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Effects of Different Variables on Magnetic Abrasive Powder in Mechanical Alloying Method

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ABSTRACT
The purpose of this study is to analyze the effects of different variables on magnetic abrasive powder in mechanical alloying process which are suitable for magnetic abrasive finishing process. The parameters such as milling time, ratio of abrasives, speed of agitated shaft plays vital role in manufacturing of magnetic abrasives. It has been observed from the experiments of the present investigation that for magnetic abrasive powders, optimum results are obtained when milling is carried out with milling time 60 min, ratio of abrasives is 40% in the iron powder and 250 rpm of the agitated shaft.
***Keywords* –** Magnetic Abrasives, Magnetic Abrasive Finishing, Attrirtor, Mechanical Alloying, Ball Mill.

I. INTRODUCTION

The mechanical alloying (MA) process, using ball-milling techniques, has received much attention as a powerful tool for the fabrication of several advanced materials including equilibrium, non equilibrium and composite materials. The MA is a unique process in which a solid state reaction takes place between the fresh powder surfaces of the reactant materials at room temperature. It can be used to produce alloys and compounds that are difficult or impossible to obtain by the conventional melting and casting techniques. Basically the ball milling has evolved from being standard technique in milling of ores in mineral dressing and particle size reduction in powder metallurgy to important techniques for the preparation of materials with enhanced mechanical and physical properties either new phases or new engineering materials. Mechanical alloying may be defined as a method for producing composite metal powders with a controlled fine microstructure. It occurs by the repeated fracturing and re welding of powder particles mixture in a highly energetic ball mill [1]. As originally carried out, the process requires at least one fairly ductile metal to act as a host or binder. Other components can consist of other ductile metals, brittle metals, and inter metallic compounds or nonmetals and refractory compounds. The high energy involved in the MA process fragments and cold re-welds powder particles that form the initial mix. The powder particles are continuously trapped between colliding balls and balls container what raises the level of micro structural strain, enhancing its mechanical properties. Besides high energy milling can bring many changes to powders subject to such a process, including refinement of particle size and crystallite size, formation of amorphous phases, deformed bonds at surfaces and changes in boundary energies. Because of these changes the free energy of reactants and the kinetics reaction can be substantially modified. Mechanical alloying is the generic term for processing of metal powders in high-energy ball mills. However, depending on the state of the starting powder mix and the processing steps involved, different terms have been used in the powder metallurgy literature. Two different terms are most commonly used to describe the processing of powder particles in high-energy ball mills. Mechanical alloying describes the process when mixtures of powders (of different metals or alloys compounds) are milled together. Thus, if powders of pure metals A and B are milled together to produce a solid solution (either equilibrium or supersaturated), inter metallic, or amorphous phase, the process is referred to as MA. Material transfer is involved in this process to obtain a homogeneous alloy [2].

1.1 MAGNETIC ABRASIVE

Magnetic abrasive is a mixture of non-ferromagnetic abrasive and ferromagnetic iron particles used to do finishing operation with the aid of magnetic force. The iron particles in the mixture are magnetically energized using a magnetic field. The iron particles form a lightly rigid matrix in which the abrasives are trapped. This is called Flexible Magnetic Abrasive Brush (FMAB), when given relative motion against a metal surface, polishes that surface. Some common types of magnetic abrasives are: sintered, bonded, adhesive based, unbonded, plasma based, others magnetic abrasives etc [3].

II. LITERATURE REVIEW

Previous literature available on mechanical alloying and different methods for manufacturing of magnetic abrasives mainly focused on the following broad areas:

- Development of various experimental set ups consists of provisions to give different-Parameters, capabilities.
- Optimization of process parameters of mechanical alloying using various experimental-set ups.

2.1 SINTERED MAGNETIC ABRASIVES

Lin et. al. (2007) prepared the magnetic abrasives by typically mixing iron powder (60 wt %) and Al_2O_3 (40 wt %) with average size of 5μm) and compressing mixture into the cylindrical shape. These compacts were sintered into a vacuum furnace. After sintering process, these cylinders were crushed to produce magnetic abrasives of average size 150 μm. The ball-shaped magnetic pole with special grooves was used with these magnetic abrasives. It was found that the design increased the finishing efficiency and created a good surface finish for the non-ferromagnetic material, SUS304. The best surface finish was obtained at a working gap of 2.5 mm, a feed rate of 10 mm/min, and an abrasive mass of two grams. The obtained maximum percentage improvement surface roughness was 60%. These abrasives were used for finishing of SS 304 material.

Zhang et. al. (2011) studied on magnetic abrasive finishing by sintering method and research on tests of magnetic abrasive finishing, analyses the effect of the sintering temperature, ratio of magnetic and abrasive particle size, sintering time and sintering characteristics of magnetic particles on magnetic abrasive during the finishing process, so as to achieve a better process and principle for magnetic abrasive finishing. The obtained maximum percentage improvement surface roughness was 65%. These abrasives were used for finishing of SS 304 material.

2.2 ADHESIVE BASED MAGNETIC ABRASIVES

Feygin et. al. (1998) prepared magnetic abrasives by mixing iron powder, Al_2O_3 and glue as adhesive (commercially known as an industrial crazy glue). Iron and abrasive particles were strongly bonded with each other by the glue. They reported that this method was simple as compared to the other methods for preparation of the magnetic abrasives. MRR was higher as compared magnetic abrasives prepared by other methods. The obtained maximum percentage improvement surface roughness was 49%. These abrasives were used for finishing of SS 304 material.

Kremen et. al. (1999) developed magnetic abrasives using an adhesive to bind magnetic component (iron powder) with abrasive component (diamond powder). All the three components were mixed thoroughly, dried and crushed into small particles of desired size for machining. Then by using glued magnetic abrasive powder and keeping magnetic flux density 0.4 tesla, machining time 5 minute and adding 4% of boric acid in water as cooling fluid, the effect of powder grain size on the surface roughness and MRR of a silicon wafer and tube was observed. The obtained maximum percentage improvement surface roughness was 45%. These abrasives were used for finishing of SS 316 material [4].

2.3 PLASMA BASED MAGNETIC ABRASIVES

Anzai et. al. (1989) developed NbC based magnetic abrasives by plasma powder melting (PPM) technique. NbC particles (65% by volume) were dispersed uniformly in the matrix of iron. The obtained maximum percentage improvement surface roughness was 51%. These abrasives were used for finishing of SS 304 material.

Yamaguchi et. al. (2008) developed spherical iron-based magnetic abrasive, which carries Al_2O_3 grains on the surface, made by plasma spray. First, they examined the feasibility of the plasma spray to make the existing magnetic abrasive more spherical, and suggested the conditions needed to produce the spherical magnetic abrasive. Secondly, they developed the new spherical magnetic abrasive made of separate particles: WA Al_2O_3 abrasive grains and iron particles in the ratio of 1:12, which carry the nonferrous abrasive on the outer surface alone. The obtained maximum percentage improvement surface roughness was 47%. These abrasives were used for finishing of brass material.

Handa et. al. (2008) fabricated fine spherical iron-based magnetic abrasives of diameter less than 10 μm by plasma spraying. Carbonyl iron powder with 7.2 μm average sizes was used as the magnetic matrix powder and diamond particles of average size 0.31 μm (10% by volume) were used as abrasive grains to produce a composite powder. The diamond particles were thermally diffused into the iron powder during plasma spraying. After the powder mixtures passed through the plasma flame, the powder mixtures were rapidly cooled and then were recovered in the powder recovery vessel. The obtained maximum percentage improvement surface roughness was 50%. These abrasives were used for finishing of SS 316 material [5].

2.4 UNBONDED/LOOSELY BONDED/MIXED MAGNETIC ABRASIVES

Fox et al. (1994) used unbonded magnetic abrasive for finishing of ceramic. The obtained maximum percentage improvement surface roughness was 26%. These abrasives were used for finishing of ceramic rollers.

Shinmura & Yamaguchi (1995) prepared mixed type of magnetic abrasives by mixing of iron particles of various sizes and sintered magnetic abrasives. These mixed magnetic abrasives were used for internal finishing of SUS304 steel tubes and clean gas bomb shells. They found that the magnetic force of the mixed-type magnetic abrasives takes the median value between those of the magnetic abrasive and iron particles. The magnitude of magnetic force increases with increasing mixed weight percentage of iron particles but the number of the cutting edges gets reduced. The obtained maximum percentage improvement surface roughness was 30%. These abrasives were used for finishing of SS 316 material.

Yamaguchi & Shinmura (2000) used loosely bonded magnetic abrasives (2.4 gm iron of size 510 µm, 0.6 gm Al_2O_3 of size 80 µm and 0.36 ml straight oil type grinding fluid) for internal finishing of tubes using pole rotation system. They reported that with a weaker magnetic field on the abrasives and oversupply of the abrasives in the machining area result in jumbling of abrasives. The jumbling resulted in increased material removal but poor surface finish. This was caused by the aggressive contact of the abrasives against the surface. The obtained maximum percentage improvement surface roughness was 21%. These abrasives were used for finishing of brass material.

Jain et al. (2001) used loosely bonded magnetic abrasives (mixture of iron, Al_2O_3 and lubricant) for external finishing of stainless steel cylindrical rod of diameter 48-50 mm. It was reported that the improvement in the surface finish is 60.83% with MRR of 58.6 mg/min. These abrasives were used for finishing of SS 304 material.

Yamaguchi et al. (2001) used loosely bonded magnetic abrasives (0.56 gm iron of 330 µm, 0.14 gm Al_2O_3 of 80 µm and 0.2 ml soluble type barrel finishing compound) for finishing of SUS304 stainless steel elbows of radius of curvature R30, R46, R80 using pole rotation system. The obtained maximum percentage improvement surface roughness was 26%. These abrasives were used for finishing of SS 304 material.

2.5 MECHANICAL ALLOYING METHOD

Hakaru et. al. (1996) developed Si-M alloy powder by mechanical alloying process. In this process the crystalline powder of Si-M (Fe or Co) in the composition ratio varying from Si-M= 1:2 to 2:1 were mechanically alloyed by the laboratory ball mill in an inert atmosphere. The amorphization reaction between Si and M proceeded according to a second order reaction.

Halil et. al. (2005) produced Fe-Fe_3C composite powder by mechanical alloying process. The elemental iron powder containing 1 wt% carbon was carried out under Argon atmosphere by using a high energy ball mill for various milling time. In order to compare and determine the effect of MA on properties the same amount of powders were mixed by a conventional mixer up to 5 hr[6-7].

III. MANUFACTURING OF MECHANICAL ALLOYED MAGNETIC ABRASIVE

Mechanical alloyed magnetic abrasives (MAMA) have been developed for efficient finishing of internal surface of tubes & outer surface of rods. Mechanical alloyed magnetic abrasives (MAMA) consisting of iron powder and Al_2O_3 have been mixed in a suitable proportion in a stirred ball mill.

The main motive is to identify the best parameters of the mechanical alloying that produce a more homogeneous embedment of the abrasive particles in the iron particles. In this study the design expert approach has been used for the systematic variations of the mechanical alloying parameters. By using design expert approach we are able to manufacture eight samples of the magnetic abrasive powder. The MA step involves a large, and indeed combinatorial, number of mechanical alloying variables such as: Alloying time, RPM of agitate shaft, Ratio of Fe- Al_2O_3 powder, Base alloying powders size, Selection of grinding media, Ball mass to powder mass ratio. It is not possible to control all of these milling variables for this study, but the milling variables that are tested include the milling time, Fe & Al_2O_3 powder ratio, RPM of agitated shaft. A baseline milling condition is established, and each sample manufactured with a single variable and held the others fixed, with the help of design expert a relative comparison between the samples is considered.

3.1 SELECTION OF PROCESS PARAMETERS

In MAM, the machining is associated with many factors. Time of machining, quantity of abrasives, work piece- magnet gap, magnetic flux density and rotational speed of the work piece are responsible to great extent for smooth finishing in MAM. Mechanical alloying governs the strength and strong bonding of the abrasive layer inside the work piece.

Following parameters are taken into consideration for fine machining with mechanical alloyed magnetic abrasives in MAM.

- Effect of alloying time for magnetic abrasives on surface finish.
- Effect of Fe- Al_2O_3 ratio on surface finish.
- Effect of rpm of agitated shaft on magnetic abrasive powder.
- Effect on surface finish of zinc stearate ratio in magnetic abrasive powder.
- Effect on surface finish of spindle oil in magnetic abrasive powder.
- Effect of mechanical alloyed dry magnetic abrasives on surface finish.
- Effect of unbonded magnetic abrasive on surface finish.
- Effect of quantity of magnetic abrasives used during machining on surface finish.

The comparison of percentage wastage of abrasives is also calculated by comparing the quantity of abrasives wasted when used mechanical alloyed and unbonded abrasive. After studying the review literature we are able to fix the magnetic flux density to 1 tesla [8] [9].

IV. EFFECTS OF DIFFERENT VARIABLES

4.1. Effect of alloying time on finishing

Mechanical alloying time plays an important role in machining process. Several experiments are made to fix the time limit for alloying of magnetic abrasive powder.

In this study when time take 20 minutes for alloying time then we observed during the experimenation internal surface finish of brass pipe was very poor, because alloying time less then 30 minutes then not proper alloying done between the Fe- Al_2O_3 particles, the Al_2O_3 particles were not proper embedd in the iron particles and surface finish was poor inside the brass pipe. In this study when time take 60 minutes for alloying time then we observed during experimentation the surface finish was also good inside the brass pipe. In this study when alloying time taken 90 minutes then we observed during the experimentation the surface finish was also good. But unnecessary alloying were done size of Fe- Al_2O_3 particles were so fine and unnecessary power and time consumptions. Another problem observed, face the problem during paper magnet test. Because particles of Fe- Al_2O_3 are so fine these were not spread properly on the white paper. These were disabling for magnetic separation test.

4.2 Effect of Fe- Al_2O_3 ratio on surface finish

Ratio of Fe- Al_2O_3 particles plays a vital role in manufacturing of magnetic abrasive powder suitable for magnetic abrasive finishing process. Several experiments are conduct to set the ratio of Fe-Al_2O_3 particles.

Following table shows various observations made regarding the effect of relative proportions of iron and abrasive powder and their corresponding behaviour during machining.

As the quantity of the iron was 60% of the weight and the quantity of the abrasive was 40% of the weight then observed good machining rate. Because quantity of iron particles and abrasive particles were. When equal quantity of iron particles and abrasive particles were used then observed the machining rate is very poor because quantity of the iron powder was more then more magnetic forces and quantity of the abrasives are also more then more abrasion were done surface finish was poor.

4.3 Effect on surface finish of zinc stearate ratio in magnetic abrasive powder

Zinc stearate ratio in magnetic abrasive powder plays very important role in surface finish by the magnetic abrasive machining. The ratio of zinc stearate in magnetic abrasive powder was select according to the literature 5% weight of magnetic abrasive powder. In this study the quantity of magnetic abrasive powder is 4gm and quantity of the zinc stearate was .20gm in the magnetic abrasive powder. The effect of zinc stearate observed on the internal surface finish of brass pipe by magnetic abrasive machining was very good, Because zinc stearate very fine and soft powder so zinc stearate provide some softness to magnetic abrasive powder then abrade the very smoothly.

4.4 Effect of spindle oil on surface finish while add in magnetic abrasive powder

The ratio of spindle oil in the magnetic abrasive powder was select according to the literature 2ml in the magnetic abrasive powder. In this study the quantity of magnetic abrasive powder is 4gm. The effect of spindle oil observed on the internal surface finish of brass pipe by magnetic abrasive machining was very good, but comparatively to zinc stearate the surface finish was poor. Because the spindle oil leave the black oil layer on surface of the workpiece. After machining then black color oil layer appeared on the surface of the workpiece.

4.5 Effect of mechanical alloyed dry magnetic abrasive powder on surface finish

In this study observed the effect of mechanical alloyed dry magnetic abrasive powder on surface finish was very poor. Because dry magnetic abrasive powder had no lubricant such as zinc stearate, spindle oil etc. then rough abrasion was done on surface of the workpiece. After machining abrasion lines were appeared on surface of the workpiece.

V. CONCLUSION

On the basis of Experimental results of the present work, following conclusions have been drawn regarding the internal finishing of brass pipe with MAF:

Amongst all the available varieties of magnetic abrasives, the mechanical alloyed magnetic abrasives give highest surface finish on most of the work materials. The best surface finish is obtained on brass pipe. It is concluded from the results the Percentage of improvement in surface finish was significantly affected by quantity of abrasives in iron, ball to powder ratio, speed of impellers mounted on agitated shaft and alloying time.

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