Overview of the ferrofluids synthesis for mechanical applications

H. Urreta[1,2], N. Murillo[3], M. M. Bou-Ali[2]

[1] IDEKO Technology Centre, Mechanical Engineering Department. Elgoibar, Spain. hurreta@ideko.es
[2] MGEP Mondragón Goi Eskola Politeknikoa, Mondragón, Spain. mbouali@eps.mondragon.edu
[3] CIDETEC Centre for Electrochemical Technologies. San Sebastian, Spain. nmurillo@cidetec.es

Introduction

Two main groups of applications has been developed in the ferrofluid framework: mechanical (e.g., seals, bearings, and dampers) and electromechanical (e.g., loudspeakers, stepper motors, and sensors). Actually, the increasing interest of ferrofluids is focused in the biological and medical applications (e.g., magnetic drug targeting [1], magnetic hyperthermia [2], contrast agents for MRI [3]) because of the institution and administrations efforts in the biomedical technologies development.

In this work, we will focus our research effort in the ferrofluid synthesis for the mechanical tools applications. New and more effective ferrolfuids could be design and fabricate to improve guidance systems. The guide systems, in particular journal bearings, are one of the most important mechanic parts of the Machine Tools, and their behaviour limits the precision and productivity of the processes [4]. To improve the actual performance of hydrostatic bearings and to overcome their drawbacks, this work will study the use of active fluids to control bearing's performance. The intelligent lubrication of bearings could be performed by the use of two active materials: electrorheological (ER) [5] and Magnetorheological (MR) fluids [6,7]. The main advantages of ferrofluids are: Low voltage compared with ER fluids, smaller size of FF particles (fitting better to bearings gap), and reduction of sedimentation problems (Brownian forces). Thereby, the research summarised in this paper will be focused to ferrofluids' desing for lubrication application in bearings.

Ferrofluids Synthesis

Ferrofluids are a colloidal suspension of magnetizable nanoparticles (superparamagnetic, ferromagnetic, ferrimagnetic or antiferromagnetic) into a carrier fluid (mineral oil, kerosene, decalin or water). The magnetic nanoparticles dispersed into the carrier fluids are coated of surfactants that increase their stability at the same time that prevent sedimentation and aggregation problems.The more critical steps in the ferrofluid synthesis are two: Magnetic nanoparticles synthesis and ferrofluid formulation.

Basically, we have done the magnetic nanoparticles selection taking into account only two specs: magnetic saturation limit and oxidation stability. Other aspect as the susceptivility, coercivity, the domain or monodomain nature of particles and the magnetic anisotropy will be studied in posterior works.

Chosen materials have been Magnetita (Fe_3O_4) –high magnetic effect- and its oxide, Maghemita (γ - Fe_2O_3), lower magnetic effect but more stable in relation to oxidation. The synthesis has been done by S. W. Charles method for Magnetita and Massart method for Maghemita [8], both via co-precipitation, and through the mixture of ferric clorure ($FeCl_3$-$6H_2O$) and ferrous clorure ($FeCl_2$-$4H_2O$) into bi-distilled water dissolution. Keeping controlled dissolution temperature [9], obtained particles have correct size as will be presented in characterisation chapter.

In the other hand, several carrier fluids have been experimented in this work, to obtain an appropriate ferrofluid: Water, Sunflower-Oil, Glycerine ($C_3H_8O_3$), Kerosene, Cyclohexane (C_6H_{12}), Toluene

(C_7H_8), Industrial Mineral Oil (ISO VG 46) and Decalin ($C_{10}H_{18}$). Among them, Kerosene and Decaline have given the best results with regard to Spiking effect or surface instability (figure 1). The surfactant that avoids agglomeration is oleic acid, added to mixture in two steps, 2ml at 55ºC.

Figure 1: Spiking effect in Kerosene's ferrofluid

Characterising of Ferrofluids

Characterising process is crucial to improve ferrofluid synthesis. The methods are: Scanning Electron Microscope, Fourier Transform Infrared Spectroscope (FT-IR) and Atomic Force Microscope (AFM). Visual exams give an idea about correct mixture of elements, that it has been achieved after mixing magnetita and kerosene (around 75ml) to 100rpm at 50ºC during 4h. But for a real improvement of the synthesis is necessary to analyse particles and their links to surfactants. AFM tests conclude that particle size is between 10nm to 50nm (figure 2), enough for selected application but too much dispersed.

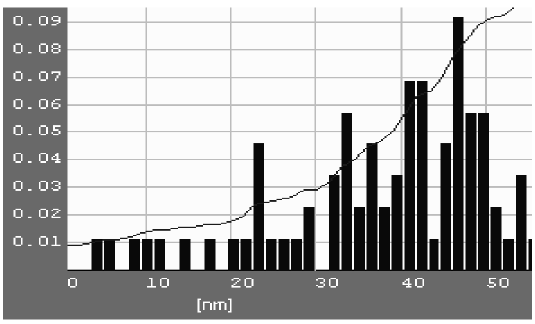

Figure 2: Histogram of particle size

FT-IR tests results represent the different elements and links present in ferrofluids. Two different experimental procedures have been tested (adding nitric acid or not after particle synthesis) and results indicate that nitric acid oxides magnetite to obtain maghemita [10]. Next characterisation step will be to obtain rheological properties of these fluids. The results of these tests will be presented in future works.

Conclusion and Outlook

The main conclusion of the work is the preliminary validation of developed ferrofluids, and the verification of magnetorheological effect of the fluids. Therefore the promising results encourage us to continue with these steps: To aboard the rheological characterisation of the ferrofluid as "smart-lubricants", and to improve magnetic particles and surfactants.

Acknowledgements

We would like to acknowledge the funding of Basque Government by projects: S-OD04MU-26 and S-OD04MU-05. It is also indispensable to credit the invaluable advises of Professor Albert P. Philipse, from Ultrecht University, and the work carried out by Zuriñe Lasa and Mikel Arriaga.

References:

[1] A. S. Lübbe; C. Alexiou; C. Bergemann: J. Surg. Res. 95 pp 200, 2001.
[2] A. Jordan; P. Wust; H. Fähling; W. John; A. Hinz,; R. Felix: *Int. J. Hyperthermia* 9 pp 51, 1993.
[3] D. Pouliquen; H. Perroud; F. Calza; P. Jallet; J. Le Jeune: *J. Magn. Reson. Med. 24* pp 75, 1992.
[4] R. Bassani; B. Piccigallo: Hydrostatic Lubrication. Elsevier, Trib. Series 22, 1992
[5] P. G. Nikolakopoulos; C. A. Papadopoulos: *Tribology Int.* 31 (5) pp. 225, 1998
[6] G. Spur; R. Patzwald: *Production Engineering* 5 (1) pp. 47-50, 1998.
[7] C. Abel-Keilhack; J. Hesselbach:. *Production Egineering* 9 (2) pp. 179-184, 2004
[8] S. Odenbach: *Ferrofluids.* Springer 2002 ISSN 0075-8450
[9] K. T. Wu; P. C. Kuo; Y. D. Yao; E. H. Tsai: *IEEE Trans. on magnts.* 37 (4), 2001.
[10] A. P. Philipse et al.: *J. of Magnetism and Magnetic Materials* 252 (1-3), 2002.