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# DEVELOPMENT OF MAGNETIC ABRASIVE PARTICLES USING SINTERING METHOD AND ITS CHARACTERIZATION

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***Abstract:*** Magnetic abrasive particles (MAPs) are developed with the use of solid phase sintering method. Carbonyl iron powder of 20 volume% and silicon carbide abrasives of 3000 mesh size with 25 volume% are mixed uniformly in ball mill. After mixing these powders, the pellets of 5 gram each are developed at 8 ton pressure using cylindrical die of 7 mm diameter and 50 mm length. These pellets are sintered at 1000°C in inert atmosphere of argon using appropriate sintering cycle. After sintering, the furnace cooling has been done in inert atmosphere of argon upto the environment temperature reached. After sintering, the sintered pellets are crushed in the ball mill to obtain the required size of the magnetic abrasive particles. The different phases of magnetic abrasive particles have been studied using X-ray diffraction (XRD). The microstructure of magnetic abrasive particles has also been studied with optical microscope.

***Keywords:*** Sintering, Carbonyl iron, Magnetic Abrasive particles, SEM, EDS.

## 1. INTRODUCTION

In sintering, compact is heated to 60-70% of the melting point of the base metal. This increases the extent of diffusion between the particles. Scientific investigations by the materials scientists have been directed towards the improvement the performance and properties of materials. The increasing demands for hotter, stronger, stiffer, and lighter than traditional materials have led to design and development of advanced materials. The high-technology industries have given an added stimulus to these efforts [1]. Silicon Carbide is a chemical compound of carbon and silicon. It formed by an elevated temperature electrochemical reaction of sand and carbon. Silicon carbide is a brilliant abrasive used in making grinding wheel and is used as abrasive product. It is used in abrasives, refractoriness, ceramics, and many high-performance uses. Silicon Carbide have low density, high strength, low thermal expansion, high hardness, high thermal conductivity and exceptional thermal shock resistance. SiC ceramics have no grain boundary impurities maintain their strength to very high temperatures, approximately 1600°C with no strength loss. Carbonyl iron powder (CIP) has high stability at high temperature. Particles of carbonyl iron (20-40%) suspended in a carrier fluid (60-80%) are used as a magneto rheological fluid. Four categories of ceramic matrix composites are classified by Nihara [2]. These are Intra-type; inter type, intra/inter-type and nano/nano-type. These nano composites show improved properties both at room temperature and at high temperature. Iron has specific saturation magnetization and it is a very soft magnetic material, low coactivity and a high Currie temperature. It is highly pure iron and is prepared by chemical decomposition of purified iron penta carbonyl. It usually has the appearance of grey powder, composed of spherical micro particles. Most of the impurities are carbon, oxygen, and nitrogen [3]. $Al_2O_3$ based sintered magnetic abrasives have been used for internal finishing of cylindrical pipes [4]. The XRD analysis has shown that reduction in heights of peaks indicates the improvement in finishing of surface with sintered abrasives. The nano-sized composites of ceramic has been developed with pressureless sintering and found that Cr-species infiltrated into $Al_2O_3$ particles by the pyrolysis of chromium carbonyl (Cr (CO) at 300–450°C [5]. The coated Cr-phase either in agglomerated or dispersive condition has restricted by applying colloidal dispersion. The microstructures has shown that the fine (20 – 600 nm) grains positioned at $Al_2O_3$ grain boundaries hardly retard the densification of $Al_2O_3$ matrix in sintering. The models have been describe quantitatively for liquid stream into isolated pores during liquid phase sintering (LPS) [6]. The grains have been assumed to keep at an equilibrium shape which is determined by surface tension and capillary pressure in liquid at the surface of specimen and the pore. With the raise of grain dimension, the grain sphering force decreases while the diameter of liquid menisci increases to continue the force balance. When the growth of grain reaches at a critical point, the liquid menisci around a pore become spherical and the force of driving for filling the pore increases rapidly as liquid tends to flows into it. Theoretical analysis shows that the critical condition for pour filling is fulfilled when the grains develop to definite size. An explanation of the pour filling procedure in a system which contains many pores of diverse size will be more multifarious. In this study the grain was assumed to be always at the equilibrium state indomitable by the liquid volume fraction. If the grain shape deviates from the local equilibrium state, unevenness between the sphering force and the liquid pressure will come into view and induce a grain figure change. Nickel-coated SiC based iron composites has been developed by DMLS technique and its abrasive wear behaviour has been characterized [7]. Microstructure, micro -hardness and abrasive wear tests were carried out on both DMLS iron and its composites sintered at a laser scan speed of 100 mm/s. Pin –on-disc type machine is used for Abrasion wear tests. SiC abrasive papers of grit size of 60, 80, and 150 have an average particle size 268, 192, and 93 μm respectively. Load was varied from 5 and 25 N in five steps, with sliding distance and sliding velocity of 540 m and 2.5 m/s, respectively. Scanning electron micrograph and surface roughness observation of worn surfaces have been shown. When SiC content increases, micro hardness also increases and decrease in density of the laser sintered iron–SiC composites. Content of SiC in iron matrix increase the abrasive wear resistance of composites. Iron–SiC composites shows excellent abrasive resistance for a given grit size of SiC at all load condition. The effect of sintering temperature, alumina particle size and sintering time on the properties of Al–$Al_2O_3$ composite has been investigated [8]. The average particle size of alumina was taken as 3, 12 and 48 μm. Sintering temperature and time were in the range of 500–600°C for 30–90 min. A correlation was established between the microstructure and mechanical properties. The investigated properties include density, hardness, microstructure, yield strength, and compressive strength. In addition, at small particle size, the hardness, yield strength, compressive strength and elongation to fracture were advanced, related to coarse particles size of alumina. Results demonstration the relative density of Al–$Al_2O_3$ was higher in samples containing fine particle sizes. The highest relative density of 99.95% was observed in specimens sintered at 600°C. The grain size of samples having fine $Al_2O_3$ particles are lesser and increasing the sintering time to 90 min leads to grain coarsening. The highest hardness was 76HB in specimens containing average particle size of 3 μm sintered at 600°C for 45 min. Further rise in sintering time to 90 min results in reduction in hardness to 59 HB. The finer the particle size of alumina, bigger the compressive strength and elongation. The highest strength was 318MPa, for the composite containing an average particle size of 3 μm and sintered at 600 °C for 45 min. Further increase in sintering time has an adverse effect on the strength. They also focused on fabrication and Characterization of composites of iron-chromium alloy reinforced with 5–25 wt. % of alumina Particles fabricated using powder metallurgy [9]. The diffraction patterns of X-Ray diffraction (XRD) reveal the influence of varying weight% of alumina. Evaluations on the mechanical properties are also being made on the unreinforced iron matrix.

## 2. EXPERIMENTAL WORK

Magnetic abrasive particles (MAPs) are developed with the use of solid phase sintering method. Carbonyl iron powder of 20 volume% and silicon carbide abrasives of 3000 mesh size with 25 volume% are mixed uniformly in ball mill. Stainless steel jar has been used in ball mill with 1:5 Wight ratio of powder and ball. The pellets of magnetic abrasive powder are prepared with the help of die and hydraulic press at 8 ton pressure and held for 25 minutes for getting uniform compaction. These pellets have been placed in alumina trays as shown in Figure 1.

Figure 1: **Pellets before sintering**

## 3. SINTERING

Solid phase sintering has been done in the tubullar furnace with argon as inert gas. Set up consist of furnace with programming software to set the sintering cycle and attachment of argon cylinder. Sintering cycle has been explained with the help of a line graph drawn between tempertature and time as shown in Figure 2. At initial stage of cycle, heating is done at the rate of 200°C/h upto 800°C temperature. After this, constant temperature heating has been done for 1 hour. Now the temperature is increased at the same rate upto 1000°C temperature and held at this temperature for four hours for getting sintered product completely. The furnace cooling is done at same rate in the inert atmosphere of argon till the room temperature of 30°C achieved.

The sintered pellets becomes hard after sloid phase sintering as shown in Figure 3. Sintered pellets are now crushed in the ball mill to obtain the desired size of the sintered magnetic abrasives.

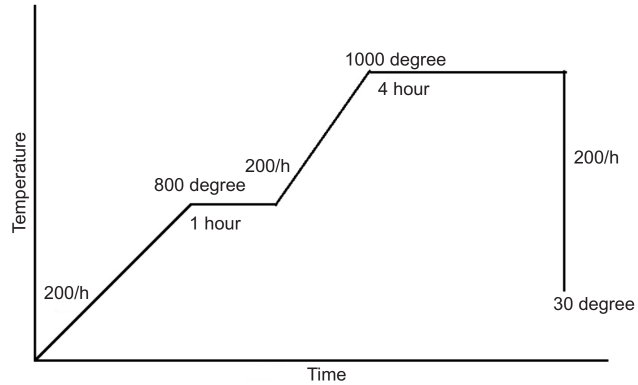


**Figure 2: Sintering cycle used in present work**

**Figure 3: Pellets after sintering**

## 4. CHARACTERIZATION

XRD analysis displayed the crystal structure of the abrasive particles. The diffraction peaks are relatively sharp and the scope of amorphous peaks is relatively small.

| | |
|---|---|
| Sample Name | Sintered Magnetic Abrasive Particles of SiC and CIP |
| Crystal system | Hexagonal Lattice |
| Type | P |
| Lattice Parameter | $a = 4.9168$ $b = 4.9168$ $c = 5.4089$ |
| Lattice Parameter | Alpha = 90 Beta = 90 Gama = 120 |
| Radiation | Cu |
| Wavelength | 1.540598micron |
| 2 Theta Start | 10 |
| 2 Theta End | 80 |
| *d* | interplaner distance |

The XRD pattern of sintered SiC and CIP is shown in Figure 4. From the figure first peak comes at 21.54°. This peaks belongs to $Fe_2O_3$ and has (1, 0, 0) *h*, *k*, *l*

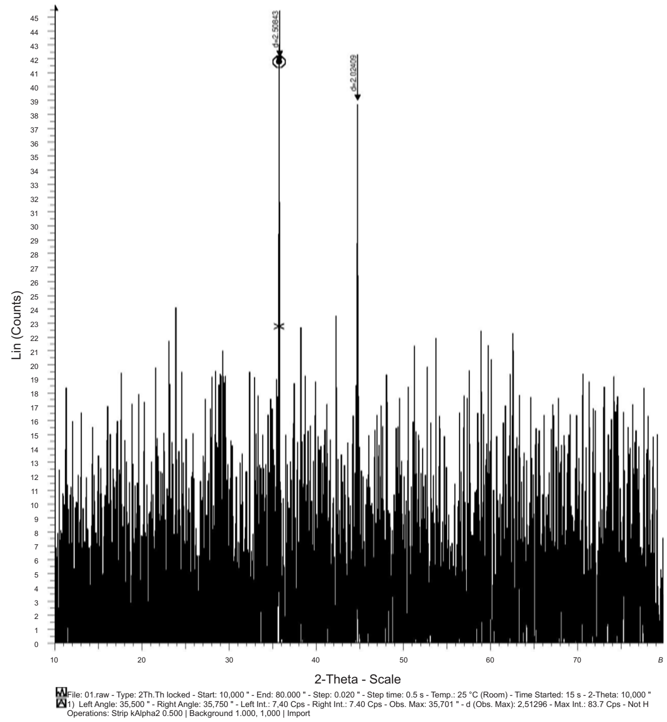


**Figure 4: XRD pattern of sintered abrasives**

value, his plane is simple cubic. Second phase is at 35.767° of SiC has (1, 1, 0) *h*, *k*, *l* value and his plane is simple cubic. Third peaks is at 44.735 of $Fe_3o_4$ has (2, 0, 1) *h*, *k*, *l*, values and his plane is FCC. Highest Peak has 2.50843Å interplaner distance.

## 5. MICRO STRUCTURE ANALYSIS

Micro structure analysis was observed by optical microscope with 100X magnification. From fig.5, it is clear that there are two phase present in the sample. In the coloured part, it is SiC and the red portion is iron.

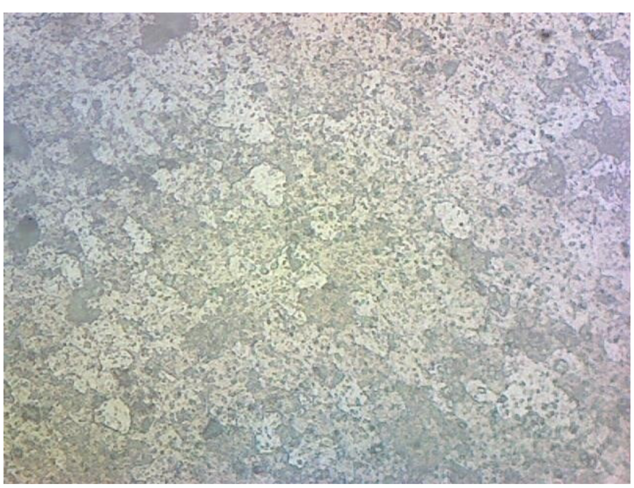

**Figure 5: Microstructure of sintered pellet**

## 6. CONCLUSIONS

The following conclusions have been drawn on the study of sintered magnetic abrasives.

1. The SiC and CIP based sintered magnetic abrasive particles have been developed by solid phase sintering method.
2. Microstructural analysis has been done on optical microscope and found two phase in the sintered magnetic abrasives.
3. X ray differaction analysis has been done on sintered magnetic abrasives and found phases with their h, k, l values.

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