Preparation and Parameters Measurement of Magnetic Fluid

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Abstract. Magnetic fluid is a liquid nano-size magnetic material which has unique properties such as flowability, paramagnetism, and magnetic permeability. The composition of magnetic fluid was introduced. The preparation devices were collected and listed. The preparation of magnetic particles was made by chemical coprecipitation. The particles were coated with surfactant in the experiment. Then the coated particles were added in the base carrier fluid according to the procedure of preparation. Magnetic fluid was prepared by chemical coprecipitation. The parameters of magnetic fluid were measured for kinds of engineering applications. The magnetism of magnetic fluid is one of the most important parameters, which was measured and displayed. The saturated magnetism should be increased for more applications.

1. Introduction
Magnetic fluid is a liquid nano-size magnetic material which has lots of unique properties such as flowability, paramagnetism, and magnetic permeability which other materials don’t possess[1]. Magnetic fluid could be applied in many fields which include sealing, sensors, dampers, biomedicines, and so on[2-8].

With the development of science technology, magnetic fluid is more and more popular for engineering applications. As a core element for applications, magnetic fluid should be prepared with good performances. The preparation work of magnetic fluid was so important that the procedure of preparation was made and magnetic fluid was prepared. The parameters of magnetic fluid were measured by devices.

2. Magnetic Fluid
Magnetic fluid is composed of magnetic particles, surfactant and base carrier fluid which are shown in figure 1. The magnetic particles coated with surfactant are dispersed in base carrier fluid to form a magnetic fluid. This kind of liquid magnetic material should meet the following performance requirements at the same time in application: high saturation magnetization, long-term stability under service temperature, no precipitation under the action of gravity and electromagnetic force, good fluidity and superparamagnetism. It is an organic combination of liquid system, nano materials and modern magnetic technology. It is a kind of liquid strong magnetic material, which has a series of unique excellent properties that other conventional materials and high-tech materials do not have.
2.1. Magnetic Particles
The size and specific gravity of magnetic particles determine the magnetization performance of magnetic liquid, so the performance of nano-size magnetic particles is the key to study magnetic liquid.

Nano magnetic particles in magnetic liquid, such as nano-sized metal oxides (Fe₃O₄) and ferrites [CoFe₂O₄, (Mn Zn) Fe₂O₄, etc.), metals (iron, cobalt, nickel and their alloys), or ferromagnetic iron nitride [FeₙN (2 < n < 8)], are nano-size in size. So the disordered Brownian motion appears in the liquid. This thermal movement is enough to counteract the sedimentation and gravity. Under the action of gravity and magnetic force, the electromagnetic agglomeration between weak particles is always stably dispersed in the base carrier fluid without agglomeration and precipitation.

2.2. Surfactant and Base Carrier Fluid
Nano magnetic particles can be uniformly dispersed in the base carrier fluid and can exist stably for a long time under the action of surfactants. Surfactants are chemically stable in the applied environment. An ideal surfactant should have a permanent adsorption effect on the interface of magnetic particles. Its special function is that it can not only adapt to the corresponding base carrier properties, but also adapt to the interface requirements of nano magnetic particles. Therefore, surfactants must have special molecular structure, that is, one end of the molecule can form a solid combination with the surface of magnetic particles through the action of ion pair, hydrogen bond and van der Waals gravity, while the other end is easily dispersed in the base carrier liquid and has appropriate length and elasticity.

Different base carrier fluids require different surfactants. Appropriate surfactants can effectively prevent the oxidation and aggregation of magnetic nanoparticles, weaken the static magnetic attraction, change the surface properties of magnetic particles, and make the magnetic particles and base fluids melt evenly.

3. Preparation of Magnetic Fluid

3.1. Instruments for the Preparation of Magnetic Liquids
The instruments and equipment required for the preparation of magnetic fluid include: high-power mixer, ball mill, high-speed centrifuge, ultrasonic cleaner, electronic balance, vacuum drying box, electric blast box, constant temperature drying box, tray balance, thermometer, beaker, test tube, measuring cylinder, permanent magnet, dropper, etc. The testing instruments include: rotational viscometer, vibrating sample magnetometer, densimeter, transmission electron microscope, etc.

3.2. Preparation of Nano-Size Magnetic Particles
The precipitation method is to add a precipitant to the solution including ion. The ion is changed into a new substance that is difficult to dissolve in the solvent or insoluble in the solvent through chemical reaction. If two or more ions in the solution are precipitated at the same time, the new substance formed is called coprecipitation[9-12].
The chemical coprecipitation method for the preparation of nano-size magnetic particles is based on the principle that magnetic particles Fe₃O₄ will be generated by the reaction of iron salt and ferrous salt in water.

The basic reaction formula for preparing Fe₃O₄ particles is as follows.

\[ \text{Fe}^{2+} + 2 \text{Fe}^{3+} + 8\text{OH}^- = \text{Fe}_3\text{O}_4 \downarrow + 4\text{H}_2\text{O} \]

The process of preparing nano-size magnetic particles by chemical coprecipitation is as follows.

1. 47g FeCl₃·6H₂O and 19.9g FeCl₂·4H₂O are weighed accurately and dissolved in 300ml and 170ml deionized water respectively. Stirring could accelerate the dissolution.

2. Mix the solution of FeCl₃ and FeCl₂ in a beaker.

3. A certain amount of NH₃·H₂O is taken and added into the mixed solution of FeCl₃ and FeCl₂. The surfactant is added and the pH value of the solution is adjusted to ensure the complete reaction in the weak alkaline environment. Stir for half an hour after reaction until particles Fe₃O₄ are completely generated.

4. The settling agent is added in the solution including Fe₃O₄. When the solid phase of Fe₃O₄ is obviously separated from the water phase, the water is poured out, and the precipitate of Fe₃O₄ containing water is left over.

5. The precipitate of Fe₃O₄ is cleaned and dried so that the nano-size particles Fe₃O₄ are obtained. The electron micrograph of nano-size particles Fe₃O₄ are prepared by chemical coprecipitation, which is shown in figure 2.

![Figure 2. TEM of magnetic particles prepared by chemical precipitation](image)

3.3. Preparation of Magnetic Fluid
The surfactant is added and dispersed in the solution under a certain condition. The preparation process is established and shown in figure 3. When the ferric chloride reacts with ferrous chloride to form ferromagnetic particles in alkaline environment, the solution should be stirring evenly. After the reaction complete, the surfactant is added to keep the particle coated magnetic particles. Stir the solution evenly at 110°C for 3-4 hours to ensure the particles are coated completely. Then the dehydration work should be done to keep the coated particles dry. When the precipitate was completely coated with surfactant, add the base carrier fluid in the precipitate. The processed coated particles are dispersed in the base carrier fluid evenly to form magnetic fluid. Stirring could help the particles coated dispersed rapidly. Finally, magnetic fluid is obtained, which is shown in figure 4.

The nano-size particles Fe₃O₄ were prepared by chemical coprecipitation method without nitrogen protection. The precipitate was directly coated with surfactant and dispersed to obtain magnetic liquid, which can reduce the agglomeration of particles and enhance the magnetism and stability of the magnetic liquid. The best experimental conditions are that the molar ratio of ion Fe²⁺ and ion Fe³⁺ is 2:1, the reaction temperature is 50°C, and the amount of ammonia is 2.0 ~ 2.5 times of the theoretical amount.

The magnetic fluid prepared could be applied in sensors experiment for measuring physics parameters,
4. Parameters of Magnetic Fluid
Parameters of magnetic fluid are important for the characteristics of the application devices[13-14]. For example, for inductance sensors, magnetic fluid is the magnetic core of the coil, so the magnetism of magnetic fluid influence the output data and the sensitivity of the sensor. For ore selecting device, the density and the magnetism of magnetic fluid both are the key factors for the characteristics of the device.

Parameters of magnetic fluid produced are measured by instruments, which include density, viscosity, saturated magnetization. The density of magnetic fluid is 1.41kg/m$^3$, which is measured by pycnometer. The viscosity of magnetic fluid is 8.8×10$^{-3}$Pa·s, which is measured by rotary viscometer.

The saturated magnetization of magnetic fluid is 28emu/g. The magnetic curve of magnetic fluid is shown in figure 5. From figure 5, we could conclude that there is no remanence and coercivity.

Superparamagnetism refers to that, the magnetic materials in single domain structure when their grains are smaller than critical dimensions show paramagnetism when temperature is lower than Curie temperature and higher than block temperature. However, their paramagnetic susceptibility is far higher than that of ordinary paramagnetic materials under the effect of external magnetic field, and this is called as superparamagnetism.

Superparamagnetism has two most important characteristics: first, if a figure is plotted with magnetization intensity M as Y-axis and H/T as X-axis (H is the magnetic field intensity applied, and T is absolute temperature), then magnetizing curve is measured under different temperatures in the temperature range when single domain particle aggregation shows superparamagnetism, these magnetizing curves are certainly coincident. Second, no hysteresis will appear, that is, the remanence
and coercivity of aggregation both will be zero. Therefore magnetic fluid has an important characteristic of superparamagnetism.

Figure 5. Magnetic curve of magnetic fluid

5. Conclusions
Magnetic fluid is introduced and prepared by technical process. The nano-size particles Fe\textsubscript{3}O\textsubscript{4} were prepared by chemical coprecipitation. After being coated by the surfactant, the particles are dispersed in the base carrier fluid. The magnetic fluid was obtained. The parameters of magnetic fluid were measured by instruments. Magnetic fluid is a potential nano-size fluidic magnetic material, which may be applied in kinds of engineering fields. The properties of magnetic fluid are so important that we should increase the parameter such as magnetism to improve the applications.

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7. References
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