Journal of Advances in Science and Technology
Vol. 12, Issue No. 25, (Special Issue) December-2016, ISSN 2230-9659

Magnetic Fluid Grinding

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Abstract – The better finish may be desired for looks, accuracy, weaving qualities or for any other reason. Some materials like glass, ceramics, acrylic resins & plastics are inherently brittle in nature, so during conventional grinding the cracks may be formed, which can significantly reduce the strength & reliability of the material in service. The conventional grinding followed by lapping or by direct polishing method consumes lot of time & add significantly to the cost of manufacture. To minimize the damage during finishing, it is necessary to process brittle materials under gentle condition that is under controlled low force, which is not possible in conventional grinding. The investigation of non-conventional finishing technology called magnetic fluid grinding in which the cutting force is controlled by the magnetic fluid.

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1. INTRODUCTION

There are many super finishing operations viz. lapping, honing, burnishing, polishing, buffing and tumbling etc. This method removes very small material and surface finish obtained is very high. Surface finish is obtained by those methods are refined. But the materials such as ceramics, glass, acrylic resins, and plastics are inherently brittle, during finishing of such brittle materials with conventional grinding process, surface defects such as cracks are formed. Those cracks can significantly reduce the strength and reliability of the parts in service.

To minimize the damage during finishing, it is necessary to process brittle material under gentle conditions. For this, we have to keep the cutting forces low which are not possible in conventional grinding methods.

Therefore, in this project we have tried to perform super finishing operation on aluminum material with the help of magnetic fluid grinding. This method can be used for grinding of brittle materials, which is the future scope of this project. This method is based on the Ferro hydrodynamics behavior of the magnetic fluid, which has the ability to float nonmagnetic abrasive particles under the influence of the magnetic field. Magnetic fluid is colloidal dispersions of sub domain ferromagnetic particles usually magnetite, in various kinds of carrier liquids. One particular class of Ferro fluid is made stable against particle agglomeration by the addition of a surface active agent. When magnetic fluid is placed in magnetic field gradient, it is attracted towards the higher magnetic field side. If a nonmagnetic substance is immersed in a magnetic fluid, it is discharged relatively to lower magnetic field side. When the magnetic field gradient is set in the gravitational direction the nonmagnetic material is made float on fluid surface by the action of the magnetic buoyant force.

2. OBJECTIVES

1. To study the conventional system of Grinding.
2. To study the construction and working principle of Magnetic Fluid Grinder.
3. To study the various process parameters of Magnetic Fluid Grinding.
4. To prepare required model for magnetic fluid grinding.
5. Taking trials on machine and measure the surface finish of the component.
6. Comparison between the conventional grinding results with magnetic fluid grinding

3. LITERATURE SURVEY

3.1 Finish of Steel Balls

- Study of the finish process of steel balls started since 1950s, by Ido et al. and a series of papers were published. In these papers, the effects of various grinding conditions such as the V-groove shape, the materials of the lapper, the grinding fluid and the grinding load on the material removal rate and sphericity of balls were investigated.

- Today the most popular production method in the world was proposed by Inagaki and Abe in 1976 [1]. They ground the same type steel balls with 14 grinding methods, and found that the apparatus which was consisted of a rotary grinding wheel and a fixed disk can get the best sphericity and surface roughness. The balls were placed into the V-grooves and driven by the rotary disk. When appropriate grinding load and abrasive or lubricant are imposed, the material removal to be obtained at the surface with smaller radius of curvature was greater than that obtained at the position with larger radius of curvature, thus the ball will be ground toward the same radius of curvature, and achieve better sphericity gradually. It is found that, ground by #500 abrasive with the rotating speed of the rotary disk below 100 rpm for 50 hours, the diameter reduction rate, the sphericity and the average surface roughness were of about 0.3 μm/min, 1 μm and 0.1 μm respectively.

- In 1993, the Itoigawa et al. [2] analyzed the effect of the geometry of the V-groove on the sphericity. They extrapolated a preferable grinding condition and ground the balls at a low rotating speed of 60rpm for 4 to 5 hours. A sphericity of 0.05μm was obtained and the result demonstrated that the sphericity improved with the number of the steel ball to be processed at the same time.

- 1996 years, Goto et al. [3] simulated the ball formation in the grinding and analyzed the error correction via Fourier series. Based on the simulation results, a three-stage lapping process of steel ball for the ultra-precision bearing was implemented, and a sphericity of 0.018μm and a surface roughness of 0.002μm were obtained.

3.2. FINISH OF CERAMIC BALLS

- With the development of precision ceramic materials, precision ceramic ball have gradually took place of steel ball in high speed, high temperature, aerospace and other harsh environment. However, most of the precision ceramic ball manufacture is still using the traditional grinding equipment. Since the 1980s, industry and academia started to develop new grinding method and equipment to enhance the processing rate of precision ceramic ball. 1988, Kato et al. [4, 5] developed magnetic fluid grinding method, which uses the slurry of magnetic fluid and grits as the abrasive. By virtue of the buoyancy which is produced by the magnetic fluid in the magnetic field, the ball can be ground by the grits in the slurry which is driven by the high speed rotating shaft. After grinding with GC#400 abrasive under 0.7 N for 3 hours, diameter reduction rate of 12μm/min, sphericity of 0.14μm and surface roughness of 0.01μm were obtained.

- In 1992, Childs et al. [6] discussed the design of the magnetic fluid grinding cell. Later in 1993, Kato et al. also investigated the grinding characteristics and did in-depth study to approach a subject of grinding theory. The effect of different grinding conditions, such as the support stiffness of the float and the processing load, different groove material, abrasive types, size, slurry viscosity and concentration, on the ball grinding were investigated.

- Child et al. [7] developed a model to predict the motion of balls and float in a magnetic fluid grinding cell, particularly to predict the onset of skidding that results in high grinding rate by the magnetic fluid grinding.

- In 1996, Umehara et al. [8] reviewed those papers and discussed the improvement on the material removal rate, sphericity and surface roughness.

- In 1995, Zhang et al. [9] improved magnetic fluid grinding method by using a taper thrust float, and discussed the effect of eccentricity between the driving shaft and the guide ring. The result showed that the material removal rate increased with the offset. However, the surface roughness is independent of the eccentricity.

- Later in 1998, Zhang [10] proposed the magnetic fluid support grinding method which can save the cost of expensive magnetic fluid. The magnetic fluid is sealed in the chamber beneath the float with a rubber membrane, and provides a soft support. Thus the ball can be ground by the grinding wheel at a high rotating speed. The diametrical reduction rate was 29μm/min and the sphericity was improved from 43μm to 6μm within a short grinding time of 6 minutes when a SD200 wheel was used.

- In 2000, Zhang [11] and his research group discussed the spherical surface generation mechanism in the grinding of balls and considered that the eccentric V-groove grinding mechanism may be one solution to distribute the contact trace over the whole ball surface and thus to improve the precision of ground balls. Furthermore, they investigated the relationship between the

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vibration of the support system and the error in the surface generation, and discussed the effect of the stiffness and damping. They concluded that ultra-precision grinding requires high damping to increase the magnification factor and minimized the phase difference.

4. EXPERIMENTATION

4.1 Magnetic Fluid Preparation

Ferro fluid is a magnetic fluid made out of nanometre sized pieces of iron or various iron oxides, suspended in a liquid. The shapes and flow of ferrofluid are surprising and beautiful, and show how magnetic field lines curve around magnetic objects.

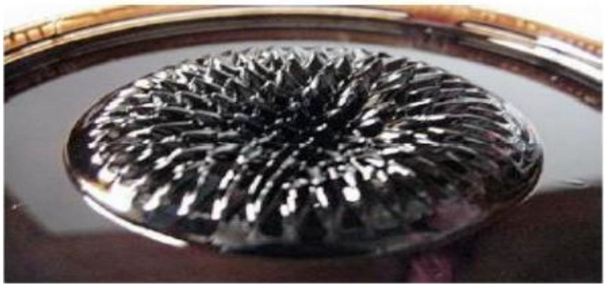

Fig 4.1: Ferro fluid

A ferro fluid is a fluid with magnetic particles in it, and if the fluid is exposed to a magnetic field, all the magnetic particles will align with the field lines, and making the fluid much denser.

When a ferrofluid is subjected to a magnetic field, magnetic field gradient and/or gravitational field, in order that the colloidal suspension remains stable the magnetic particles generally have to be of approximately 10 nm in diameter. Particles of this size, whether they are ferrite or metal, possess a single magnetic domain only, i.e., the individual particles are in a permanent state of saturation magnetization. Thus a strong long-range magneto static attraction exists between individual particles, the result of which would lead to agglomeration of the particles and subsequent sedimentation unless a means of achieving a repulsive interaction can be incorporated.

In order to achieve this repulsive mechanism, the particles can either be coated by a surfactant (surface active material) to produce an entropic repulsion, or the surface of the particles can be charged thereby producing an electrostatic repulsion. For dispersions in liquid a metal, stability has not been achieved due to the lack of a method to produce a repulsive mechanism.

4.2 VARIOUS METHODS OF PREPARING MAGNETIC FLUID:

The various methods of preparing magnetic fluid are discussed below:

- Acetone: We need separate Ferric oxide from plastic tapes. Acetone will melt binder and separate Ferric oxide.

- Cooking oil: Cooking oil is needed so as to mix it with ferrite particles Fig shows cooking oil.

Fig 4,3: Acetone

Fig 4.4: Vegetable oil

- Magnets:Magnets are used to produce magnetic field so that when ferro fluid is exposed to magnetic field, all the magnetic particles will align with the field lines, and making the fluid denser.

Fig 4.5: Magnets

PROCEDURE

The procedure to prepare the ferrofluid is as follows:

1) Collect the ingredients as follows:

Table 1: Ingredients for magnetic fluid

S. N.	Ingredient	Proportion
1.	Acetone	500ml
2.	Tapes	10 music or 4 video
3.	Cooking oil (Soya)	5ml
4.	*Magnets*	*strong magnet*

2) Take a large bowl as shown in Fig 4.6.

Fig 4.6: Bowl

3) Melt binder and separate Fe2O3:

We need separate Ferric oxide from plastic tapes. Acetone will melt binder and separate Ferric oxide. Find large enough bowl. Put all tapes in and fill bowl with acetone. Wait few hours. You should close bowl with something to keep acetone from vaporizing. The process is shown in Fig 23 respectively.

4) Ferric oxide from the plastic tapes is mixed with the cooking oil which makes a substance that's liquid when it's sitting around, but turn solid in the presence of a magnetic field as shown in Fig 24.Therefore magnetic fluid is prepared.

Fig:4.7: Placing tapes in the bowl containing acetone

Fig 4.8: Ferrofluid prepared

METHOD 2 (USING MAGNETIC INK)

This is also an easy and best way of preparing magnetic fluid. The ingredients required for its preparation are as follows:

- Magnetic (MICR) ink: The ink is a dry magnetic ink that's used to print checks and other documents that use magnetic character recognition.

- Household oil: Many types of oils can be used, but it seemed like a light lubricating oil works best, but any cooking oil will work fine, as well. The amount of oil you have is pretty much the amount of ferrofluid you'll get out--about 50mL is good for starters.

Fig 4.9: Magnetic ink

Fig 4.10: Vegetable oil

Procedure:

Following steps shows procedure for preparing method 2 type of ferrofluid,

1 Pour some oil into a mixing cup.

Fig 4.11: Poured oil in a mixing cup

1) Add a bit of the ink, and stir it into the oil.

Fig 4.12: Addition of ink into the oil

2) You're making a suspension, so the ink won't dissolve in the oil. Just stir it.

3) Keep on adding ink and stirring until you have a thick solution.

Fig 4.13: Thick solution of ferrofluid

4) A good guideline for identifying a well-mixed fluid is that if you tip your mixing cup, the fluid should ooze rather than slosh.

5) Therefore ferrofluid is ready.

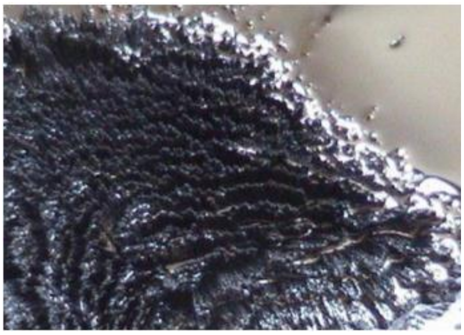

Fig 4.14: Ferrofluid

4.3 WORKING MECHANISM

This method is based on the Ferro hydrodynamics behaviour of the magnetic fluid which has the ability to float a nonmagnetic abrasive under the influence of the magnetic field. Magnetic fluids are colloidal

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dispersions of sub domain ferromagnetic particles, usually magnetite, in various kinds of carrier liquids. One particular class of Ferro fluids is made stable against particle agglomeration by the addition of a surface active agent. When magnetic fluid is placed in magnetic field gradient, it is attracted towards the higher magnetic field side. If a nonmagnetic substance is immersed in a magnetic fluid, it is discharged relatively to lower magnetic field side as shown in fig 12. When the magnetic field gradient is set in the gravitational direction the nonmagnetic material is made float on fluid surface by the action of the magnetic buoyant force.

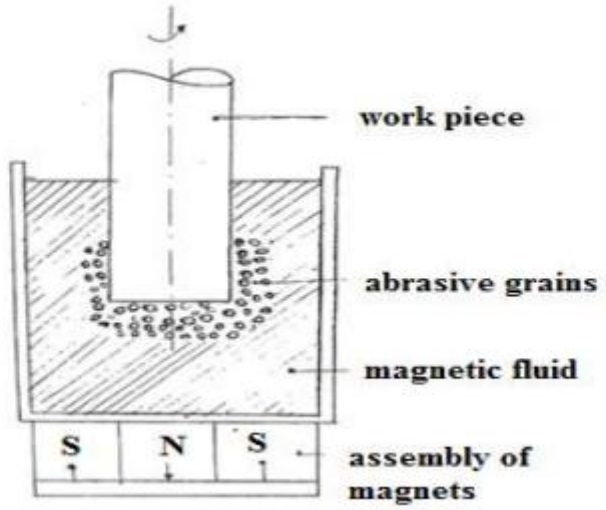

Fig 4.15: Working mechanism of M.F.G.

Following represents the specifications observation table prepared during the performance,

Table2: Specification table

Sr. no	Parameter	Specification
1.	Motor speed	2880 rpm
2.	Work piece material	Aluminium
3.	Supply voltage	240V
4.	Magnetic field strength	0.7tesla
5.	Abrasive	Aluminium oxide
6.	Magnetic particles	Magnetic ink

4.4 COMPONENTS

ABRASIVES

The abrasive grains used are non-magnetic. Hard abrasives are used for soft work materials. The grain size of abrasive used is about 4 to 34 microns and is very fine powder. The most commonly used abrasives are silicon carbide (Sic) and aluminum oxide (A12O3). Silicon carbide is used for rapid stock removal and aluminum oxide for improved surface finish. In this experiment aluminum oxide is used as abrasive. Photograph shows the fine white powder of aluminum oxide (A12O3).

Fig 4.16: Magnetic ink

PERMANENT MAGNETS

To obtain magnetic field, assembly of permanent magnets are used. In order to obtain a large buoyant force, large magnetic field gradient as well as large magnetic field is necessary.

For satisfying such condition, several permanent magnets are placed so that the magnetic poles of adjacent magnets are opposite. Magnets used are neodymium-iron-boron magnets or samarium cobalt magnets having magnetic induction of 0.8 to 1.2 T (Tesla).

It is interesting to note that in the magnetic field of 1.1 Tesla a magnetic induction of 10 A/m is generated. Depending upon the requirement of magnetic field, number of magnets to be used is decided.

In this experiment the magnetic field achieved is about 0.7 Tesla and number of magnets used are 6. Photograph 14 shows 6 numbers of magnets.

Fig 4.17: Permanent magnets

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WORKPIECE

Work piece to be polished in this experiment used is aluminum. Due to unavailability of hard brittle materials in the desired shape and size we have chosen aluminum. The reason behind selecting aluminum is it's easily available in required shape and size. One end of the aluminum is held in the fixture, and other end is free to rotate in the magnetic fluid for its grinding. The outer diameter of work piece to be held is equal to the internal diameter of the fixture.

Table 3: Specifications of work piece

Sr. No.	Parameter	Specification
1.	Work piece material	Aluminum
2.	Outer diameter at fixture end	20mm.
3.	Outer diameter at free end	25mm.

SURFACE ROUGHNESS MEASURING INSTRUMENT

The surface measuring instrument shown in photograph 16 is used to measure the surface roughness value of the work piece before and after the operation. The specifications of the instrument are as follows:

Fig 4.19: Assembly of components

Fig 4.18: Roughness measuring instrument

Table 4: Instrument Specifications

Sr. No.	Parameter	Specifications
1.	Company name	Mitutoyo
2.	Probe stroke length	12.5mm
3.	Calibration standard piece value	icrons

5. ASSEMBLY

The components required for the project are discussed in above points. The final stage in the setup is to assemble all the components so that it is ready for experimentation. The assembly is carried out in following steps,

1. Clamp motor to rigid body with the help of nut and bolt arrangement.
2. Attach fixture to the motor shaft with the help of bolting arrangement.
3. Press fit the beaker filled with magnetic fluid against the wooden arrangement.
4. Fix the workpiece to fixture by tightening the bolts provide on it.
5. Connect all the motor terminals to the autotransformer.
6. Locate workpiece below beaker by providing required support beneath it.

7. Start the motor by supplying 3 phase power supply.

Table 5: Observation table

Sr. No.	Time required for grinding (minutes)	Initial roughness value 'Ra' (µm)	Final roughness value 'Ra' (µm)
1.	20	1.65	1.24
2.	20	1.24	0.79
3	20	0.79	0.34

6. CONCLUSION

With the help of magnetic fluid grinding it is possible to grind aluminum material which is a nonmagnetic material. This method is also applicable to various nonmagnetic materials such as ceramics, hard plastics and glass.

The initial roughness before grinding process is carried out was 1.65µm, which reduced to 0.34µm after process is completed. Therefore the purpose of doing this project is accomplished.

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