Global Journal of Researches in Engineering: A
Mechanical and Mechanics Engineering
Volume 14 Issue 4 Version 1.0 Year 2014
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN:2249-4596Print ISSN:0975-5861

Study of Graphite Content and Sintering Temperature on Wear and Microstructure of Fe+C Powder Metallurgy Preform

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Abstract- The present paper investigates the effect of sintering temperature and graphite content on the microstructure and effect on wear and frictional properties of Fe+C powder metallurgy preforms. For the present work the specimens were prepared with graphite content 0.5%, 1%, 1.5% and 2% by weight and were sintered at three sintering temperature 800°C, 900°C and 1050°C. Microstructural properties were evaluated using scanning electron microscopy. The wear and friction property of the powder preforms were tested on Pin-On-Disc apparatus. The powder specimen was used as pins and the disc was of AISI 51200 steel. The experiments was carried out under load of 40 N, speed 1000 rpm, time 1500 seconds and relative humidity 60% - 65%. The result was 2% graphite content specimen with sintering temperature 1050°C showed good wear resistance. The wear rate decreased with the increase in sintering temperature and increase in graphite content of the specimen.

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GJRE-A Classification : FOR Code: 091399p

STUDYOFGRAPHITECONTENTANDSINTERINGTEMPERATUREONWEARANDMICROSTRUCTUREOFFE+CPOWDERMETALLURGYPREFORM

Strictly as per the compliance and regulations of:

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Abstract- The present paper investigates the effect of sintering temperature and graphite content on the microstructure and effect on wear and frictional properties of Fe+C powder metallurgy preforms. For the present work the specimens were prepared with graphite content 0.5%, 1%, 1.5% and 2% by weight and were sintered at three sintering temperature 800°C, 900°C and 1050°C. Microstructural properties were evaluated using scanning electron microscopy. The wear and friction property of the powder preforms were tested on Pin-On-Disc apparatus. The powder specimen was used as pins and the disc was of AISI 51200 steel. The experiments was carried out under load of 40 N, speed 1000 rpm, time 1500 seconds and relative humidity 60% - 65%. The result was 2% graphite content specimen with sintering temperature 1050°C showed good wear resistance. The wear rate decreased with the increase in sintering temperature and increase in graphite content of the specimen.

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I. Introduction

The technology of pressing metal powders into required shape is not new and known as powder metallurgy technology. It is a popular route for producing light automotive and engineering parts. By the use of this technology the finished products can be produced with least wastage. But the parts obtained by this method are not fully dense as obtained by convectional process the effects of graphite content and temperature on microstructure and mechanical properties of iron-based powder metallurgy parts by Xiaxun Zhang, Fang Ma, Kai Ma and Xia Li (2011) the density of the specimen with higher sintering temperature are higher and with increase of graphite content porosity decreases. The minimization of wear and friction of any materiel is very important due to the energy crises faced by the world now days, therefore the materials should be wear resistant as well as lighter in weight. The study of wear resistant application of powder metallurgy iron based ternary alloy was studied by S.B. Halesh and P. Dinesh (2013) was carried out using pin-on-disc apparatus under different normal loads under lubricated dry conditions. The effect of load, sliding speed and times on wear rate of steel, aluminum and brass using pin-on-disc was studied and mathematical model has been made for all cases by Hani Aziz Ameen, Khairia Salman Hassan and Ethar Mohamed Mhdi Mubarak (2011). The effect of sliding speed and normal load on friction and wear property of aluminum using pin-on-disc apparatus was done by M.A. Chowdhury, M.K. Khalil, D.M. Nuruzzaman and M.L. Rahaman (2011) and found wear rate increases with the increase of sliding speed and normal load. Lubricated sliding wear behavior of a CI effect of Graphite and/ or talc fraction in oil with the effect of suspended solid lubricant was studied by B.K. Prasad (2010). The effect of temperature and sliding speed on adhesive wear of high speed steel and tungsten carbide coating under load 30 N and 150 N was studied by A. Babilius, P. Ambroza (2003). The effect of carbon on tensile properties and wear behavior of P/M Fe-Al alloy the ductility was due to grain refinement in carbon added alloy wear was studied by ball-on-disc apparatus by Xingsheng Guan, Su-Ming Zhu, Koji Shibata and Kunihiko Iwasaki (2002).

The graphite present in the specimen itself acts as the solid lubricant in addition it also provides hardness to the specimens, it is observed in the experiment that with the increase of graphite content in the specimen. The sintering temperature selection also plays important role in achieving better wear resistance of the specimens and the selection of sintering temperature is also very important to get the fully dense structure of the specimens. After sintering process the samples was cleaned and polished the get a better surface finish and appearance, some carbon deposits was also found on the surface of the specimen containing higher amount of graphite content which is illustrated in the experiment.

In this paper, the experimental study was conducted for the effect of sintering temperature and graphite content on wear and frictional properties and microstructure obtained for the specimen were examined using pin-on-disc apparatus and SEM (scanning electron microscopy).

II. Experimental Procedure

a) Materiel Preparation

For the experiment the sample was prepared press sinter path, the methods used are discussed below. The iron and graphite powder was purchased for

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Global Journal of Researches in Engineering (A) Volume XIV Issue IV Version I Year 2014

G.I.D.C. Industrial Estate Nandesari, Vadodara, Gujarat.
Qualikems Fine Chemicals PVT. LTD. Plot No 68/69,

- *Iron powder specification*

Atomized IRON powder of purity 99.5% and finer than 44µm was used throughout the experiments with 300 mesh size.

Element	Fe	HCl (insoluble)	As	Cu	Mn	S	Ni	Pb	Zn
Wt%	99.5	0.05	0.0005	0.005	0.05	0.02	0.05	0.002	0.01

- *Graphite powder specification*

Electrolytic Graphite powder of purity 98.8% and 325 mesh was used throughout the experiment.

Element	C	Fe	H_2O (insoluble)	Others
Wt%	98.0	0.045	0.5	1.45

Four groups of 20g of iron and graphite powder were stirred well and mixed uniformly. Then, four groups of powder mixture were produced and their graphite contents were 0.5%, 1%, 1.5% and 2%, respectively. These powder mixtures were used to make specimen used in the experiments.

b) Powder Blending

For the experiment iron and graphite of varying percentage was needed. The percentage of graphite was varied with different weight percentage, these percentages are 0.5%, 1%, 1.5%, 2%. Then, the samples were taken and blended together properly using a pestle and mortar for 30 minutes to ensure uniform distribution of the graphite particles throughout the iron matrix.

c) Sample Preparation

- *Cold Compaction*

A cylindrical die with a diameter of 12.5 mm was adopted to compact the powder. The cotton with acetone used to wipe and clean the mold wall. Powder mixture of 20g of weight is taken and put into the die. A UTM (universal testing machine) hydraulic press is used to compact the powder and the load put on the die is 100 KN and the holding time is 15 minutes. Then, the green compact was ejected from the die.

- *Green Compact Sintering*

The specimens were sintered in a muffle furnace. Every single sample three temperature ranges 800°C, 900°C, 1050°C, holding time is 20 minutes and cooling with the furnace.

- *Finishing operation*

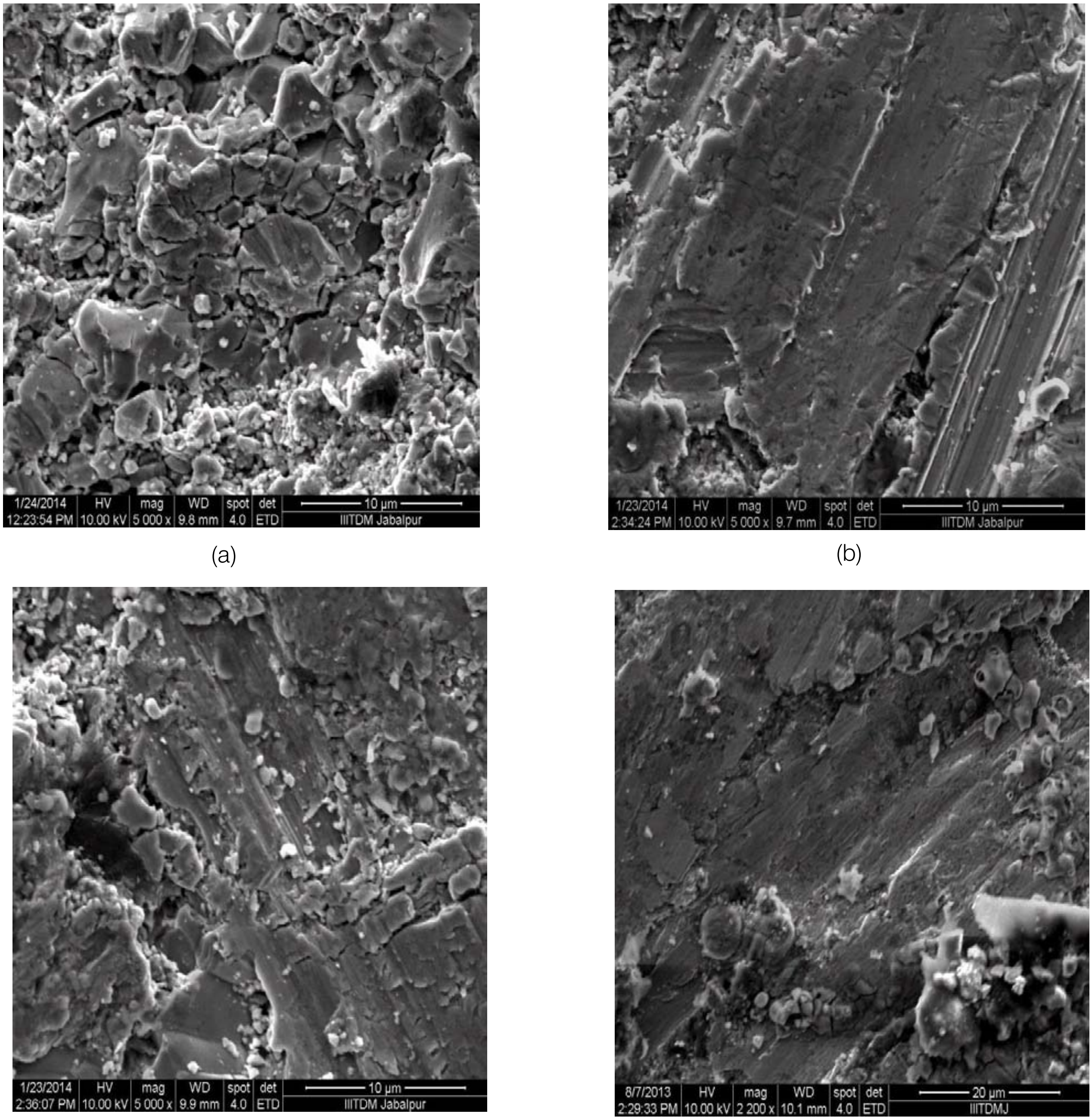
Grinder, Amery paper is use in operation of minimizing mechanical surface damage that must be removed by subsequent polishing operations. The metallographic specimens were polished and then etched by nitric acid and alcohol solution.

Figure 1 : Finished specimen

III. Experiment & Result Discussion

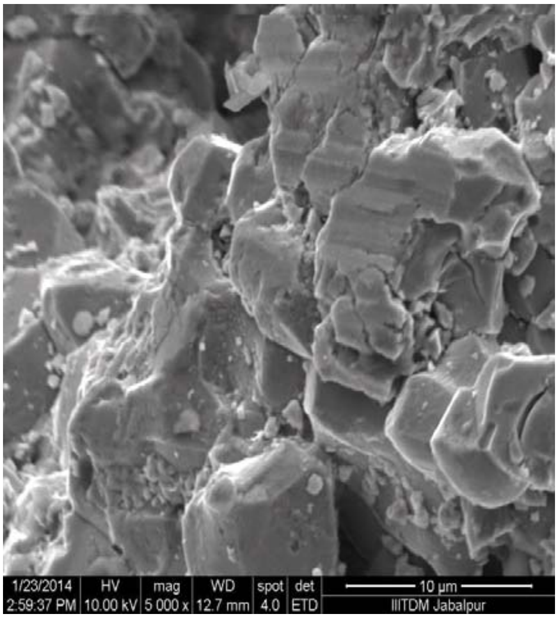
a) Microstructure observation

The microscopic structure of specimen by Scanning Electron Microscope has been analyzed. It is done to find the structure formed after sintering. . The specimens were produced at three sintering temperatures, 800°C, 900°C and 1050°C, respectively, and with four graphite contents, 0.5%, 1%, 1.5% and 2%, respectively. The polished and etched specimens were examined by scanning electron microscopy (SEM) and the magnification 10 to 40*µm*. The effects of temperature and graphite content on the microstructure of the iron-based powder sintered products by metallographic analysis were shown

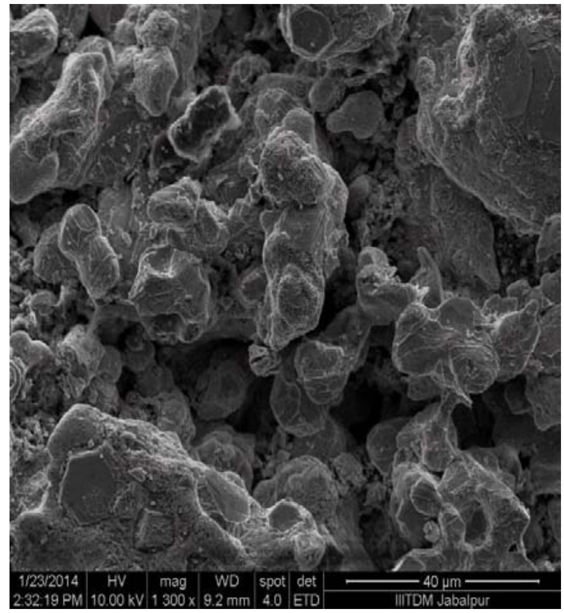


(c) (d)

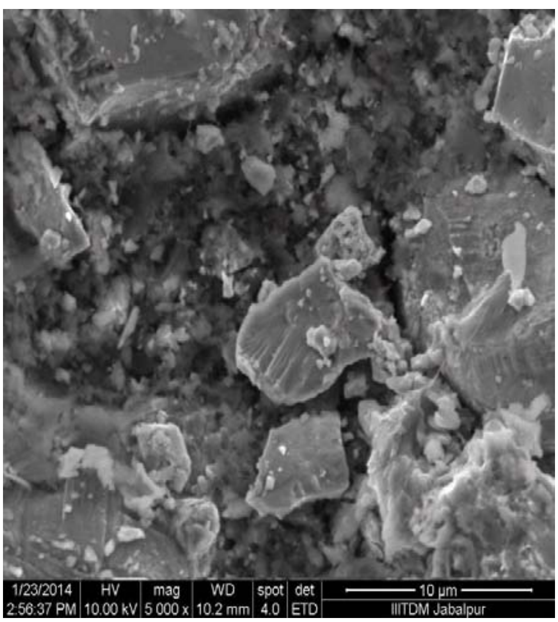
Figure 2 : Microstructure of the iron- based PM parts sintered at 800°C with different graphite content (a) 0.5%, (b) 1%, (c) 1.5% and (d) 2%



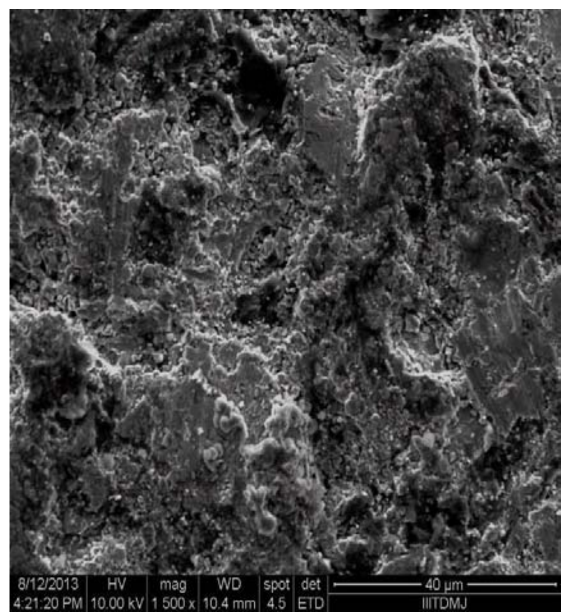
(a)



(b)



(c)



(d)

Figure 3 : Microstructure of the iron-based PM parts sintered at 900°C with different graphite content (a) 0.5%, (b) 1%, (c) 1.5% and (d) 2%

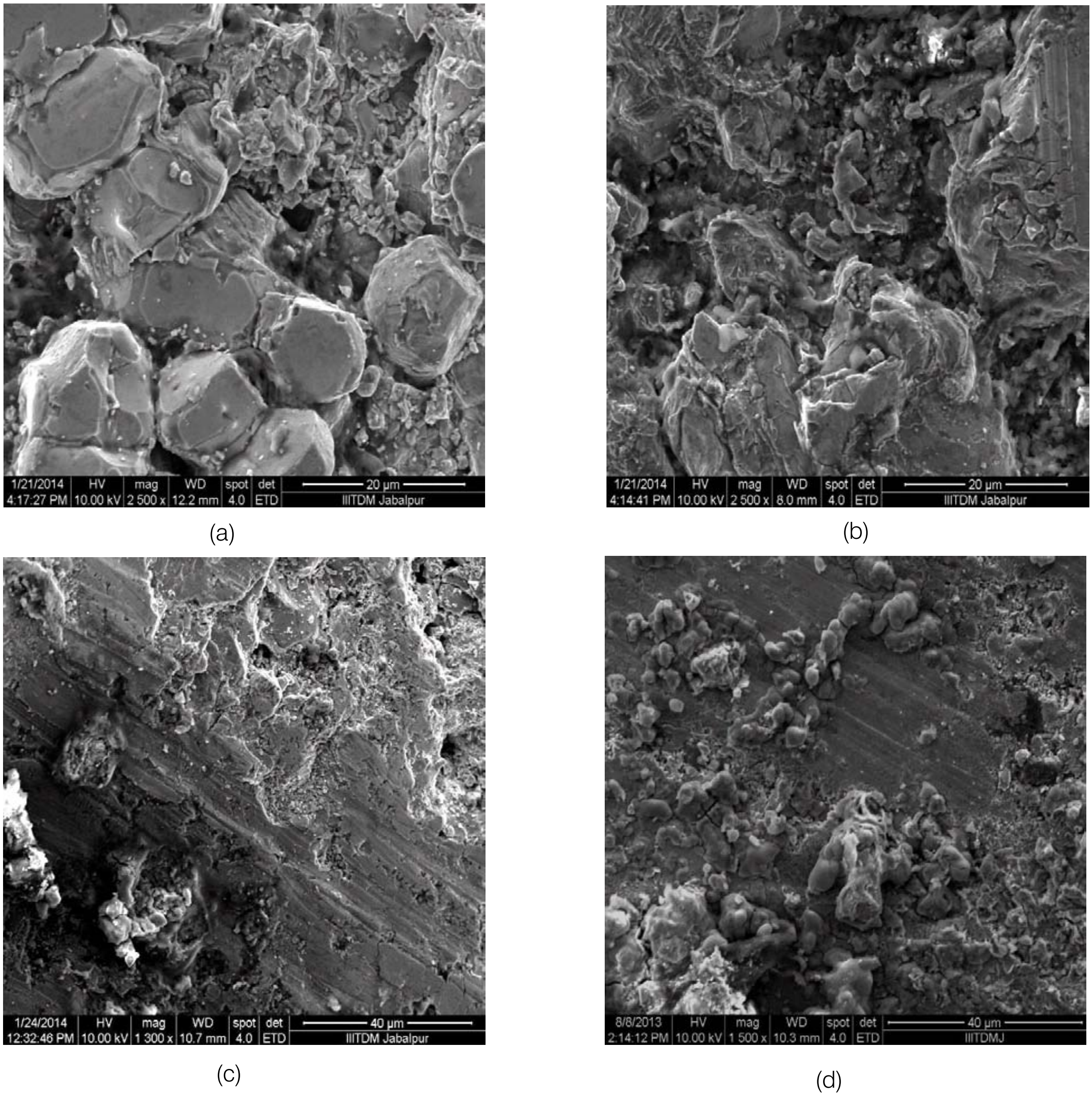


Figure 4 : Microstructure of the iron-based PM parts sintered at 1000°C with different graphite content (a) 0.5%, (b) 1%, (c) 1.5% and (d) 2%

The microstructures of the sintered specimens with the graphite content from 0.5% to 2% were shown in above images. It can be seen that as the graphite content increases from 0.5% to 2%, the microstructure of the iron-based powder sintered specimen changes gradually from ferrite (white microstructure) and a small amount of pearlite (black and white lamellar microstructure) to pearlite and a small amount of ferrite. A small amount of cementite (Fe_3C) also appeared in the microstructure when the graphite content increased to 1%. It can also be seen that the grain size decreases gradually when the graphite content increases, the decrease in grain size shows that the structure is denser and with the more dense structure wear of the specimen will be less. This is because, degree of superheat increases as the graphite content increases when the sintering temperature is constant, thus contributing to the growth of austenite grain. In 1% and 1.5% specimen we can see that there is some pocket formation and micro cracking observed in the structure which is eliminated in 2% specimen therefore less wear in 2% specimen and a denser microstructure and spheroidal structure increases from 0.5% to 1.5% graphite content specimen. In 2% samples some carbide formation can also be seen which gives a hard structure formation in the sample and thus reducing the wear of 2% specimen. As the graphite percentage increases to 2% some flakes are observed in the microstructure images in form of black spots. The reason is increased graphite percent is not properly absorbed by the iron specimen.

Compare the microstructures of the sintered specimens at 800°C to 1050°C by SEM images. It can be concluded that as the sintering temperature increases, the micro structures of the sintered interface become uniform. This is mainly because of the formation of many meshes of grain boundary and their interactions with the interwoven pores. The excess vacancies at the edge of the sintering neck and on the surface of micro-pores are easy to pass the adjacent grain boundary and diffuse or absorb. The higher the sintering temperature, the greater the coefficient of the atomic diffusion within the particle, and the faster the sintering carried out. As percent of graphite increases the micro cracking gradually increases.

III. Wear and Friction Test

The dry sliding wear tests for the binary powder performs of Iron-Graphite have been conducted using pin-on-disc machine model TR-20 supplied by M/S Ducom, Bangalore (India). The tests have been conducted in ambient condition of 29⁰C to 32⁰C temperature and a humidity of around 60% to 65%. Wear tests have been conducted using cylindrical samples of Ø 12.3 mm (avg. value) 28±1 mm in length that had flat surfaces in contact region and the rounded corner. The pin is held stationary against the counter face of a 10 mm. The control parameters for the wear tests are the normal, track radius and the rotational speed of the disc. Composition of the counter face is of following proportion, Fe- I.3-1.6, Cr,-0.95-1.1, C-0.2-0.35, Si-0.25-0.45, Mn-0.025, P-O.O25S (AISI 52100). The Disc was used be cleaned after every single experimentation. Figure below is the photograph of the wear testing machine.

Figure 5 : Pin-on-disc wear tester

The variation of wear and friction change with the change in sintering temperature and graphite content are discussed below.

Fig 6, Fig 7 and Fig 8 shows the experimental testing carried out for 1050°C, 900°C and 800°C sintered specimen with graphite content of 0.5%, 1%, 1.5% and 2%. The load applied was 40 N and track radius was selected 40 mm for 1500 seconds which means the track distance 6000 m, selected for test. As the test started the specimen got started rubbing with the disc of wear tester, this rubbing generated intense noise and sparks. From the above figures it is visible that the specimen with graphite content of 2% for all sintering temperature shows the maximum wear resistance as compared to other percentage of graphite content. The samples sintered at 1050°C for all graphite percentage when compared to 900°C and 800°C shows good wear resistance. Thus hard and dense samples were obtained for 1050C sintered with was also seen in the microstructural analysis of the samples by SEM analysis (Fig 2, Fig 3 and Fig 4). The average wear of the specimens studied was

It is clearly visible from the above Fig 9 that the average wear of the samples decreases with the increase in graphite content for same sintering temperature and wear resistance of the samples increases with the increase in sintering temperature.

IV. Conclusion

- As the sintering temperature increases from 800°C to 1050°C the microstructure of the specimen shows the dense and harder structure.
- With the increase of graphite content the microstructure of the specimen shows better bonding of the particles thus micro cracks of the specimen is reduced with the increase of the graphite percentage from 0.5% to 2%.
- With the increase of graphite percentage of the specimen it is observed in the microstructure that the graphite particles are deposited in freeform on the surface of the specimen.
- Wear resistance of the specimens was increased with the increase in graphite content.
- Average wear rate of the specimens was decreased with the increase in sintering temperature. The best result was obtained with the specimen of 2% for all sintering temperature and least wear was found in specimen with sintering temperature 1050°C and 2% graphite content.

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