In the quest for novel domains of S&T exploration, FERROFLUIDS is found to be an exciting area of scientific and technological pursuit with excellent academic interests, research opportunities, developmental challenges, application avenues, device innovation prospects, and business openings etc. In the global scene, monumental work is done in Ferrofluids, their Flow Behavior, Magneto Rheological Fluids, Magneto Rheological Finishing, Electro Rheological Fluids, Magneto-Hydro Dynamics, Magnetic Ionic Liquids and many associated areas of ferrofluids in terms of synthesis, characterization, application areas, device innovation and development. May patents have been filed and good number of commercial activity is also in progress, using the fruits of S&T pursuits in this area.

In India, a number of groups (in academia, R&D laboratories, industry) have been active in R&D in different aspects of ferro-fluids and have done pioneering work. However, for achieving major breakthroughs, it is necessary to combine the expertise of various groups in a harmonious manner to achieve challenging goals. Hence, to optimize the benefits of the R&D groups pursuing the areas of ferrofluids, Department of Science & Technology (DST), Government of India has conducted Brain-Storming Session "**FERRO FLUIDS: S&T & APPLICATIONS**" at the CSIR-Central Scientific Instruments Organisation, Chandigarh. The aims were: a) to identify R&D groups keen to participate in a national coordinated program b) to identify specific areas to be pursued and d) to formulate a road map for this Ferro-Fluid R&D Programme in the country.

About FORTY FOUR delegates have participated in this session, with SIXTEEN Concept Papers submitted, presented & discussion. Based on the deliberations at the session, it was decided that R&D work should be carried out in the following areas: 1) Materials: Synthesis & Characterization; 2) Ferro Fluids: Applications for Energy Sector and 3) Ferro Fluids for Strategic Applications.

Accordingly, project proposals were prepared by the identified groups and forwarded for a preliminary scrutiny by a select committee headed by Prof. Krishan Lal, followed by the groups' interaction with the committee. The project proposals were suitably refined as per suggestions of this interaction and were submitted to DST for funding. DST has scrutinized these project proposals and has sanctioned the following R&D Projects with respective details. In each project, the investigating teams have identified clearly their respective Collaborators, User Agencies, Other Beneficiaries and the Industries involved and finally following projects were supported:

A) Materials: Synthesis & Characterization:

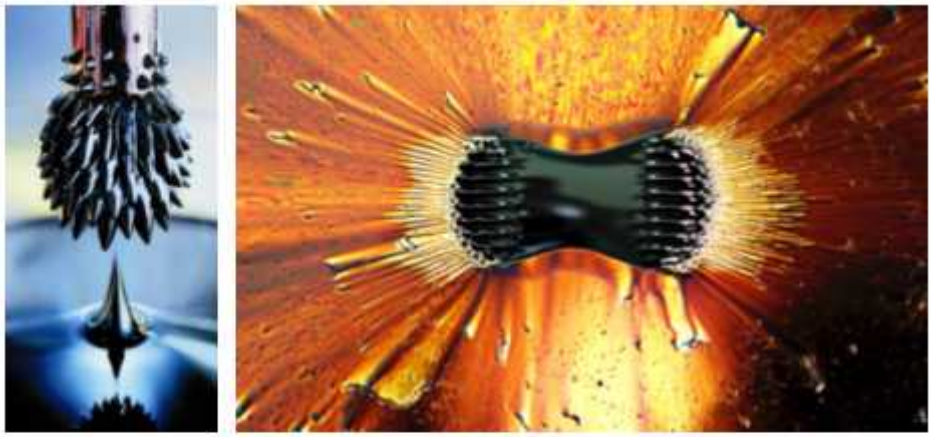
- Ferro Fluids: Science & Technology Application at Charotar University of Science & Technology-CHARUSAT, Gujarat
- Preparation & Characterization of Ferro-Fluids for Energy Conversion Application at CSIR-National Physical Laboratory, New Delhi

B) Ferro Fluids: Applications for Energy Sector:

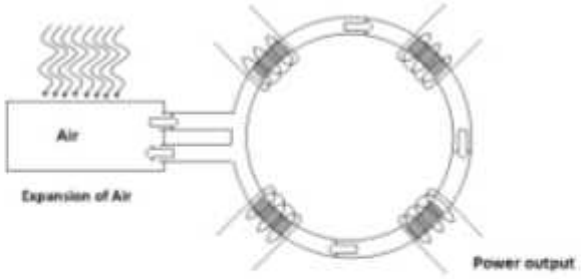
- Development of solar power generator using rare-earth magnets & ferro-fluids at Amity University, Noida

C) Ferro Fluids for Strategic Applications:

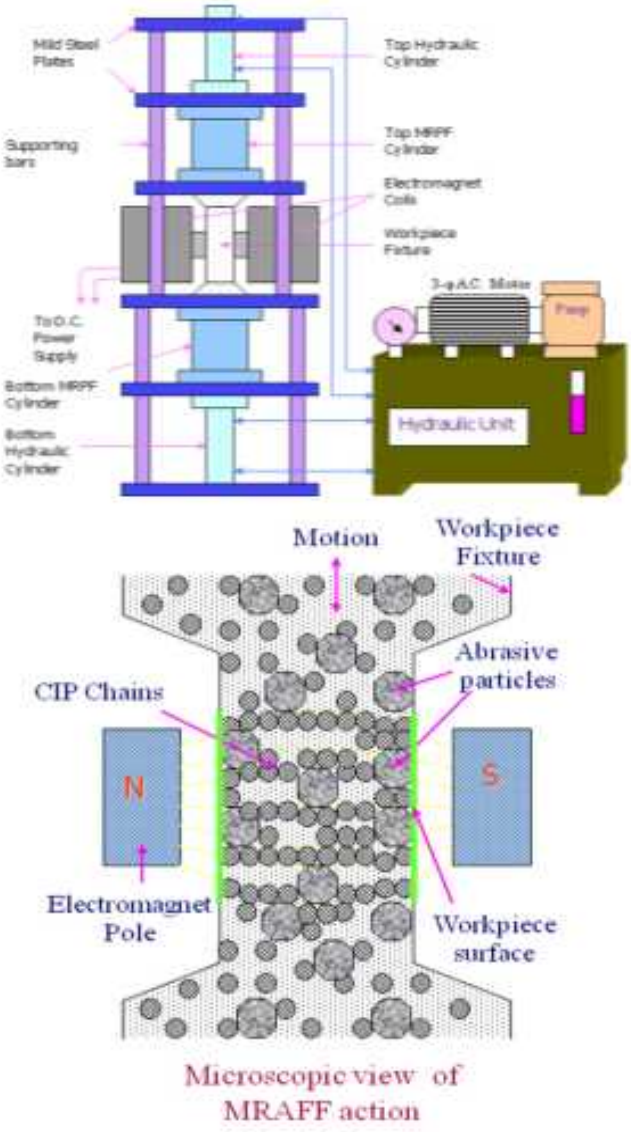
- Exploration of ferro-fluids for strategic applications: Athermalization in advanced optical systems at CSIR-Central Scientific Instruments Organisation, Chandigarh & Bhavnagar University, Gujarat;
- Design and Development of CNC Magneto-Rheological Finishing (MRF) system at Indian Institute of Technology, Delhi
- Exploration of ferro-fluids for magneto-rheological finishing in advanced optical systems with strategic applications at CSIR-Central Scientific Instruments Organisation, Chandigarh & Bhavnagar University, Gujarat .



Ferro Fluid collects near the poles of a powerful magnet



Solar Electric Power Generator using Ferrofluid - Concept



Magnetorheological Abrasive Flow Finishing (MRAFF) Process

A) Ferro Fluid

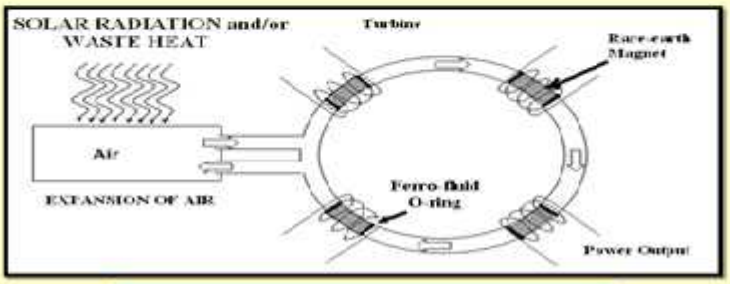
DEVELOPMENT OF SOLAR POWER GENERATOR USING RARE-EARTH MAGNETS AND FERRO FLUIDS

Objectives: — To develop solar power generator using Ferro-Fluids and Rare-Earth Magnets.

Methodology: — To design, fabrication and optimization of various parameters of solar power generator.

Deliverables: A prototype Solar Power Generator using Solar Thermal Energy, Ferro-Fluid and Rare- Earth magnets. This is the new concept and it will provide the different type of power generator using solar energy. The work will also produce the trained manpower in this area of ferro-fluids.

In this project the principal of levitation of the magnets with the help of nano magnetic fluid is used. Using ferro-fluid, the friction between magnet and the walls of the generator circular tubes will become extremely low.. Due to the very small friction the magnets rotate will very high speed with a small pressure of air. The continuous motion of these magnets will be provided with the help of expansion of the air due to solar thermal energy. The continuous motion of the rare earth magnets inside the coils will produce electric power.



Development of Solar Power Generator Using Rare- Earth Magnets and Ferro Fluids

AC to DC Convertor + Electronic Charge Controller

DC Output

Features of prepared ferro-fluid power generator

- Clean Energy
- Efficient
- Safe
- Portable
- Cost Effective

Project Investigators: — Dr. Abhishek Verma, Assistant Professor and Dr. V. K. Jain, Professor, Amity Institute of Renewable and Alternative Energy (AIRAE), Amity University, Sector-125, Noida-201 303, Uttar Pradesh.

B.) FERRO FLUIDS: S&T & APPLICATIONS: Up-scaling of tailor made magnetic fluids & its characterization for different applications: Coolant, Damper, Seal, etc. by Dr. R V Upadhyay, CHARUSAT University, Changa, Gujarat.

The adoption of magnetic fluid for various applications like damper, coolant, etc. are far from being optimized due to the variable performance of magnetic nanoparticles systems especially during large scale production. Herein, we aim to tune a reproducible and potentially scalable magnetic fluid for damper and coolant applications.

C.)

*i*5-P CNC MRF Redefining Finishing

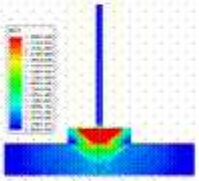
Through 5-axis CNC MRF System

Indigenous design and development of World's 1st CNC Ball end Magnetorheological Finishing (MRF) system for 3D surface finishing.

- New BEMRF Tool Design
- Improved MR Fluid Delivery System
- 5-axis CNC MRF Controller

Nano-finish Materials

- Hi Cr Steel
- Stainless Steel
- Copper
- Aluminium
- Polycarbonate
- Glass
- Silicon



Patented Technology by I.I.T. Delhi

- Funding under "Technology System Development (TSD)" scheme on Ferro-fluids by DST

Email: suniljha@mech.iitd.ac.in

i5-P CNC MRF Assembled Tool Head

i5-P CNC MRF System

Technical Specifications

- Table size L (mm) X W (mm): 840x700
- X axis travel (mm): 150
- Y axis travel (mm): 150
- Z axis travel (mm): 300
- Rotary Table gear Ratio 180:1
- Spindle speed (rpm): 200-3000
- Spindle motor power (KW): 0.67
- Feed motor: Servo Motors
- X-axis torque (Nm): 3.5
- Y-axis torque (Nm): 3.5
- Z-axis torque (Nm): 3.5
- Ball lead Screw (diameter mm / pitch mm): 16/5

- PC Based CNC controller Software developed on Parker Motion Controller
- Fully automated MR-fluid delivery system and process control
- MR-Finishing Tool with 5 mm and 10 mm Dia
- Achievable surface finish: 1 nm

Other Activities

- Technology Licensed for Commercialization for 3 Years to "Innovative Mechatronix Systems Pvt. Ltd., Delhi"

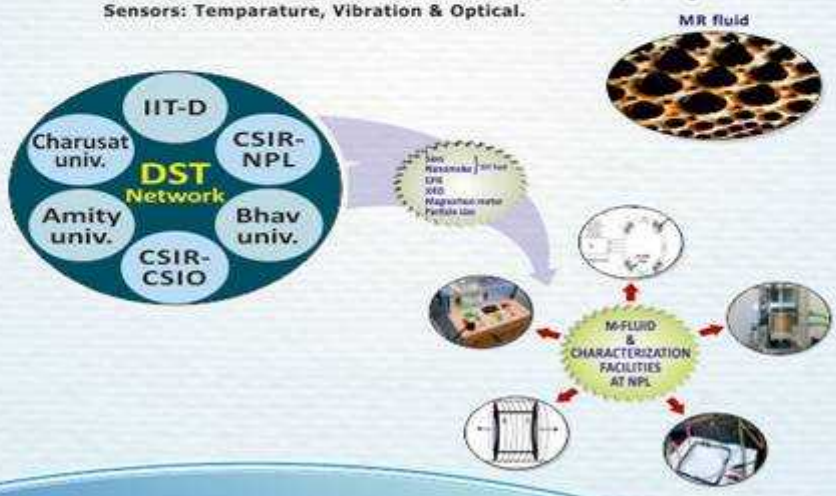
D.) DST - National Network Program on Ferrofluid

Ferrofluid-Nanotechnology: colloidal dispersion of magnetic nanoparticles size 10 -20 nm.

Ferrofluid Activity
CSIR- National Physical Laboratory
DST National Network Project Programme

Preparation and Characterization of Ferrofluids for Energy Conversion Application

AIM:
1. Ferrofluid Preparation and Characterization
2. To Provide ferrofluid & Characterization facilities to other network projects
3. Development of Energy conversion devices: μW-mW power generator; Sensors: Temparature, Vibration & Optical.



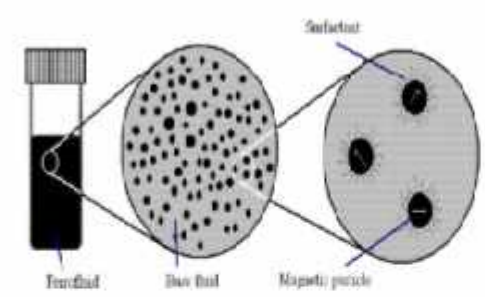
Technology Development and Transfer (TDT) Division
Department of Science & Technology (DST)
New Delhi –110016, www.dst.gov.in

Government of India

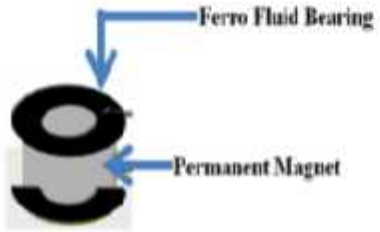
CSIR-NPL (www.nplindia.org)

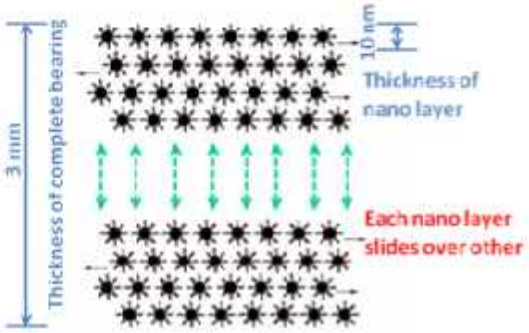
Ferrofluid Network Project
CSIR-National Physical Laboratory

- **Ferrofluid Synthesis and Characterization**
- **Energy conversion devices- sensors and power generator**



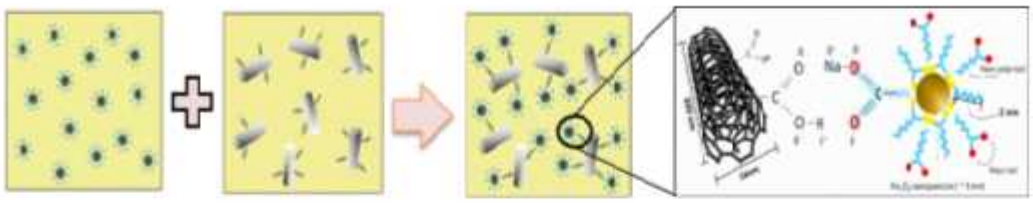
Chain formation of ferrofluid particles with magnetic field works as a liquid bearing of very low coefficient friction for various applications.



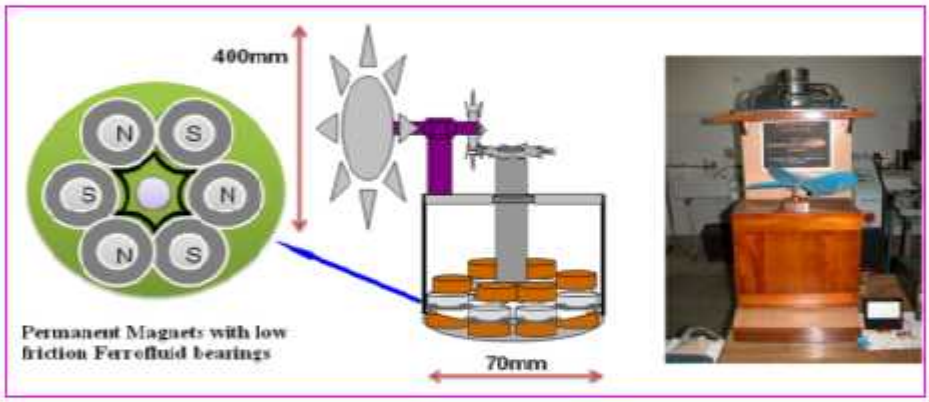


We at NPL have developed verities of ferrofluids and tailored the properties suitable for application Utilizing these unique properties we at NPL have developed a portable ferrofluid electric power generator and also sensors.

- **Functionalised CNT based Ferrofluid** (Filed US Patent 1673 DEL 2014)



- **Ferrofluid based electric power generator**



- **Milli watt power generator**

Ferrofluid Facilities at NPL

XRD

PSA

Magneto-rheometer

Nano MOKE -3

Electron Paramagnetic Resonance

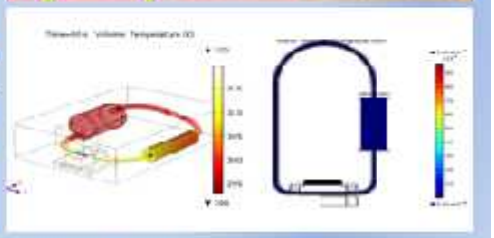
E.)

EXPLORATION OF FERRO-FLUIDS FOR STRATEGIC APPLICATIONS: ATHERMALIZATION IN ADVANCED OPTICAL SYSTEMS

Ferro Fluid Based Liquid Cooling System

Ferrofluid based Smart Miniature Cooling System is a cooling device which utilizes heat and magnetic field to dissipate heat from the circuit or heat source. Traditional devices have certain limitations in terms of heat, vibration, noise and at the same time they require power from working system to dissipate heat. The proposed work discusses a novel technique which is truly 100% passive without conventional cooling components and thereby enhancing the reliability. The invention makes use of high heat transfer coefficient and natural circulation caused by the magnetic pump of ferrofluid so as to constitute a high performance cooling device. The heat transfer can be scaled depending upon the heat load and space constraints. The invention of Ferrofluid based Smart miniature cooling system, adapted for dissipation of heat generated from heat source (electronic device), which comprises, micro-fin arrangement for high heat removals mounted directly on the cooling setup

Patent No: 2007DEL2214
Ferro Fluid Based Liquid Cooling System



Funding under "Technology System Development (TSD)" Scheme on Ferro-Fluids by DST, New Delhi

Optical Devices & Systems, CSIR-Central Scientific Instruments Organisation, Sec 30C, Chandigarh , Email: harry.garg@csio.res.in

EXPLORATION OF FERRO-FLUIDS FOR STRATEGIC APPLICATIONS: ATHERMALIZATION IN ADVANCED OPTICAL SYSTEMS

Features

Removal of heat using heat transfer coefficient & thermal conductivity of fluid

- *True 100% passive cooling system*
- *Virtual magnetic pump (Magnet)*
- *Efficient for Miniaturized Systems or Microsystems*
- *Customized Horizontal & Vertical Systems*
- *Less weight and aesthetic looks*
- *Less components*

Specifications

Working range (Flux)	*:50-100W/cm²*
Operating temperature	*:45-60°C*
Heat Transfer Coefficient	*:10000W/m²K*
Size (customized)	*:61.5x63.5x25.4mm*
Material	*: Copper and Aluminium*
Weight	*:400-500gm*
Flow rate	*: 10-15 ml/m.n.*
Magnet	*:Permanent*

Applications

- *Electronic passive cooling*
- *Computer passive cooling*
- *Customized Miniature cooling*

Industrial Interactions

- *Participated in the Bangalore International Exhibition 2014*
- *Actively talking to ISRO for application in Miniaturized Systems. Already held discussions & presentations at ISRO*
- *Active Talks with Thermosea, Bangalore for Technology Transfer.*
- *Talks are going on with SMEs of Indian Companies for solutions & applications to their Technology.*

Optical Devices & Systems, CSIR-Central Scientific Instruments Organisation, Sec 30C, Chandigarh , Email: harry.garg@csio.res.in