

[7] Mark R. Jolly, Jonathan W. Bender, J. David Carlson, “Properties and Applications of Commercial Magnetorheological Fluids,” Thomas Lord Research Center Lord Corporation 110 Lord Drive Cary, NC 27511.

[8] Katsuaki Sunakodaa, Hiroshi Sodeyamaa, Norio Iwatab, Hideo Fujitanic and Satsuya Sodab, “Dynamic Characteristics of Magneto-Rheological Fluid Damper,” SPIE’s 7th Annual Int. Symposium on Smart Structures and Materials, 2000

[9] Mahmoud El-Kafafy, Samir M. El-Demerdash, Al-Adl Mohamed Rabeih, “Automotive Ride Comfort Control Using MR Fluid Damper Engineering,” Published Online April 2012 at (http://www.SciRP.org/journal/eng)

[10] Lord Corp. http://www.lord.com/products-and-solutions/magneto-rheological.

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