DEVELOPMENT AND SYNTHESIZATION OF MRP FLUID AND MR FINISHING

A Major Project

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For the award of the degree of

MASTERS OF TECHNOLOGY

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By

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CERTIFICATE

Date:-_____

This is to certify entitled "DEVELOPMENT AND SYNTHESIZATION OF MRP FLUID AND MR FINISHING" BY Miss. PRIYANKA is the requirement of partial fulfilment for the award degree of Master of Technology in Production Engineering at Delhi Technological University. This work was completed under our supervision and guidance. He has completed his work with utmost sincerity and diligence. The work embodied in this project has not been submitted for the award of any other degree to the best of my knowledge.

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ABSTRACT

The project is focused on the development and characterization of magnetic abrasive particles (MAPs) using solid phase sintering method. The Plain iron powder of 300 mesh size with 20 Volume% and 25 volume% SiC abrasives of 3000 mesh size have been mixed uniformly in the ball mill. The pellets of 5 gm each have been prepared at 8 ton pressure using cylindrical die with dimension 7 mm diameter and 50 mm length. After preparation of all pellets, the pellets were sintered in the tubular furnace in the inert atmosphere of argon at 1000^0C in a proper sintering cycle using solid phase sintering method. After sintering, the sintered pellets were crushed in ball mill to obtain the required magnetic abrasive particles. The particle characterization has been done on scanning electron microscope to understand the morphology of the particles and different elemental composition exist.

The magnetorheological polishing fluid has been synthesized with 45 volume% magnetic abrasive particles (MAPs) and 55 volume% base fluid. Another sample is prepared with 20 volume% plain iron powder, 25 volume% silicon carbide abrasives of 3000 mesh size and 55 volume% base fluid.

After synthesization of MRP fluid, the experiments have been conducted on ball end magnetorheological finishing (BEMRF) tool. In magnetorheological finishing, the finishing is carried out in controlled atmosphere by controlling the applied magnetic field. The initial surface roughness before the experiments and final surface roughness after conducting the experiments has been measured with Talysurf using 4 mm data length and 0.25 mm cut off length. Then percentage reduction in surface roughnes (%ΔR_a) has been calculated and compared with %ΔR_a obtained by conducting the experiments with unbonded magnetic abrasive based MRP fluid and found better results.

KEY WRDS: Solid Phase Sintering, SEM, EDS, MRP fluid, MRF.

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CHAPTER 1 INTRODUCTION

From the ancient age to this modern era requirement of strinct dimensional tolerance and good surface quality is always a matter of concern. Therefore for obtaining quality of surface finish various finishing technique has been developed which are classified mainly under two category i.e. traditional and advanced. in traditional approach where abrasive are fixed geomatry cutting tool processes like honning ,lapping, grinding but there are some constraints in traditional approach that they are enable to finish complicated and hard, brittle surface like atomic energy parts , medical instruments and aerospace parts need precise surface finish. Therefore for such complicated geomatry advanced finishing technique were developed called Magnetic Field Controlled machining processes. some of the magnetically controlled machining processes are Magnetic Abrasive Finishing (MAF), Magnetorheological finishing(MRF), and Magnetorheological abrasive flow finishing (MRAFF).

In these processes , the force acting on the workpiece surface through the abrasive particle is controlled externally by changing the magnetic flux density , also unlike the conventional finishing processes like lapping ,grinding etc. in advanced micro-nano machining processes are loose flowing abrasive i.e. abrasive orientation and its geomatry at the time of interaction with workpiece is not fixed . these magnetically controlled processes are produced the surface finish of the order of sub-nano meter level by using the nanometer size of abrasive particle with precisely controlled forces. Magnetic abrasives particle are the most important parameter in magnetic abrasive finishing. magnetic abrasive particles consists of hard abrasive particles with ferromagnetic particles and when magnetic field is applied in the required machining area , abrasive particles stic to ferromagnetic particles will follow the ferromagnetic particle motion, and thus finishing is done. Magnetic abrasive particles used in magnetic field assisted process are also classified under unbonded and bonded category . bonded where loose mechanical mixture or alloying and easy for mixing requires less cost but there is loose adhension between the particles and chances that the ferromagnetic particle may get detach,especially while finishing complex surfaces, while in bonded one the abrasive particle are synthesized using solid phase sintering and thus due to presence of elevated temperature bond formation take place between the abrasives particles [1].

1.1 Magnetic Abrasive Finishing

MAF is a process for mainly for finishing hard and brittle materials. In MAF ferromagnetic particle sintered with fine abrasive particles and finishing action has been controlled by magnetic field across the machining gap b/w workpiece and electromagnetic pole. Magnetic field acts as a binder and retains ferromagnetic abrasive particle in machining gap. Normal component because of magnetic force is responsible for abrasive penetration in the workpiece material while rotation of the ferromagnetic abrasive brush intact to north pole results in tangential force. Tangential component of magnetic force is mainly responsible for removal of work material in the form of small chips. Flexible magnetic abrasive brush has mutiple cutting edge and it behaves like a multi-point cutting tool to remove material from workpiece in the form of tiny chips, also due to the axial rotational motion surface and edge finising is done at much faster rate and efficiently. Finising rate is mainly depend upon w/p circumferential speed, density of magnetic flux ,working gap b/w the pole and w/p, workmaterial properties their size ,type and volume fraction of abrasives

Other than rotation axial motion is for finising surface and edge at much faster rate with better quality. The process is highly efficient and the material removal rate and finishing rate depend upon the workpiece circumferential speed, magnetic flux density ,working gap, workmaterial properties, size ,type and volume fraction of abrasives.

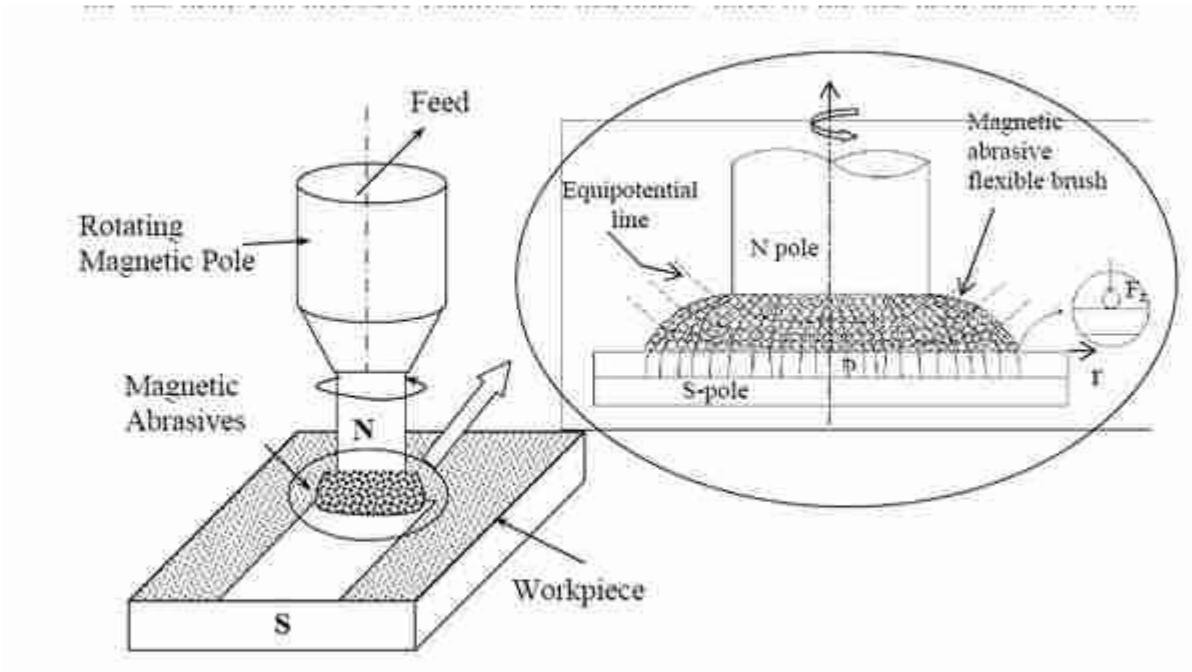


Fig. 1.1 shows the schematic diagram of Magnetic Abrasive Finishing [1].

1.2 Magnetorheological finishing

It is based upon smart fluid called Magnetorheological fluid is tha mixture of micro-sized magnetizable particle (CIPs) dispersed in a non-magnetic carrier. in absence of magnetic field, MR-fluid have behavior like Newtonian flid ,while in the presence of external magnetic field acts as non-Newtonian fluid and Magnetorheological effect observed to MR-fluid. The normal magnetic force is results in abrasive pentration in workpiece and because of relative motion b/w abrasive particles and work material material removal take place. For deforming and breaking the chains which is provided by microstructure transistion as a control yield stress and this yield stress provides resistance to applied shear strain. On increasing the magnetic field fluid strength increses non linearly because of ferromagnetic nature of abrasive particle and due to the magnetization behavior in various parts of particles which occur non uniformly, While on the removal of applied magnetic field abrasive particle acts as newtonian fluid. MRF process has many applications in finishing of optical glasses, glass ceramics, plastics and non-magnetic material.

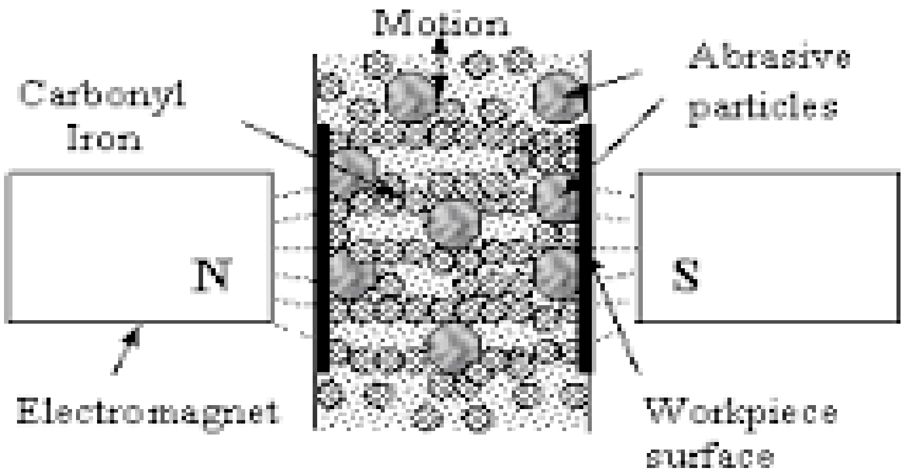


Fig. 1.2 shows the diagram of Magnetorheological Finishing [2].

1.3 Magnetorheological Abrasive Flow Finishing

MRAFF is the mixture of MR-Polishing fluid with fine abrasive particle immeresed into it. MRAFF has been developed by combining both AFF and MRF . Abrasive particles mixed with viscous base fluid acts as self deformable stone and abrading forces is least controlled through external means . MRAFF process can able to precisely finish the complicated parts. MRAFF process has better controllability than AFF process because of control on abrading medium rheological behavior by magnetic field. MRAFF process comprises MR-polishing fluid having fine abrasive particles dispersed in it.

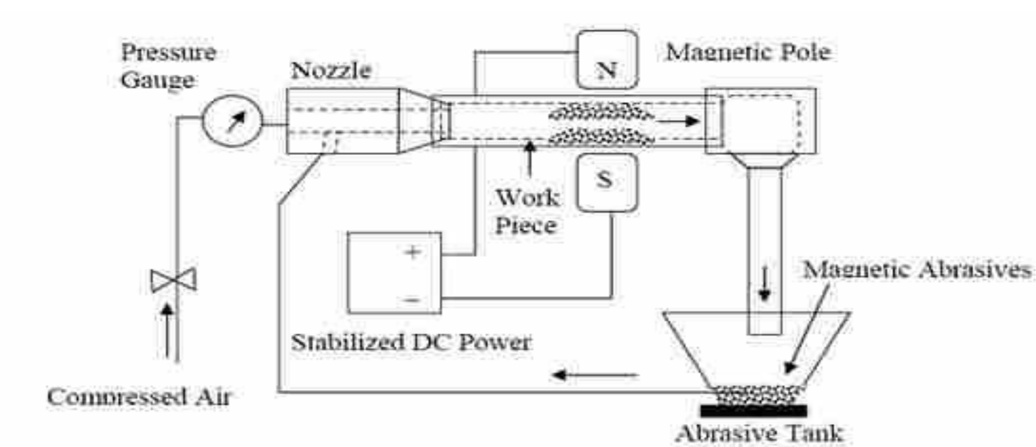


Fig 1.3 shows the magnetorheological abrasive jet machining [1].

1.4 Magnetic Float Polishing

It is for flat, cylindrical and comlicated three dimensional parts surface finishing. MFP technique is based on ferro-hydrodynamic behavior of magnetic fluid in which non-magnetic float and abrasive particles suspended in it because of magnetic field. force applied by the abrasive particle is depend upon the magnitude of magnetic field which is very small and effectively controlled [2].

1.5 Powder Metallurgy

Powder metallurgy is a continuously rapidly evolving technology embracing most metallic and alloy materials, and a wide variety of shapes.PM is a highly developed method of manufacturing reliable ferrous and non ferrous parts. It involves blending (mixing), compacting and sintering. It is a technique for forming precision metal components from metal powders. Powder metallurgy is a technique in which metal powder or alloys are mixed in definate proportion and after mixing of metal powder compacted in desired shape at room temperature then sintering is been done on the compacted pallets in a high temperature tubullar furnace on a specified sintering cycle. PM process is used for making highly precise component by mixing of metal powder or alloys. PM process is preferred over casting and other metal forming techniques also the cost of devloping the component of required shape and dimensional tolerances is lower and results in lower scrap and less processing time ,also meet the   adequate physical and mechanical properties while meeting the desired performance characterstic also the volume and production rate is quite high in powder metallurgy technique.

In the powder metallurgy process following steps are followed:

i) Mixing : homogenous mixing of metal powder or alloys is done .

ii)Compacting : in compacting mixed powder is pressed in die on the reqiured pressure by hydraulic jack at a pressure range of 100 to 1000 MPa, so that mixed powder acquire the required shape and size at room temperature. In process loose powder is densified and compacted.

iii) Sintering : is a heat treatment applied to a powder compact in order to impart strength and integrity. The temperature used for sintering is below the melting point of the major constitute of the Powder Metallurgy material. After compaction , neighbouring powder particles are held together by cold weld which give the compact sufficient " Green strength" to be handled. At sintering temperature, diffusion processes causes necks to form and grow at these contact points.There are two necessary precursors before this "solid state sintering " mechanism can take place :-

- Removal of the pressing lubricant by evaporation and burning of the vapours
- Reduction of the surface oxides from the powder particles in the compact.

CHAPTER 2 LITERATURE REVIEW

The various researches done on the magnetic abrasive finishing and powder metallurgy by number of researchers is given in this section. Description of various research papers studied and their description is given in this present section by different researchers which have done remarkable work in the field of Magnetorheological finishing (MRF) and sintering, they investigated various types of parameters involved in MRF. Below are the details of the research paper review.

Singh D. K. et al [4] have given a comprehensive overview of the dominant role of magnetic force in forming the abrasion pressure and magnetic abrasive brush. This paper gives the idea of microscopic changes in the surface texture resulting from MAF process to characterize the behaviour of magnetic abrasive particles, surface roughness, atomic force, and SEM analysis gives the wear pattern of the finished surface.

Jain V.K. et al [5] have given a comprehensive overview of classification of finishing technique i.e. on the traditional and advanced. In traditional one has the fixed geometry cutting tool process while in advanced abrasive orientation and geometry is not fixed at the time of interaction with work piece. Experimental results show that surface finish of the order nano level of nano size of abrasive particle with precisely controlled forces. Micro-nano machining (MNM) process can be controlled by controlling the magnetic field which further controls the forces acting on abrasive particle and amount of material removed. MNM processes are capable of producing very low value of surface roughness of the order of nano meter. It is concluded from the experiments that effective control of forces and finer abrasive particle results in effective controls of material removal rate and help in rationalization of the observation also explain the reason for use of magnet have slot in it while the area of slot has non- machining zone and use of pulse D.C. power supply over smooth D.C. power supply is more beneficial.

Shukla Asit et al [6] proposed magnetic abrasive finishing technique which can produce surface finish in the range of 0.04-1.00 um and dimensional accuracy up to 0.5 um. In order to predict the effect of various machining parameters on material removal rate, tool wear rate and surface roughness value so it is important to model and optimise these machining parameters. In the paper process parameter of a MAF process is optimized using a very effective evolutionary algorithm called genetic algorithm (GA). Response Surface Methodology is applied for developing the models using the techniques of Design of experiments and central composite rotatable design was used to plan the experiments. They have concluded that Response of magnetic abrasive finishing process can be controlling process parameter variables, which are current (magnetic flux density), machining gap, abrasive grain size and no of cycle.

Jain V. K. et al [7] have been studied Magnetic abrasive finishing is advanced method for surface finishing where work piece is kept between the magnets and cutting force has been controlled by working gap and magnetic field between the magnets. MAF setup has been designed for finishing cylindrical work pieces. An unbonded powder has been prepared by uniform mixing of iron powder, abrasive powder and lubricant and investigate the rate of material removal and improvement in surface finish by changing the working gap and circumferential speed of workpiece and found that material removal has been decreased by increment in working gap and decrement in circumferential speed of work material.

Mulik S Rahul et al [8] has studied the method to nano level of finishing using magnetic abrasive finishing assisted by ultrasonic vibration in a very short time interval. In this experiment an experimental setup has been introduced which mainly focussed on five important parameter supply voltage, mesh no. of abrasives, magnet rotation, weight percentage of abrasives, on time of pulse should be selected and when unbonded SiC are used as abrasives for finishing the steel work material surface value change is measured and from the experiment it has been found that with ultrasonic assisted MAF has better finishing capability over MAF process for the same working conditions and surface roughness value of the order of 22 nm is obtained in a very short duration on steel work piece. Along with the surface roughness measurement characterization of magnetic abrasive powder is also done with SEM and atomic force microscopy to obtain the surface texture and finishing mechanism.

Wang Yan et al [9] comprehensive has given a comprehensive overview of the magnetic abrasive finishing on inner surface and proposed for producing highly finished inner surfaces of tubes. This paper gives the process principle and the finishing characteristics with unbounded magnetic abrasive on internal tubing finishing are described. MAF setup has been developed to finish mainly for brass, stainless steel and Al alloys. Experiments result concluded that different finishing parameter such as polishing speed, magnetic abrasive supply; abrasive material, magnetic abrasive manufacturing process and grain size have critical effects on material removal rate (MRR).

Yamaguchi Hitomi et al [10] studied the magnetic abrasive finishing for inner surfaces which include clean gas or liquid piping. In this paper has investigated the effect on microscopic structure results from processing also provides the understanding of mechanism of the process and material removal for this paper gives the aim of this paper is for producing highly finished surface of tubes in critical application. Proposed magnetic abrasive finishing is used for producing highly finished inner surfaces of tubes used in critical applications and examines the microscopic changes in the surface texture resulting from processing. In addition to the surface roughness measurement, atomic force and scanning electron microscopy were used to characterize the material removal process and provide a fundamental understanding of the process mechanism concluded that surface texture shows that the process is an accumulation of micro scratches from the abrasive cutting edges, generating a characteristic magnetic abrasive finished surface. Moreover, surface is finished by removing the material from not only peaks but also from valleys of the surface, as far as cutting edges of the magnetic abrasive are introduced into the valleys.

Yin Shaohui et al [11] have given a comprehensive overview of detailed study of automatic precision method for 3D surfaces where high efficiency and high surface finish is desired which is being failed to fulfil by present method. So this paper is a study of vibration assisted MR polishing and aim of the research work is to characterize the work material vibration effects on the magnetic field, polishing pressure, abrasive behaviour and performances of polishing in three mode of vibration and explained the mechanism of machining.

Mori T et. al.[12] investigate the planar process on a non-magnetic work material for understanding the mechanism of MR polishing . In this process a magnetic abrasive brush formed between magnetic pole and workpiece, where summation of three kinds of energy necessary for magnetization of abrasives is to be minimum. Two forces were developed during the process one is normal force that pushes the abrasive on the brush end in order to intend the abrasives onto the workpiece material surface is generated because of the magnetic field while other one is the tangential force is the returning force developed when the abrasive deviates from the magnetic balance point. Thus the magnetic abrasives polished the work surface.

Palwinder Singh et al. [13] have introduced an MAF process for finishing intricate parts in complicated geometry. In this research paper mechanism for finishing intricate parts using sintered magnetic abrasives which is the mixture of Al_2O_3 and ferromagnetic particles. Experiments results show that the measurement of surface roughness gives the effect of the behavior of abrasives on surface and value of surface finish is being analysed by percentage improvement of surface roughness. It is also concluded from the experiment that maximum PISF found is 95% while minimum value of surface roughness is 0.05μm R_a which is characterization through X-ray Diffraction technique.

Shinmura T. et al [14] have given the process and method of Magnetic abrasive finishing processes and it is concluded from the experiments that sufficient pressure is applied by abrasive brush for finishing the work surface for the corresponding magnetic field while strength of magnetic field is affected due to type, size, shape of work material

Shinmura T et al. [15] also suggested a MAF process for internal finishing in which iron abrasives with small magnetic abrasives of suitable diameter and wt. % generate high pressure for obtaining precise surface finish.

Yin S. and Shinmura T. [16] studied the finishing and deburring on magnesium alloy with vertical assisted vibration MAF. In this method on the feeding table a vibrating table is clamped where workpiece is fixed so that it is vibrate in vertical direction by cam motor. The experimental results reveal that high quality surface is obtained by magnetic abrasive finishing and more material is removal take place with MAF process over brass and stainless steel in a short time interval, also with vibration finishing efficiency has been increased.

Yamaguchi H. and Shinmura T. [17] proposed an MAF process for precisely finishing of complicated internal parts using a pole rotation system. From the experiments it is concluded that smooth rotary motion of abrasive particles produces fine surface finish because of uniformly direction of machining in one direction by cutting edges of abrasives increases the material removal.

Yamaguchi H. and Shinmura T. [18] proposed a new magnetic field assisted technique for finishing of inner surfaces with the mixture of ferrous particles and conventional abrasives and concluded that finished surface is depend upon volume of lubricant, which affects the abrasive contact against the surface, on the ferrous particle size, which changes finishing force acting on abrasives and on grain size of abrasive which control the depth of cut. And by changing this condition a nano level of surface finish is achieved and imparts minimum residual stress to the surface.

Yan B. et al. [19] have given the comprehensive overview of Electrolytic magnetic abrasive finishing process. The aim of this research paper is to produce an oxide film which removes the metal film easily while finishing and also describes process principle, mechanism of material removal. On the basis of results obtained concluded that electrode gap, density of magnetic flux, current of electrolyte should be correctly chosen to create the oxide film and also formation of oxide film and workpiece revolution rate should be matched. In the condition of high current and low rate of work material revolution makes easy extraction of the steel abrasives. Finishing efficiency can be improved by increasing the electronic current and rate of revolution of workpiece also the surface roughness improves greatly. But the electrolytic current should be optimum chosen as high current disturbs the magnetic field and extracts the steel abrasives from working gap.

Singh D.K. et al [20] have studied the Taguchi procedure in finding out the parameter which affects the surface quality and concluded from the experiments that voltage is the major factor which affects the surface quality of work material and the other factor which affects is working gap ,although grain size and rotational speed is also there in row but their effect is negligible. From the experiments it is found that high voltage, low working gap, high rotational speed, and large grain size improves the surface roughness greatly. Models of linear regression were developed to show the change in surface roughness value, magnetic force, cutting forces increasing with increase in voltage and working gap.

Girma B.et al. [21] have studied the MAF process for analysing surface roughness and material removal in plain surface. It is found from the experiments surface roughness value is greatly influence by grain size of abrasives, size-ratio, feed rate, current. Coarser the grain size more is the surface roughness value.

Jha S. and Jain V. K. [22] have introduced the highly precisely finishing method for complicated geometry using smart MR polishing fluid. MR polishing fluid consists of CIP, SiC abrasive mixed with base fluid which is the mixture of grease and mineral oil. Under the application of magnetic field the rheological behaviour of MR polishing fluid has been changed and controls the finishing forces and surface finish. An experimental set up has been designed which consists of MR-polishing fluid cylinders, hydraulic actuator, fixtures and electromagnet to study performance and process characteristic. Experiment performed at different magnitude of magnetic field to study the effect of magnetic field on surface finish and found that when no magnetic field is present there is no appreciable change in surface finish. More surface finish is been achieved with increased in magnetic field.

Mori T.et al [23] studied the mechanism of magnetic abrasive polishing in which three kinds of energy necessary for magnetization of abrasives. A normal force that pushes the abrasives on the brush end to be indented into material surface is generated by the magnetic field. A tangential force acts to be the returning force created when abrasive deviates from the magnetic balance point and hence abrasives particles are expected to polish the work material surface gently.

Wang Y. and Hu D. [24] also gives a magnetic abrasive finishing for inner surfaces. In this paper Principle of mechanism and finishing characteristic of loose magnetic abrasives and examined that magnetic field distribution defines the magnetic abrasive configuration and the magnetic force acting on abrasive. It concluded that material removal increases with the increasing the rotational speed of magnetic pole, optimum abrasive particle size, magnetic abrasive volume and examined that once the surface roughness is saturated , the increase in MRR gradually slow down and reach to a stable value.

Yamaguchi H. et al [25] proposed the factors affecting the condition required for successful uniform internal finishing .And concluded that the pole arrangement can be adjusted to control the strength of the magnetic field. Stronger the field results in proper rotation of more type of mixed type magnetic abrasive. Size of particle controls the force which further controls the surface finishing.

Lin C.T et al [26] employs CNC machining centre for magnetic abrasive finishing and the operations were performed by Taguchi. After the analysis of the Taguchi method the factors which affects the surface finish are working gap, feed rate, and abrasives and above all factors working gap has the largest impact on surface quality.

Kwak J. S [27] proposed a method for improving the magnetic flux density in the surface finishing of non-ferrous materials and installed a permanent magnet at opposite side of work piece to be machined is evaluated by computer simulation and experimental verification.

Chang G. W. et al [28] describe the process and the finishing characteristics of unbounded magnetic abrasive. The unbounded magnetic abrasive is a mixture of SiC abrasive particle and ferromagnetic particle with a lubricant.

2.2 Research Gap-

From the literature survey, it has been observed that existing finishing processes can be used at somewhat low rotational speed. It is due to the fact that the non magnetic abrasive particles are thrown away from the working area due to high centrifugal force during finishing and reduces the finishing efficiency of the process. The non magnetic abrasive particles are embedded in between iron particles when they form chain structure in the presence of magnetic field. These iron particles have the limit to hold the non magnetic abrasive particles upto certain value of rotational speed of finishing tool during the finishing process. After this critical value of rotational speed of finishing tool, the non magnetic abrasive particles start to throw away from the working area during finishing and reduce the productivity. To overcome this challenging problem, the abrasive particles have been bonded on the surface of plain iron powder with the help of sintering process. These bonded abrasives have been called as magnetic abrasive particles (MAPs) in the present work.

2.3 Research objectives-

i) Development of magnetic abrasive particles (MAPs) using solid phase sintering method.

ii) Characterization of magnetic abrasive particles with scanning electron microscope (SEM) and energy dispersive spectroscopy (EDS) analysis.

iii) Synthezation of magnetorheological ploshing (MRP) fluid.

iv) To conduct the experiments with synthesized MRP fluid and unbonded magnetic abrasive based MRP fluid.

v) To compare the results

CHAPTER 3 PROBLEM DESCRIPTION

3.1 Sintering

The thermal treatment of powders or alloys of metals and compacting the solid mass of material with the help of heat or pressure at a temperature which is below the melting point of the main constituent, for increasing its strength by bonding together particles. Sintering is a method objects are prepared from powder; by heating the material at a temperature which is below its melting point till all its particles get adhere to each other. Sintering controls both Densification and grain growth. Densification reduces porosity and making it more dense. Grain growth is the process which increses the grain boundary motion and also increase the average grain size. Sintering reduces the porosity and enhances properties like strength , electrical conductivity, translucency and thermal conductivity. During the firing process , atomic diffusion takes placees , starting from the formation of necks between powder to final elimination of small pores in the process end. The driving force for densification is change of free energy from decreasing the surface area while lowering the surface free energy through the replacement of solid- vapour interfaces. After compaction , neighbouring powder particles bind together through cold weld which provide compact strength also known as Green strength. At sintering temperature, due to diffusion necks form and grow at those contact points. during solid state sintering mechanism two things happen one is removal of the pressing lubricant through evaporation and burning of the vapours and second is reduction of the surface oxides from the powder particles. In the solid state sintering only solid phases are there at the sintering temperature, in Liquid phase sintering Small amounts of liquid phase are present during sintering, while the third stage Reactive sintering where particles reacts to form new product. Sintering is also categorized into four categories:

i) Preparation of Powder where particle size, their shape and size distribution are important factor.

ii) Second phases distribution.

iii) Consolidation of powder which depends upon green density, Pore size distribution.

iv) Firing/Sintering is a process where sintering is done in high temperature furnace where heating rate, temperature, time, applied pressure are the controlling parameter.

Atomic diffusion takes place during sintering welding and areas formed during compaction grows till lost in each other completely. Recrystallization and grain growth will follow after the compaction; pores become rounded and hence decrease the total porosity and volume. During pressing powder particles has been brought together and deformed at the contact point. At elevated temperature the atoms move more easily and fastly along the surface of particle called as Diffusion, new crystallites form at the contact point and hence original interparticle boundaries will disappear or become as grain boundaries called Recrystallisation. The total internal surface area after pressing is reduced through sintering. The main possible driving forces for sintering are curvature of the particle surfaces, externally applied pressure, chemical reaction.

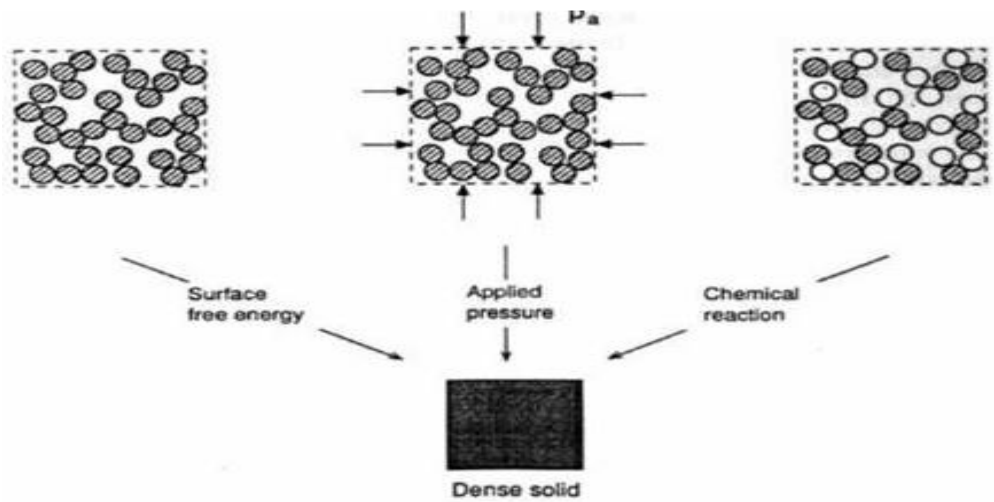


Fig. 3.1 shows the different stages of sintering [3]

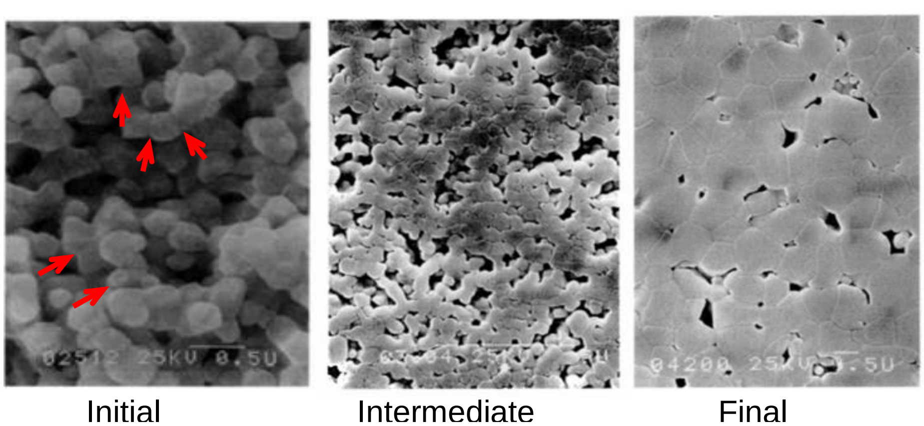


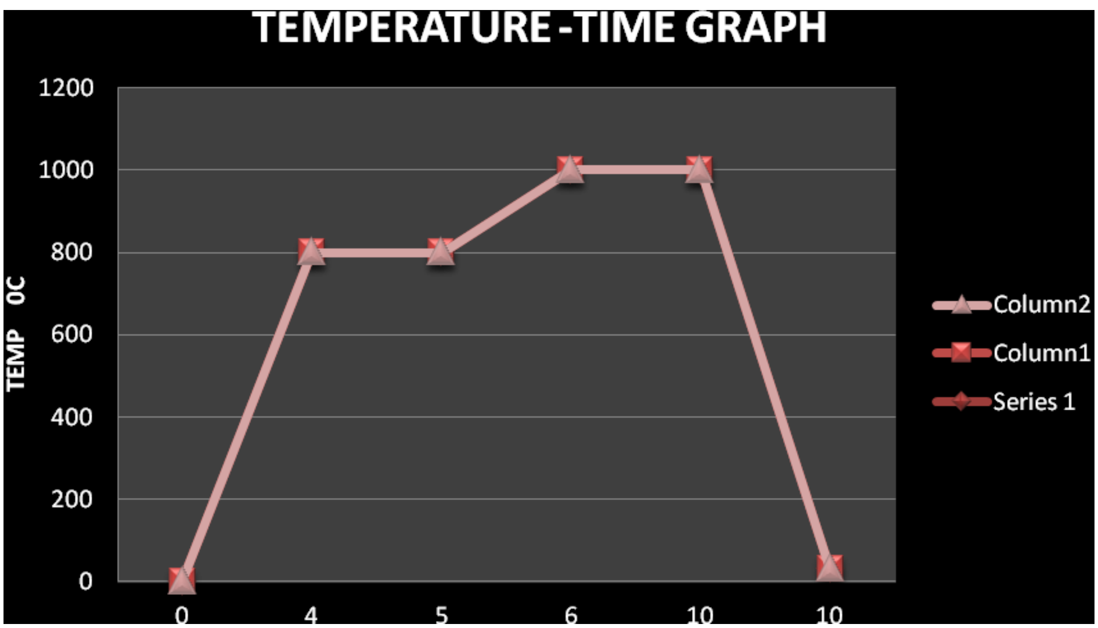
Fig. 3.2 shows the mechanism of sintering [3]

3.1.1 Sintering Procedure

A mixture of binder, water and ceramic powder is pressed into a mold to form a green body (unsintered item). The green compact is placed on a mesh belt and moved slowly through the sintering furnace. In the preheat zone, the lubricant volatilizes, leaves the part as a vapor, and is carried away by the dynamic atmosphere flow. The temperature within the furnace rises slowly in the preheat zone until reaching the actual sintering temperature. It remains essentially constant during the time at that temperature, and proceeds into the cooling zone where the drop in part temperature is controlled.

3.1.2 Sintering cycle

As the parts travel through the furnace, the temperature cycle results in changes in composition and microstructure. In the hot zone metallurgical bonds develop between particles and solid state alloying takes place. The microstructure developed during sintering determines the properties of the part.



TIME (Hrs)

Fig. 3.3 shows the solid state sintering cycle

3.2 Development of magnetic abrasive particle

The aim of the experiment is to development and characterization of magnetic abrasive particle. Process of powder metallurgy is carried out to produce pellets of magnetic abrasive powder and then solid phase sintering is done and after that the sintered pellets is crushed in ball mill in order to obtain the micro sized particle of magnetic abrasive powder. Then through the process of EDS and Scanning Electron Microscope (SEM) techniques testing of mechanical properties and characterization of magnetic abrasive powder is carried out.

3.2.1 Powder selection and mixing

To make magnetic abrasive powder, selection of plain iron carbon of 300 mesh size and silicon carbide is mixed well for preparing the magnetic abrasive powder. Then these two powders is uniformly mixed in the ball mill with 20 volume% of plain iron powder and 25 volume % of SiC abrasives for 60 minutes.

Fig. 3.4 Ball Milling Machine

3.2.2 Compaction

For compacting purpose use 12 ton capacity hydraulic jack with 13 mm die. For compacting purpose take 5 gm powder for making the pallet in die and compressed it with hydraulic jack at 8 ton pressure for 25 minutes. Total 25 pallets are prepared for solid phase sintering.

Fig 3.5 Hydraulic Jack with die

3.2.3 Sintering

Solid phase sintering is done in High temperature tube furnace ,having capacity upto1600^{0}C . Inert environment of argon gas is used to avoid any kind of atmospheric comtamination. Furnace atmosphere and temperature are the two most important factors involded in sintering. Rate of change of properties is greatly increases by increasing the sintering temperture. 1000^{0}C is maximum temperature for solid phase sintering .heating rate is 200^{0}C/hour.

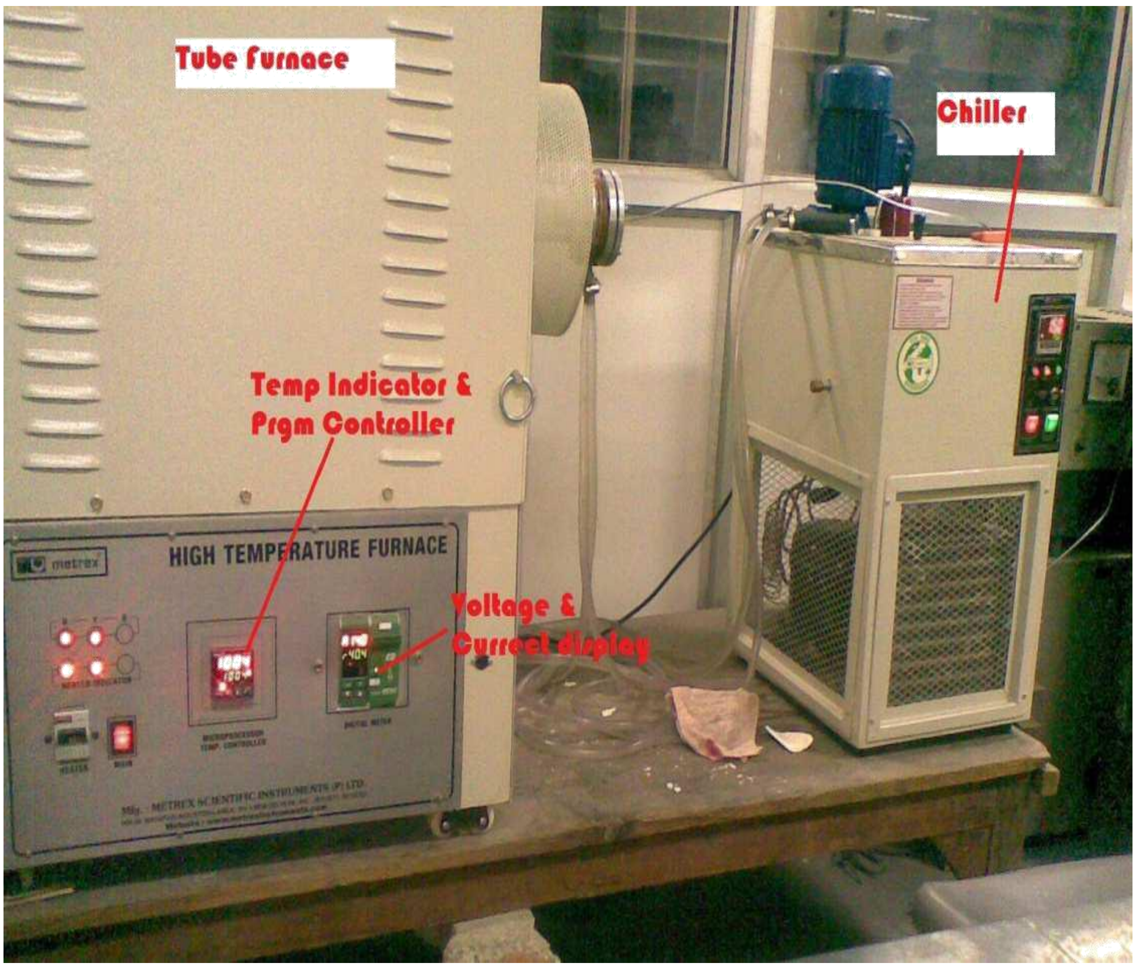


Fig 3.6 High Temperature Tube Furnace

Fig. 3.7 Sintered Pellets

3.3 Characterization of Sintered Samples

The sintered samples were studied for phase analysis of SIC and plain iron powder , density, mechanical properties, and micro structural study by optical micro structure and SEM.

3.3.1 SEM ANALYSIS

Microstructure and morphological characteristics of coatings were obtained by SEM and with the help of Energy Dispersive Spectroscopy (EDS) calculate the % composition of metal and SIC in the mixture. EDS shown the peaks of maximum energy where most X-rays have been received.

Fig 3.9 Scanning Electron Microscopy (SEM)

3.3.2 EDS Analysis

Various elemental composition present in the mixture is being identified through EDS process. It gives the percentage values of different composition present in the mixture. EDX analysis of the composites to confirm the existence of iron, silicon, and oxygen. For EDX purpose accelerated Voltage was used 15.0 KV and take off angle 54.6 degree.

3.4 Synthesis of MRP fluid-

In synthesis of fluid two types of MRP fluid has been prepared .first mixture has been prepared by mixing 45 volume % of magneic abrasive fluid bonded powder and 55 volume % of base fluid.

Composition of bonded abrasive powder in 60 volume % of MRP fluid

Plain Iron composition   60*20/100= 12 ml

12*7.9=94.8 gm

95 gm

SiC composition of 3000 mesh size = 60*25/100 = 15 ml

15*3.22(density of SiC)

48.3 gm =49 gm

Base Fluid composition = 60*55/100= 33 ml

33* 0.812 (density of base fluid)

26.796 gm =27 gm

Firstly plain iron powder and SiC has been mixed together in ball mill homegenously. After mixing powder pellets has been prepared by compacted under 8 ton of pressure in the hydraulic jack then pellets sintered in high temperature tubullar furnace on 1000^0C. after sintering pellets are again crushed in ball mill until the required magnetic abrasive powder is obtained. Then this magnetic abrasive powder is mixed uniformly with the required amount of base fluid.

And second sample has been prepared by mixing plain iron of 300 mesh size with 20 volume % and 25 volume % of SiC of 3000 mesh size sintered powder and 55 volume % of base fluid. Composition of unbonded sample in 15 ml of fluid

Plain Iron Composition = 15*20/100=3 ml

=3*7.9 (density of plain iron)

=23.7 gm

SiC Composition (3000 mesh size)= 15*25/100 =3.75 ml

= 3.75* 3.22(density of SiC) =12.075 gm

Composition of Base Fluid= 15*55/100 = 8.25 ml

=8.25*0.812(density of base fluid) = 6.699 gm

3.7 Experiment Conducted

For Finishing of 3D geometry like grooves, slots, intricate shapes and projections, or complicated parts in depth profiles on workpiece surfaces is a very difficult for the existing advanced finishing processes. To overcome this ball-end magnetorheological (MR) finishing tool is developed for finishing both type of ferromagnetic and non-ferromagnetic materials. The smart behavior of MRP fluid is utilized to precisely control the finishing forces and hence the final surface finish. A computer controlled experimental setup is designed and developed to study the process characteristics and performance.

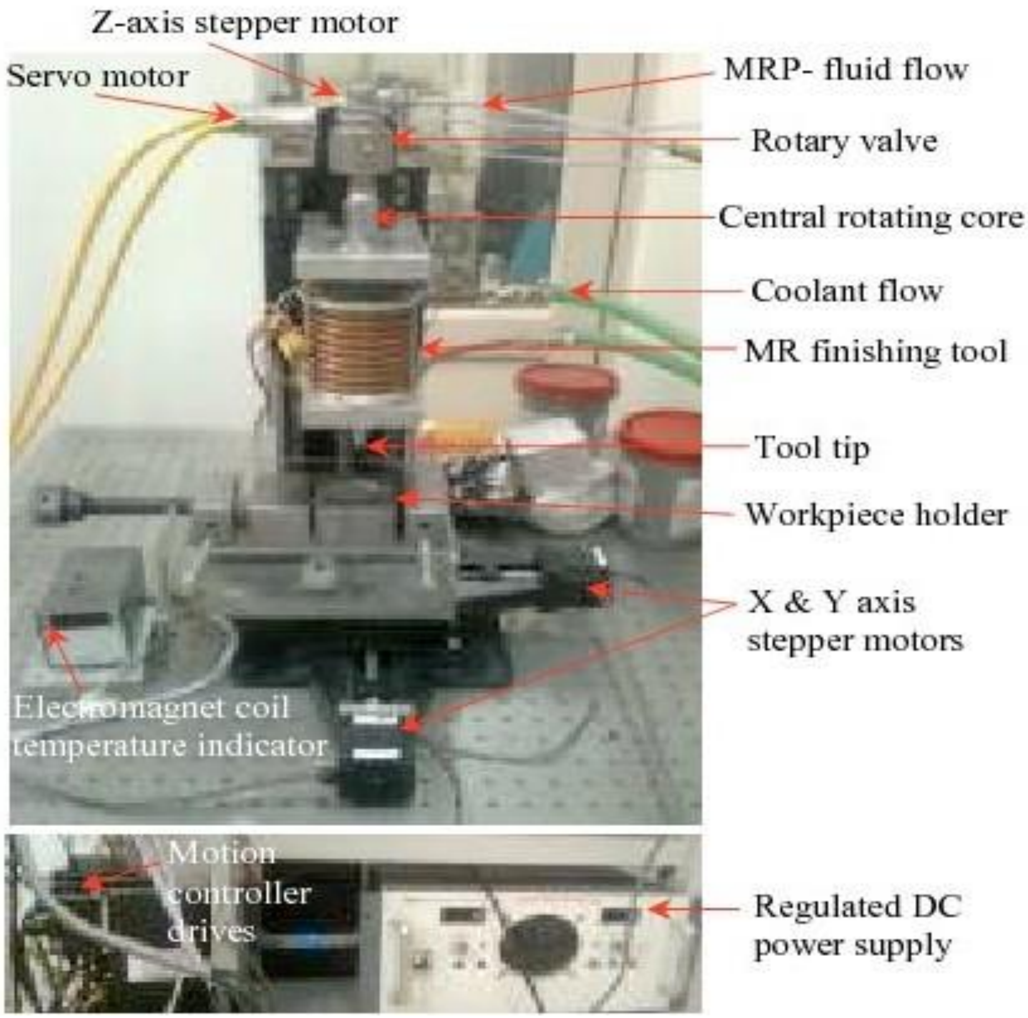


Fig.3.10 Shows the MR finishing setup.

Parameter on which finishing is performed are:

Current - 5.7 Amp

Gap between the tool and workpiece is maintained as- 0.66 mm

Tool rotational speed - 600 rpm

Finishing time- 1 hour

Feed -10 mm/min and Sampling length- 35 mm.

Experiment has been conducted on mild steel workpiece surface with both types of MRP fluid samples (sample S1 and S2) using ball end magnetoreological finising process. Initial surface roughness before experiments and final surface roughness after conducting experiments have been measured with taly surf at 4 mm data lengt and 0.25 mm cut off length. After measurement of surface roughness, te percentage reduction in surface rougness has been calculated as shown in table 3.1.

Table 3.1: Initial and final surface roughness and %ΔR_a

Sample No.	Initial Roughness(µm)	Final Roughness (µm)	Percentage change in Roughness $[(\Delta R_{aintial} - \Delta R_{afinal})/\Delta R_{a\ intial}]*100$
Unbonded Magnetic abrasive based MRP fluid(S_1)	R_a = 0.144 µm R_q = 0.188 µm R_z = 1.2 µm	R_a = 0.0581µm R_q = 0.0744 µm R_z = 0.63 µm	59.22% 60.42% 47.5%
Magnetic abrasive particles (MAPs) based MRP fluid(S_2)	R_a = 0.149 µm R_q = 0.235 µm R_z = 1.84 µm	R_a = 0.0402 µm R_q = 0.0575 µm R_z = 0.72 µm	73.02% 75.53% 60.87%

CHAPTER 4 RESULT AND DISCUSSION

The magnetic abrasive particles (MAPs) are developed by solid phase sintering method at 1000^0 C in the inert atmosphere of argon. The elemental composition of MAPs powder has been tested with the help of energy dispersive spectroscopy.

4.1 EDX ANALYSIS

EDX analysis of the composites has been tested to conform the existence of iron, silicon, oxygen and carbon. The EDX was used at accelerated voltage 15 KV and take off angle 54.6 degree. The EDX analysis has been done on both types of powder such as unbobnded magnetic abrasive and bonded magnetic abrasive powder.

i) green unbonded powder

EDX analysis has been done to see the elemental composition of the various elements present in unbonded powder. It shows sillicon as 15.75% while iron as 84.22% of the total percentage as shown in the table 4.1. It shows the peaks of various elements. EDX analysis is been done on 15 Kvoltage and the take angle is 79.6 degree.

ii) Elemental composition of bonded abrasive powder has also been done to see the various elements present in the sintered powder. In this, the percentage of sillicon is found as 36.93% and percentage of iron is 63.07% and shown intable 4.2. it shows that oxygen content is found as 0%. This shows that there is no oxide formation takes place during sintering process.

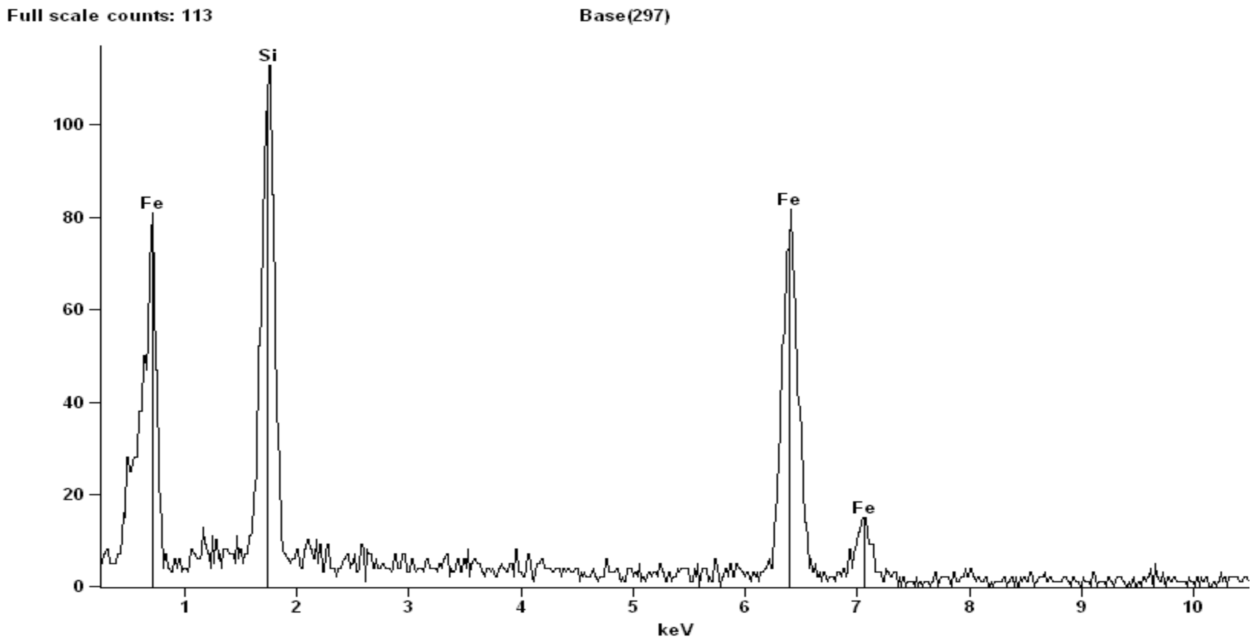


Fig. 4.1 shows the various peaks of various elements in unbounded powder.

Table 4.1: Percentage composition of various elements in unbonded magnetic abrasive powder.

Element Line	*Net Counts*	*Int. Cps/nA*	*Weight %*	*Weight % Error*	*Atom %*	*Atom % Error*	*Formula*	*Standard Name*
Si K	1249	---	15.78	+/- 0.57	27.15	+/- 0.98	Si	
Si L	0	---	---	---	---	---		
Fe K	1367	---	84.22	+/- 4.19	72.85	+/- 3.62	Fe	
Fe L	743	---	---	---	---	---		
Total			100.00		100.00			

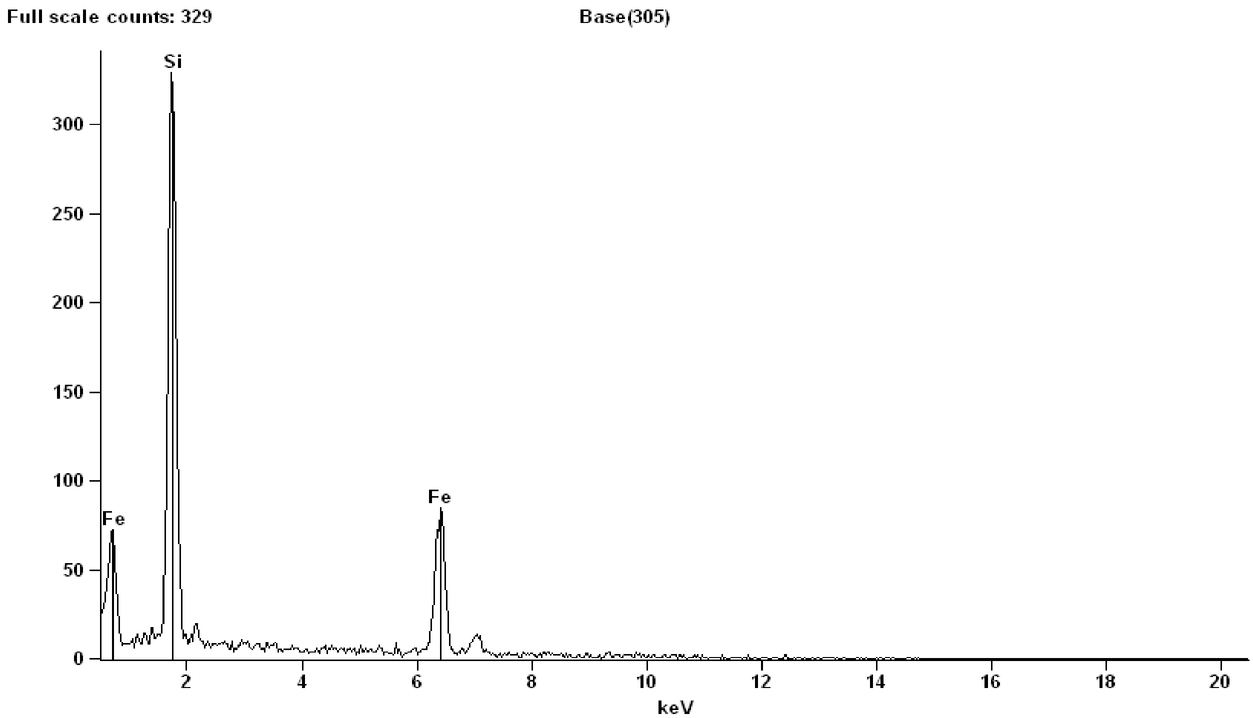


Fig. 4.2 shows the various peaks of various elements in bounded powder.

Table 4.2: Percentage composition of various elements in bonded magnetic abrasive powder

Element Line	Net Counts	Int. Cps/nA	Weight %	Weight % Error	Atom %	Atom % Error	Formula	Standard Name
Si K	4678	---	36.93	+/- 0.82	53.80	+/- 1.20	Si	
Si L	0	---	---	---	---	---		
Fe K	1532	---	63.07	+/- 3.42	46.20	+/- 2.50	Fe	
Fe L	929	---	---	---	---	---		
Total			100.00		100.00			

4.2 SEM ANALYSIS

After the elemental composition study, the morphology of particles has been study with the help of scanning electron microscope (SEM). Figure 4.3 to 4.12 showing the SEM microstructure of magnetic abrasive particles at magnification of 5, 10, 20, 50 and 100 µm respectively. The microstructure analysis shows the morphology, particle shape and size at different resolution for synthesized powder and loose green powder. It has been observed that, the silicon carbide abrasive particles get diffused on the surface of iron particles due to heating at high temperature. Results show that the average particle size for sintered sample after crushing in ball mill has been found as 32.65µm.

Similarly SEM microstructure for loose green powder is also done at different magnifications. The results shows that abrasive particles have random shape with sharp edges while plain iron powder also have irregular shapes. Since the powder is in loose form, silicon carbide abrasives and plain iron powder particles can be seen individually. Plain iron particles are found comparatively larger than silicon carbide abrasive powder.

Microstucture images of green powder

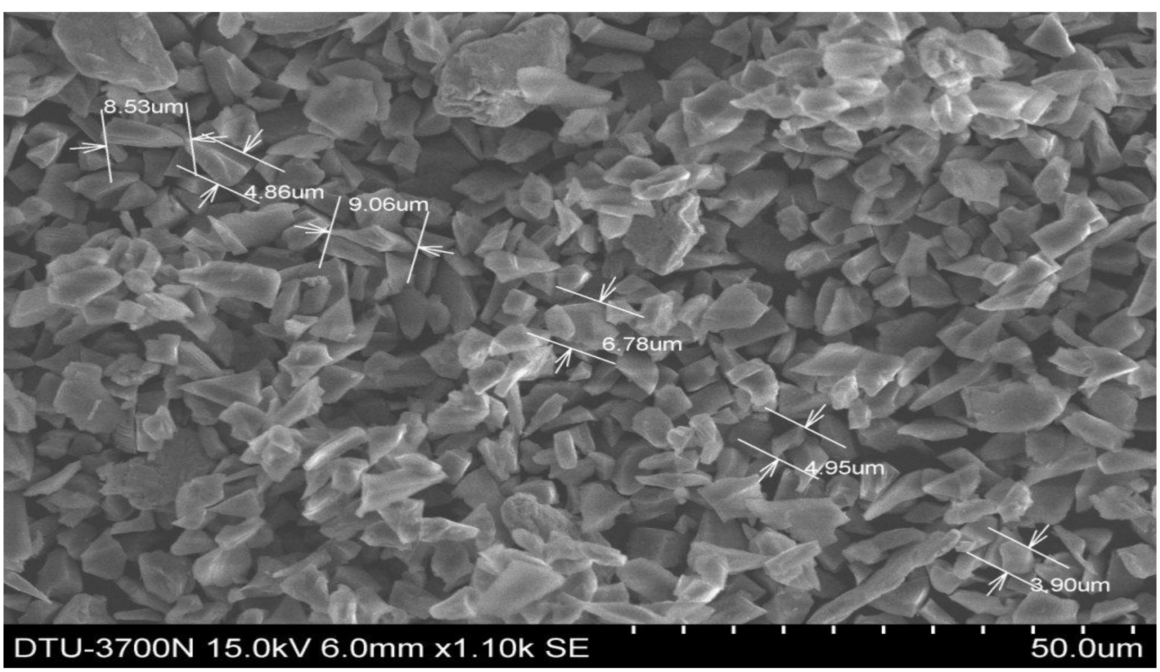


Fig. 4.3 shows the average size of the particles in green powder at 50 µm magnification.

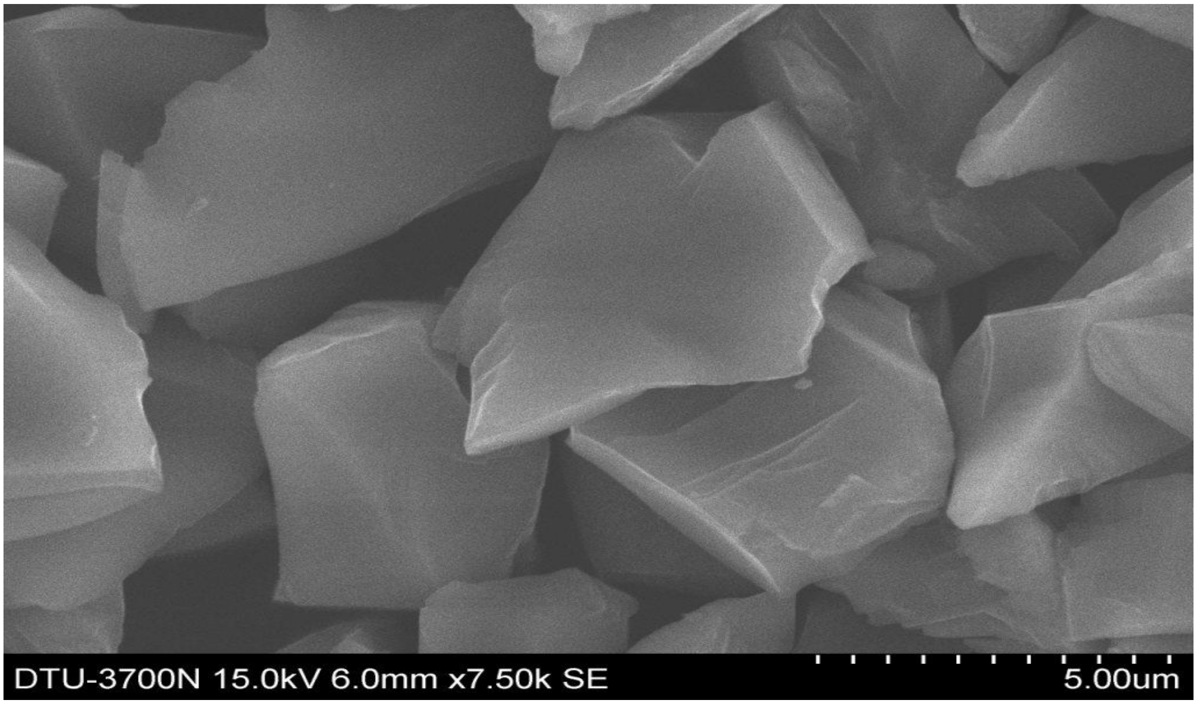


Fig. 4.4 showing the size of particles at 5 µm magnification

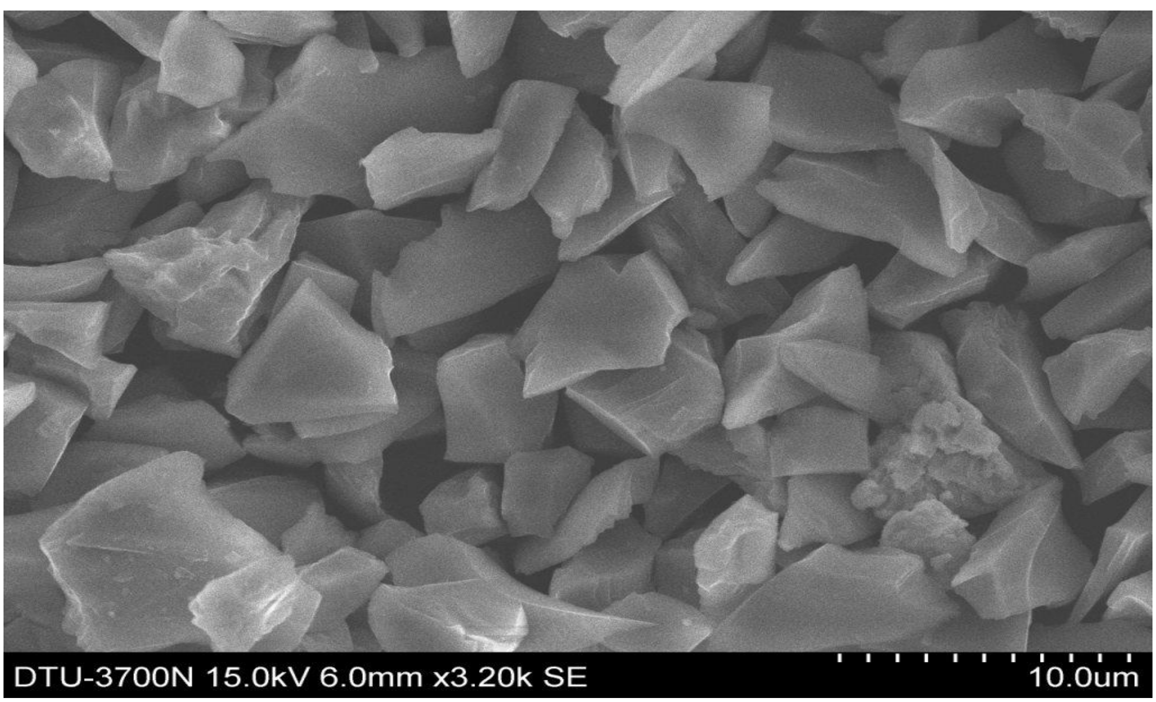


Fig. 4.5 showing the size of particles at 10 µm magnification

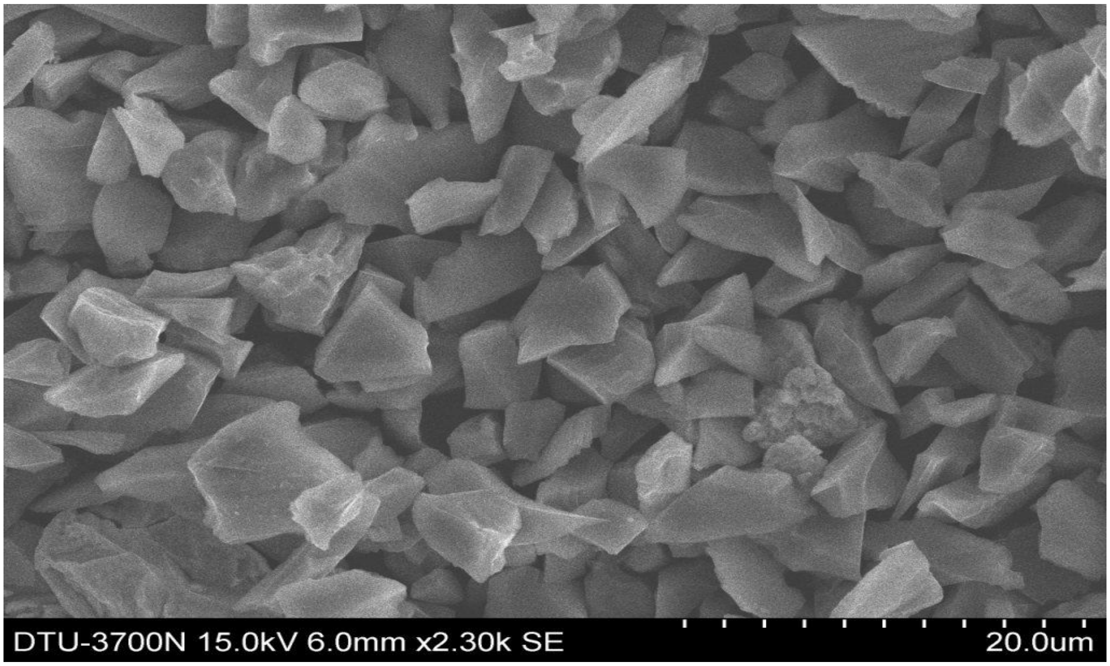


Fig. 4.6 showing the size of particles at 20 μm magnification.

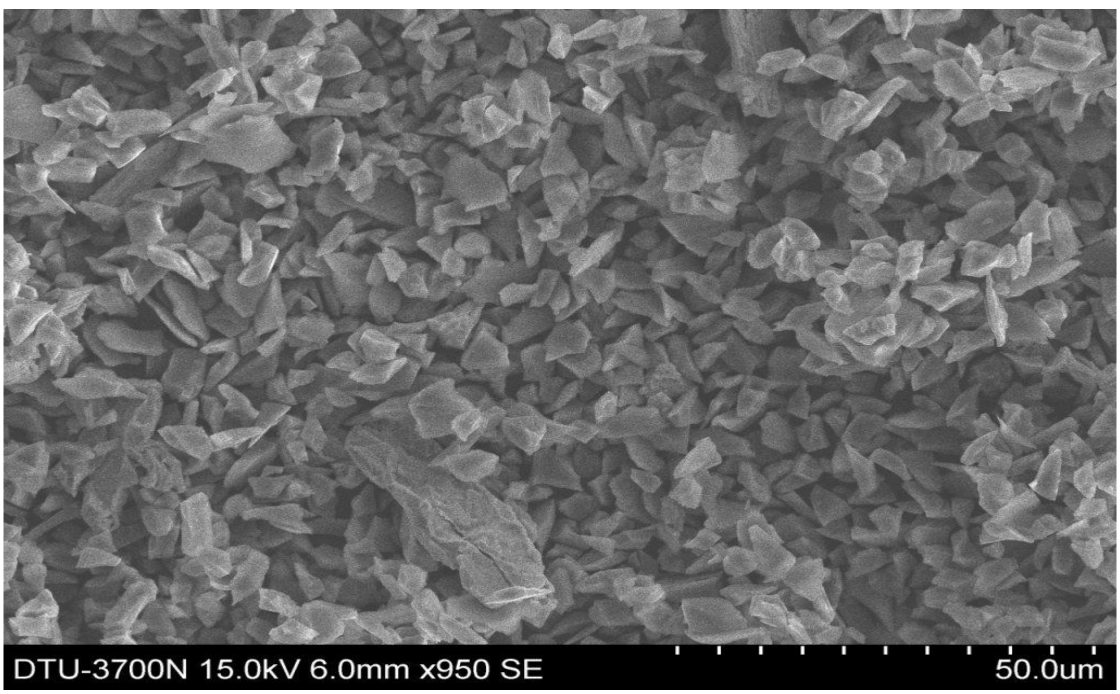


Fig. 4.7 showing the size of particles at 50 μm magnification

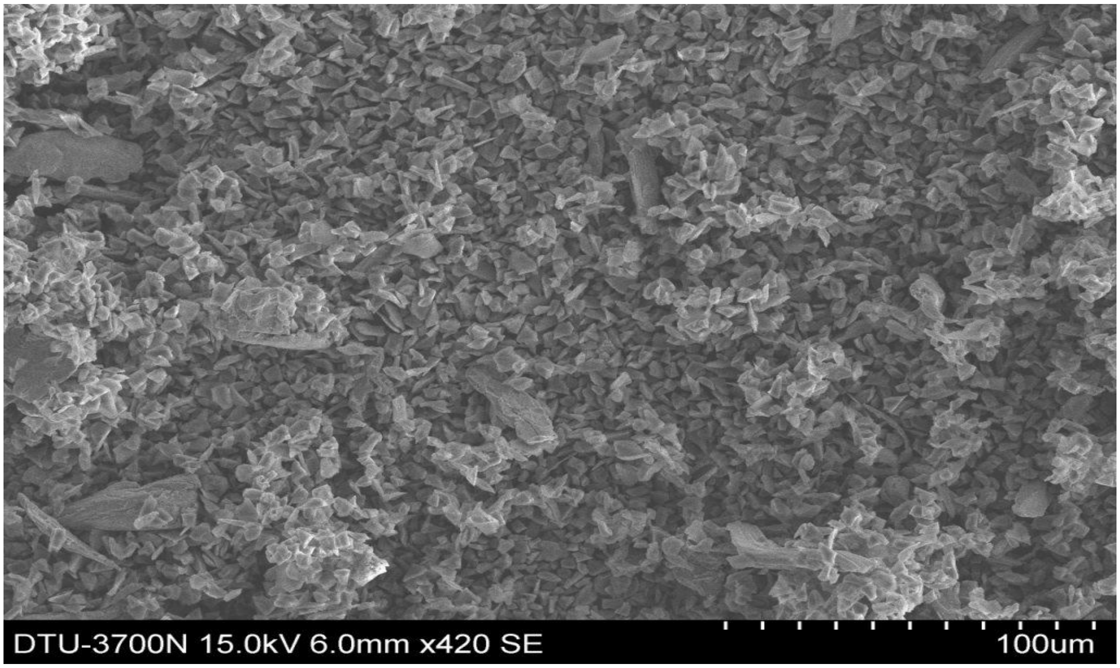


Fig. 4.8 showing the size of particles at 100 µm magnification.

Microstucture images of sintered magnetic abrasive powder

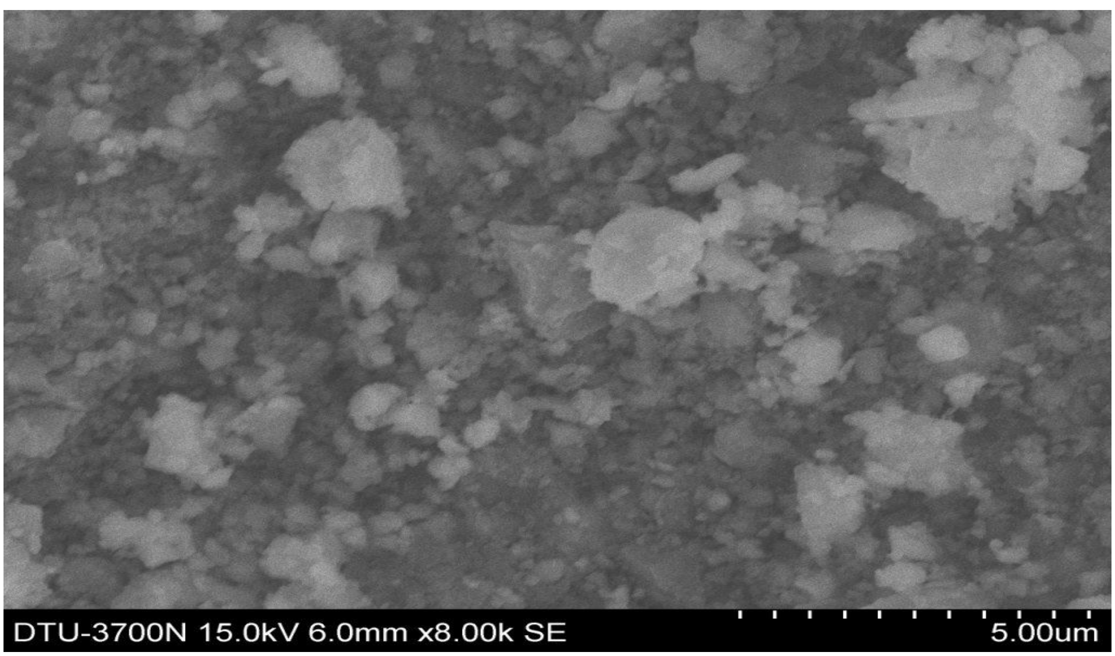


Fig. 4.9 showing the Microstructure image of particles at 5 µm magnification

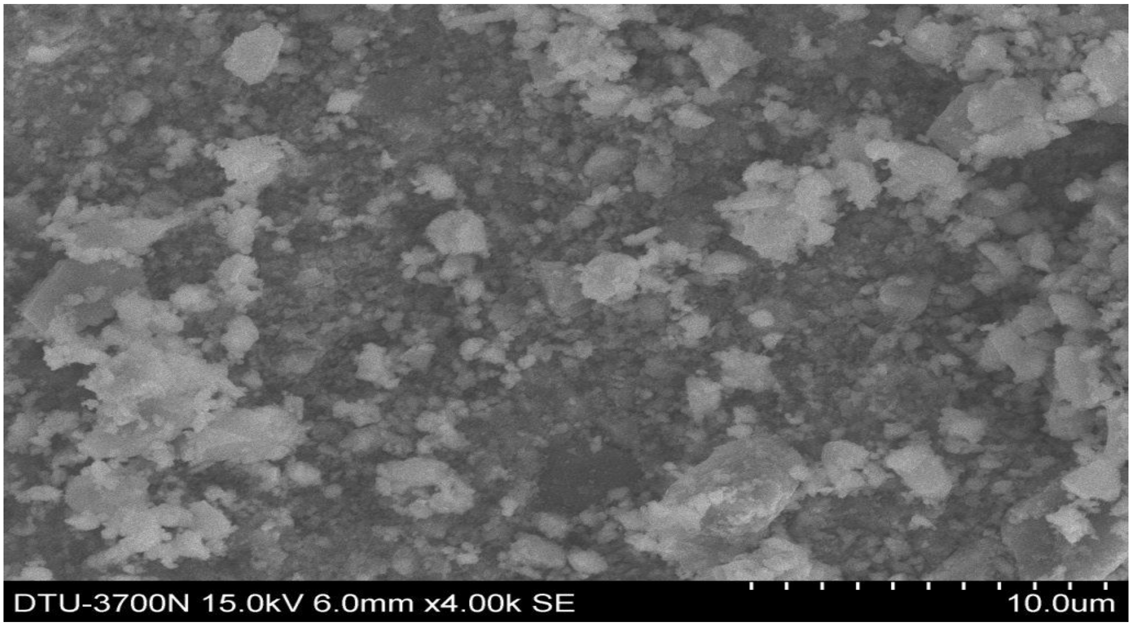


Fig. 4.10 showing the Microstructure image of particles at 10 μm magnification

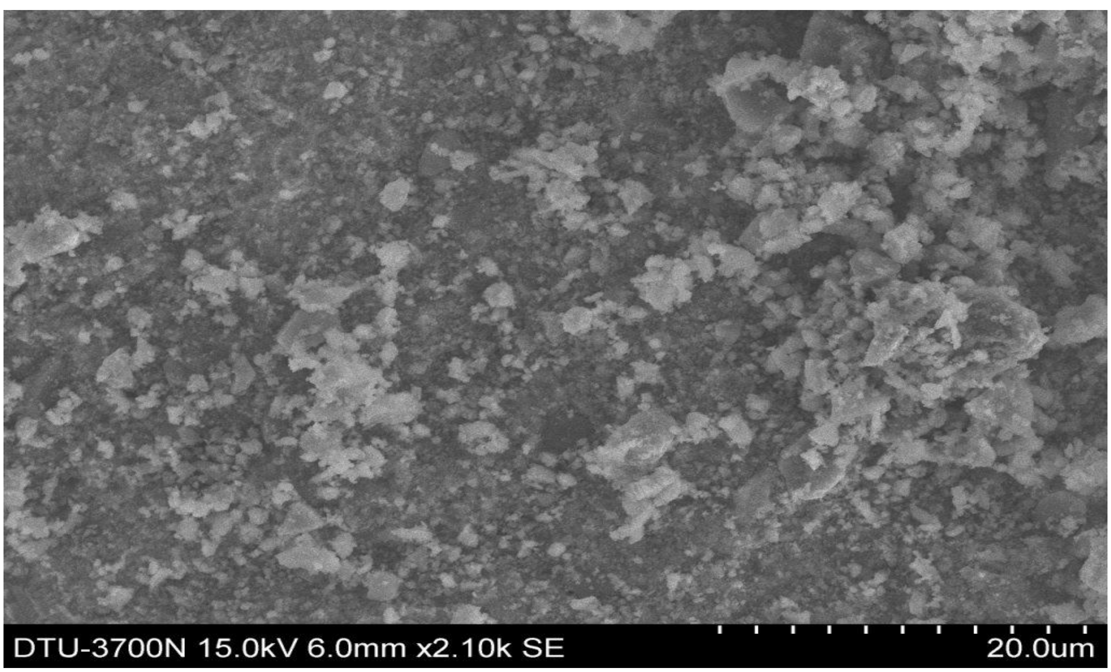


Fig. 4.11 showing the Microstructure image of particles at 20 μm magnification

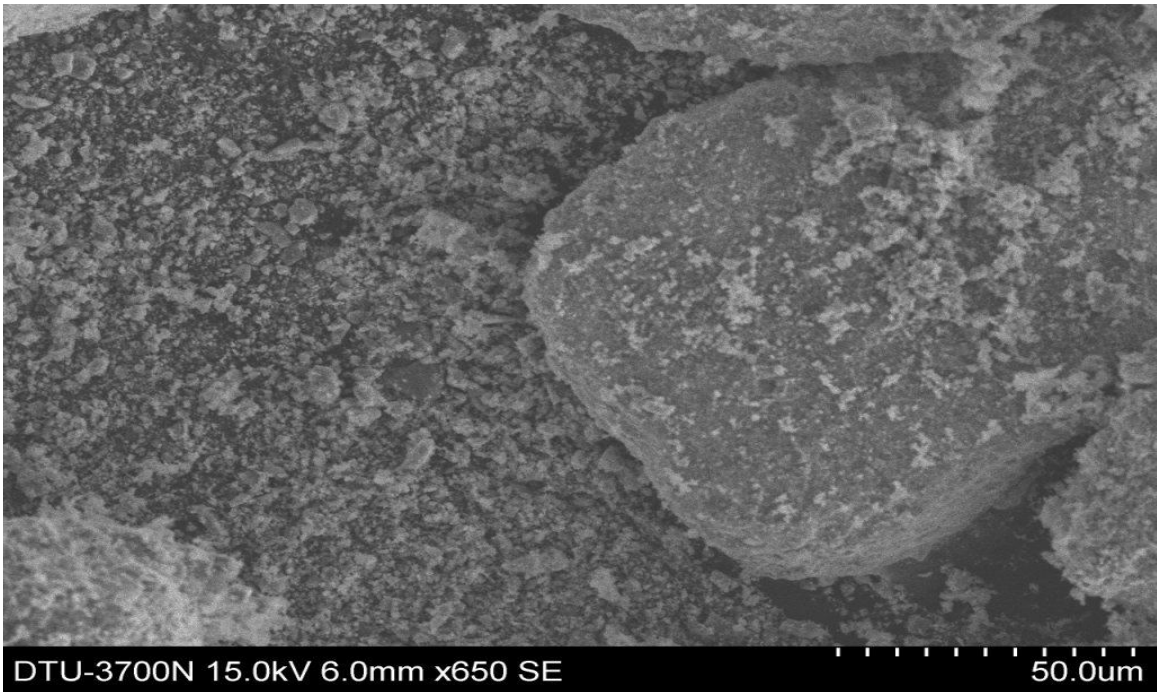


Fig. 4.12 showing the Microstructure image of particles at 50 μm magnification

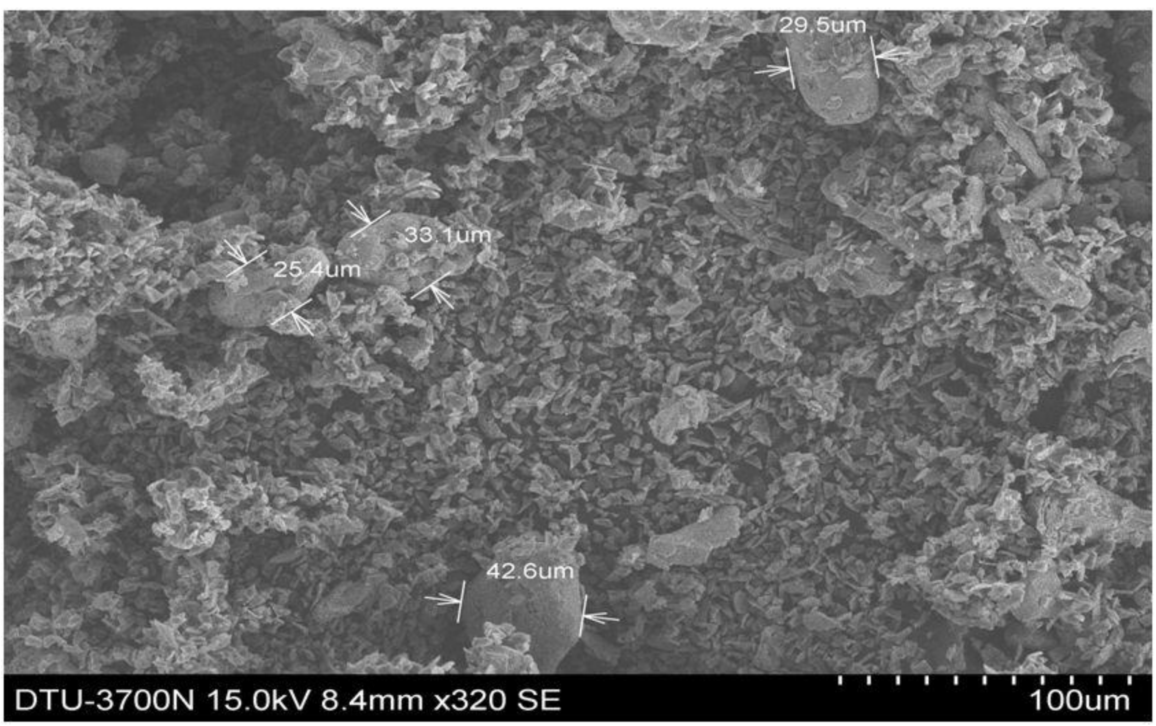


Fig. 4.13 showing the average size of particles at 100 μm magnification.

4.3 surface rougness analysis:

After caracterization of magnetic abrasive particles, the surface roughness before and after experiments as been measured. Then percentage reduction in surface rougness as been calculated and shown in table 3.1.

The profile of initial surface roughness before experiments and final surface roughness after conducting the experiments have been shown in figure 4.14.to 4.15.

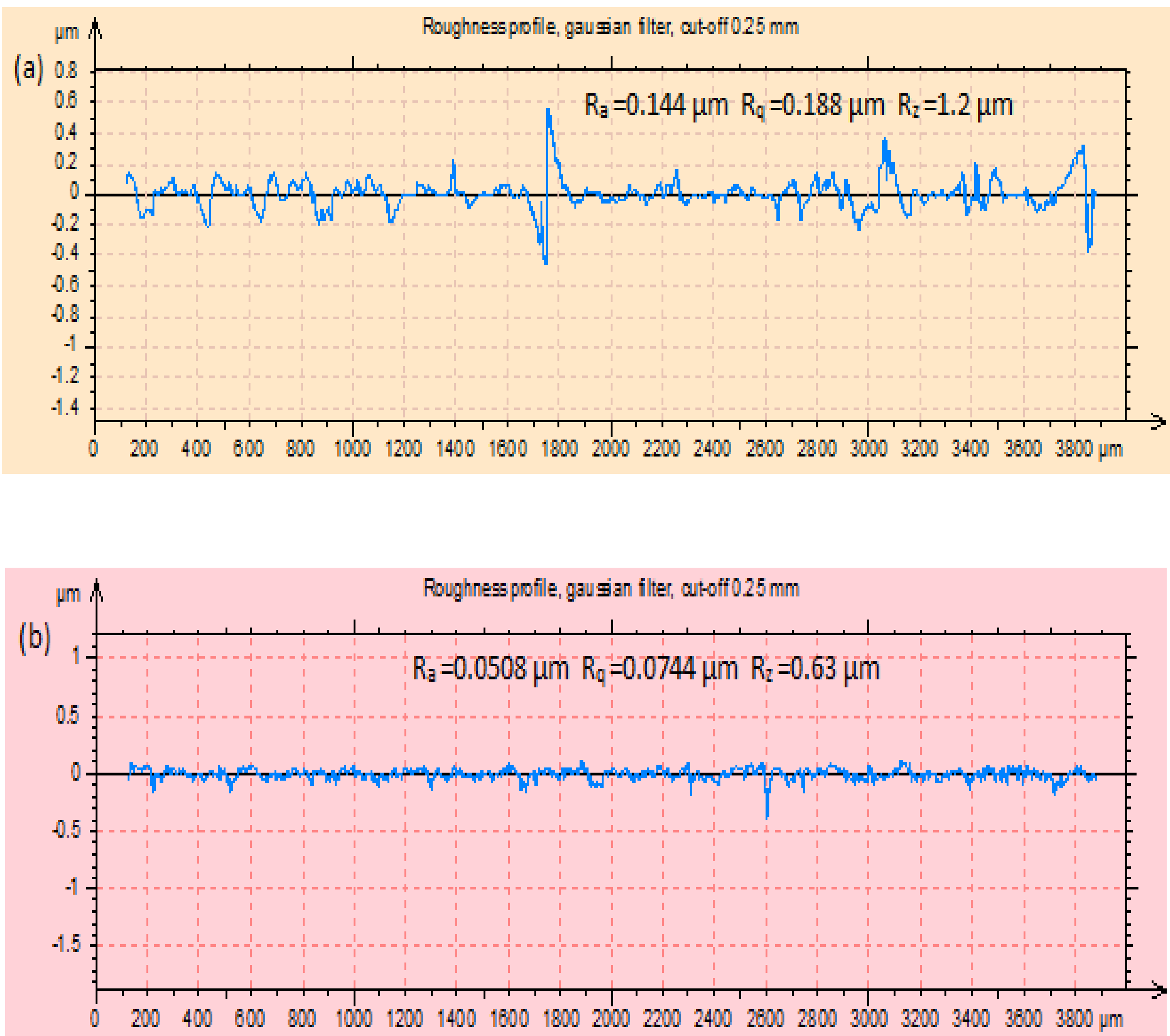


Fig. 4.14 (a) intial surface roughness of work-piece (b) final surface roughness of work-piece finished with MRP fluid sample (S1)

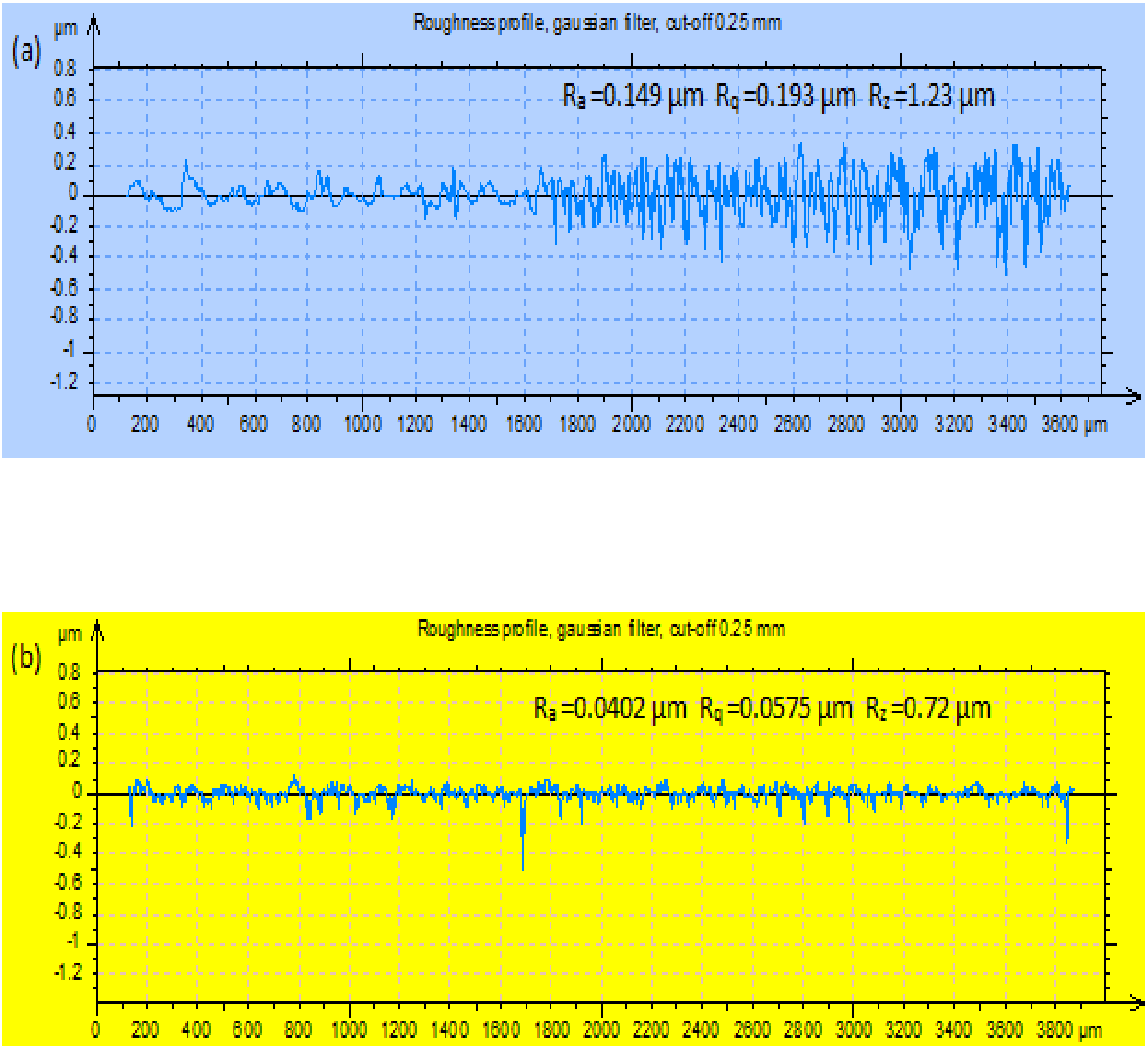


Fig. 4.15 (a) intial surface roughness of work-piece (b) final surface roughness of work-piece finished with synthesized MAPs based MRP fluid sample (S2)

After calculating the percentage reduction in surface roughness, it has been observed that $\%\Delta R_a$ has been found better by finishing the work-piece surface with MAPs based synthesized MRP fluid as compred to unbonded magnetic abrasive based MRP fluid at same machining conditions.

It shows that MAPs obtained by sintering process impart more finishing force on the work-piece surface and remove work-piece surface material more quickly as compare to unbonded magnetic abrasive particles.

Conclusions

Following conclusions are drawn from the present study:

1. Magnetic abrasive particles have been developed by sintering process and morphology of the sintered particles have been study with scanning electron microscope (SEM). The SEM micrograph shows that the abrasive particles are diffused on the surface of plain iron particles. MAPs are found in irregular shapes with sharp edges.

2. The elemental composition of sintered powder has been done to study the various elements present in the powder. It has been found that there is no oxygen content in the sintered powder. This shows that there is no oxides present in the powder.

3. The experiments have been carried out at given machining parameters with both types of samples (S_1 and S_2) on BEMERF tool. The percentage reduction in surface roughness has been calculated after the experiments. It has been observed that the percentage reduction in surface roughness has been found more for finishing the work-piece surface with magnetic abrasive particles (MAPs) based MRP fluid sample (S_2) as compare to unbonded magnetic abrasive based MRP fluid sample (S_1).

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