Comparison of Performance by Same Abrasive Using Various Samples Prepared by Different Techniques upon Magnetic Abrasive Finishing Machine

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Abstract

Magnetically Assisted Abrasive Finishing (MAAF) processes are most suitable for obtaining quality finish on plane, internal and external cylindrical surfaces of metallic as well as non-metallic materials. These products are highly demanded in modern industrial applications. In spite of remarkable results of MAAF processes, the major constraint towards wide spread use of this technology is the non availability of suitable magnetic abrasives. The available manufacturing techniques for preparing magnetic abrasives are time consuming and complicated. The main aim of the present work is to prepare magnetic abrasives by making use of Microwave Sintering and Mechanical Attrition. Magnetic abrasives are prepared by mixing iron powder and Al_2O_3 sintered by microwave heating followed by crushing and secondly by mechanical alloying. Experiments have been conducted to evaluate and compare the performance of microwave sintered magnetic abrasives and mechanically alloyed magnetic abrasives. It is observed 15% of Al_2O_3 and 85% of iron gave best performance. Best performance for Al_2O_3 and iron was obtained 60 % for microwave sintered and 51 % obtained for mechanically alloyed magnetic abrasives.

Keywords

Mechanical Alloying, Magnetic abrasive Finishing, Microwave Sintering

I. Introduction

Various industrial applications require very high surface finish upto the range of nanometers or even above with the development of modern manufacturing trends. Presently, it is required that the parts, used in manufacturing semiconductors, atomic energy parts, medical instruments and aerospace applications, have a very fine surface roughness. Amongst them, vacuum tubes, wave-guides and sanitary tubes are difficult to be polished by conventional finishing methods such as lapping, because of their shapes. The surface roughness of these tubes affect the performance of the entire system, but the finishing technology for these tubes is very scant in manufacturing fields. Some newly developed non-conventional fine machining processes are used to obtain surface finish upto the required level. Among various nontraditional finishing processes, Magnetically Assisted Abrasive Finishing (MAAF) processes produce very good results in terms of surface finish improvement. In 1938, Harry P. Coats mentioned about this technology. It was then adopted in the Soviet Union, Bulgaria, Germany, and the USA. More extensive research has been done in Japan since 1980. The results of experimental investigations and industrial use, have confirmed that MAM is more efficient and produces a better surface finish than conventional methods of finishing.

In MAAF processes, the surfaces and edge finishing is obtained by creating a magnetic brush formed by magnetic abrasives in powdered form and hold together to each other with the help of magnetic field. Magnetic field can be produced around the abrasive particles either by permanent magnets or by electromagnets. These processes have many advantages, such as self-sharpening of cutting edges of abrasive particles, self-adaptability, controllability and the finishing tool requires neither compensation nor dressing.

II. Magnetic Abrasives

In MAAF processes, surface and edge finishing is obtained by a flexible magnetic abrasive brush in the influence of magnetic field. Magnetic abrasives used in MAAF mainly contain two components i.e. ferromagnetic component and abrasive component, these components should be bonded to each other, to make them ferro-magnetic in nature. Conventional abrasives like aluminum oxide and silicon carbides may be used as well as the costly super abrasives such as cubic boron nitride and diamond may be used for hard to machine materials and any ferromagnetic component like iron may be used for making magnetic abrasives. Most of the abrasives are prepared by chemical reaction or sintering of iron particles and abrasives. The different techniques used for preparing magnetic abrasives are [4]:

1. Sintering
2. Adhesive based
3. Gel Based
4. Plasma based Bonding (Powder melting/ Plasma Spraying)
5. Simple mixing
6. Chemical treatment

III. Introduction About Mechanical Alloying/Attrition (MA)

Mechanical alloying was originally invented as a method to manufacture oxide dispersion strengthened nickel alloys. It is a high energy ball milling process, where alloying is the result of repeated fracture and cold welding of the component particles. Highly metastable materials such as amorphous alloys and nanostructured materials can be prepared by the process. High energy ball milling can also induce chemical reactions. The research area of mechanochemistry was developed to study and utilize these processes. As many mechanical alloying processes involve chemical changes, the distinction between mechanical alloying and mechanochemistry is often arbitrary.

Mechanical Alloying (MA) is a solid-state powder processing technique involving repeated cold welding, fracturing, and re-welding of powder particles in a high-energy ball mill [1]. Originally developed to produce Oxide-Dispersion Strengthened (ODS) nickel- and iron-base superalloys for applications in the aerospace industry, MA has now been shown to be capable of synthesizing a variety of equilibrium and non-equilibrium alloy phases starting from blended elemental or pre-alloyed powders. Mechanical alloying is akin to metal powder processing, where metals may be mixed to produce superalloys. Mechanical Alloying has recently been gathering world wide attention as a means of producing metastable and non-equilibrium alloy phases. There is a large potential for producing amorphous alloys by this technique. Mechanical alloying is also well suited for the production of nano-crystalline materials and oxide dispersion strengthened (ODS) superalloys, as well as for the synthesis of metal nitrides and hydrides.

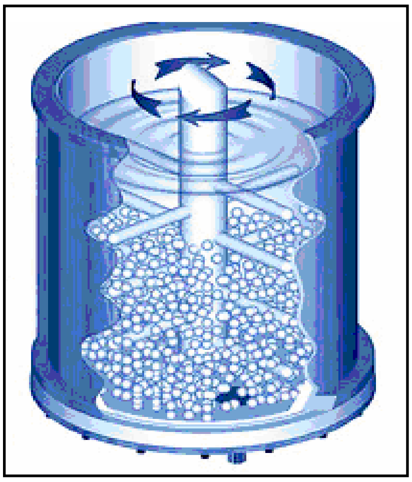

Fig. 1: Attritor Mill

The actual process of MA starts with mixing of the powders in the right proportion and loading the powder mix into the mill along with the grinding medium (generally steel balls). This mix is then milled for the desired length of time until a steady state is reached when the composition of every powder particle is the same as the proportion of the elements in the starting powder mix. The milled powder is then consolidated into a bulk shape and heat treated to obtain the desired microstructure and properties. Thus the important components of the MA process are the raw materials, the mill, and the process variables.

MA is a unique process for fabrication of several alloys and advanced materials at room temperature. It is used to produce alloys and compounds that are difficult or impossible to be obtained by conventional melting and casting techniques. The MA process was developed in 1966 at The International Nickel Company (INCO) as part of a program to produce a material combining oxide dispersion strengthening with gamma prime precipitation hardening in a nickel-based super alloy intended for gas turbine applications. This chapter focuses only on the application of milling for fabrication of engineering materials via MA process. The major process in MA for producing quality powders of alloys and compounds with well-controlled microstructure and morphology is the repeated welding, fracture, and rewelding of the reactant mixed powders. Several types of mills are employed for such purpose. The MA process is successfully performed in both high-energy mills, and low-energy tumbling mills.

IV. Introduction About Microwave Energy

Although the use of microwave ovens is common as a kitchen appliance, the use of microwave energy in processing of metal, polymer and ceramic materials for industrial use is a relatively new development. Microwave ovens are rarely used by orthopedic and dental implant manufacturers, except a few who may use them for drying polymeric materials.

The use of microwaves in ceramic processing is a relatively recent development. They can be applied effectively and efficiently to heat and sinter ceramic objects. The most recent development in microwave applications is in sintering of metal powders, a surprising application, in view of the fact that bulk metals reflect microwaves. However, reflection by a metal occurs only if it is in a solid, nonporous form and is exposed to microwaves at room temperature. Metal in the form of powder will absorb microwaves at room temperature and will be heated very effectively and rapidly. This technology can be used to sinter various powder metal components, and has produced useful products ranging from small cylinders, rods, gears and automotive components in 30-90 min.

Recently, researchers have shown that metals can be heated and sintered by microwaves also. Although it is true that bulk metals reflect microwaves, metals powders are capable of absorbing microwaves at room temperature and being sintered. The main difference between microwave and conventional sintering is the direction of the heat transfer.

Ceramics are not capable of absorbing microwaves at room temperature and thus, need to be heated to a higher temperature such that they can couple with microwaves directly [2]. A process known as hybrid microwave sintering is utilized to render successful sintering of the ceramic body. To achieve this, a combination of high susceptibility (e.g., silicon carbide) materials that can interact with microwaves at room temperature are placed along with the low susceptibility materials in the same thermal chamber of the microwave furnace. Once the microwave is turned on, the high susceptibility materials absorb the microwaves first (since they are capable of absorbing them at room temperature). This will transfer the heat to the low susceptibility materials (in this case, any ceramic material) until the low susceptibility materials can directly couple with the microwaves. At this point, the ceramic materials will be directly sintered using microwave energy.

V. Experimental Conditions

A. Preparation of Magnetic Abrasives By Mechanical Alloying/Attrition (MA)

Mechanical alloying is a commonly used technique to mix different alloying elements into a parent metal powder. In this process of mechanical alloying, two or more number of parent metal powders are mixed in the required composition. And then special types of balls are inserted into the Attritor mill (Planetary Ball Mill) in specific quantity depending upon the quantity of metal powders. Then the mixture is agitated by a stirrer powered by a high speed electric motor. During the agitation process, balls apply high energetic pressure upon the different metal powders, and due to these heavy collisions, cold pressure welding and fracturing of powders occurred repeatedly between the powder particles [3]. Due to this process, powder particles of one parent metal clung into the base metal powder matrix and bonding takes place between them without any bonding agent between them. Steel balls generally used in the attritor were of different sizes and different shapes like cylindrical, spherical, oval etc. So that maximum contact surface and hammering force can be produced. Along with steel, some other materials can also be used like stainless steel, chrome steel, tungsten carbide, ceramic or zirconium oxide. After the proper setup of attritor, stirrer and steel balls, four different compositions of parent metal powders were inserted into the vial of mechanical attritor. Those four compositions of ferromagnetic powder and abrasive powder are given in the table below:

Table 1: Composition of Ferromagnetic, Abrasive and Quantity of Balls

Sample Number	Percentage of ferromagnetic component (Iron powder)	Percentage of abrasive component	Quantity of steel balls
1.	60	40	1 kg
2.	70	30	1 kg
3.	85	15	1 kg
4.	90	10	1 kg

B. Preparation of Magnetic Abrasives By Microwave Sintering

Initially, the samples were placed in a high temperature bearing sintering crucible prepared specially for this purpose. Then compaction of powders is done using a special type of die. Then sintering is done in the microwave sintering furnace to form a solid mass. The melting temperature for Silicon Carbide is above 2400 deg. C and for aluminum oxide it is about 2200 deg. C. The sintering temperature should be half of the melting temperature [13].The sintering temperature therefore was taken as 1250 deg. C. At sintering temperature, the powder particles of both the components get fused into each other. After a suitable period of sintering about 2 minutes, sample is taken out of the furnace as a solid mass and allowed to cool. After complete cooling, the solid mass is crushed and sorted out to get the required size of magnetic abrasive powder. The composition of the two parent powders is kept constant as in case of Attrition.

VI. Experimental Scheme

To assess the performance of microwave sintered magnetic abrasives and mechanically alloyed magnetic abrasives, an experimental scheme was selected. In this experimental scheme, microwave sintered magnetic abrasives and mechanically alloyed magnetic abrasives were used in MAAF to finish work piece pipes of Aluminum material. The Experimental scheme is given in the table given below:-

Table 2: Scheme of Experimentation

Proportion of Samples	Magnetic Field	Abrasive Material	Output parameters
60:40 70:30 85:15 90:10	1 Tesla 1.5 Tesla	Aluminum Oxide	Surface Finish

VII. Results and Discussions

Various experiments were conducted at Magnetically Abrasive Finishing Machine at different machining conditions to find the optimum improvement in surface finish and material removal rate.

Table 3: Percentage improvement in Surface Finish at 1 Tesla

Sample No.	Percentage improvement in Surface Finish			
	Mechanical Alloyed Magnetic Abrasives		Microwave Sintered Magnetic Abrasives	
	Dry	Wet	Dry	Wet
1.	27.45	30.35	38.64	39.35
2.	36.64	37.89	41.62	45.74
3.	48.63	50.35	53.66	59.63
4.	40.46	42.49	43.57	49.46

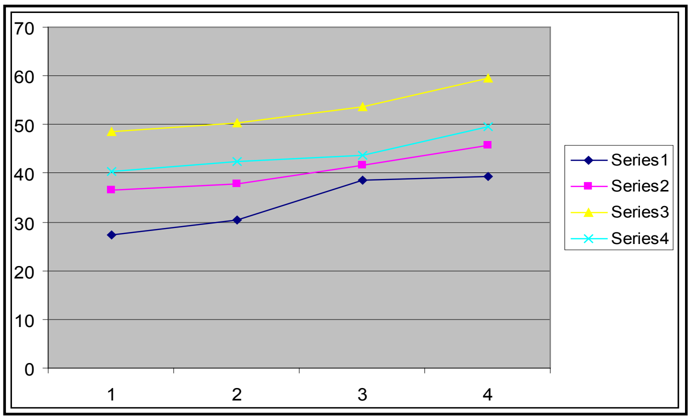

Fig. 2: S.F. Improvement at 1 Tesla

At magnetic field of 1 Tesla, a strong magnetic brush of abrasives formed, which generates more cutting force and ultimately results into better surface finish upon the work piece surface. At higher magnetic field intensity, ferromagnetic component of magnetic abrasive will be attracted by more force against the work piece surface, which applies the force upon the abrasive component of magnetic abrasive powder.

Table 4: Percentage improvement in S.F. (At 1.5 Tesla Magnetic Field Intensity)

Sample No.	Percentage improvement in Surface Finish			
	Mechanical Alloyed Magnetic Abrasives		Microwave Sintered Magnetic Abrasives	
	Dry	Wet	Dry	Wet
1.	25.74	27.36	36.53	38.57
2.	32.55	34.64	39.46	42.35
3.	43.76	45.64	51.57	57.63
4.	33.83	36.26	43.36	46.46

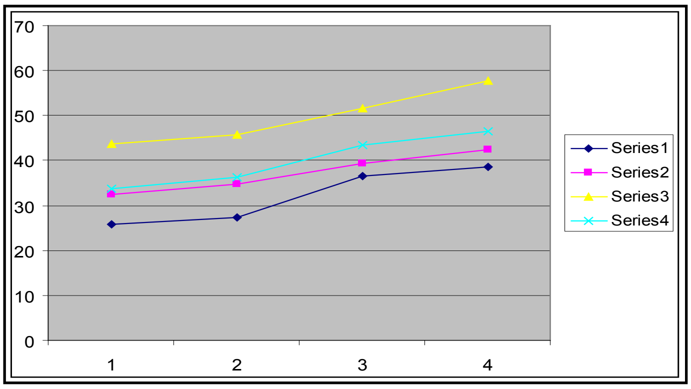

Fig. 3: Graph Between S.F. Improvement and Magnetic Abrasive Composition at 1.5 Tesla

The Table and Figure given above shows the effect of Magnetic Abrasive powder proportion and Preparation technique i.e. mechanical alloyed and microwave sintering upon the percentage improvement in surface finish at magnetic field intensity of 1.5 Tesla. But now the performance is decreased as compared to that of a 1 Tesla. This is due to the fact that at higher magnetic field, a much stronger magnetic brush of abrasives is formed, which generates more cutting force which causes more erosion upon work piece surface and scratching of work piece takes place. And ultimately results into poor surface finish upon the work piece. So it is concluded from these results that the best surface finish results obtained at 1 Tesla magnetic field intensity and at wet condition of magnetic abrasive powder at 400 rpm rotational speed of work piece for both types of magnetic abrasive powders. These are the optimum results of the experimentation.

VIII. Conclusion

Present work was undertaken for the development of an alternative magnetic abrasive with the aim of exploring its utility for magnetically assisted abrasive finishing machine and also to develop cost effective magnetic abrasives by two different techniques. On the basis of experimentation performed, following conclusions have been drawn:

The newly developed magnetic abrasives by mechanical alloying and microwave sintering are able to fine machine the tubes of Aluminum.

The maximum percentage improvement in surface finish upon stainless steel has been obtained as 60% (approx.) for microwave sintered.

The best improvement in surface finish was obtained by using composition of 85% iron and 15% abrasive by weight for both types of magnetic abrasives.

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