ISSN (Online): 2456-0448
International Journal Of Innovative Research In Management, Engineering And Technology
Vol. 3, Issue 2, February 2018

Development And Analysis Of Conventional And Carburized Pm Gear

[1] Vishvaksenan. A, [2] Vinith. R, [3] Mukilan. B.M, [4] Dr. S. Selvib
[1] [2] [3] Department of Mechanical Engineering Institute of Road and Transport Technology, Erode.
[4] Associate Professor, Department of Mechanical Engineering Institute of Road and Transport Technology, Erode.

Abstract: ***Powder Metallurgy is a novel manufacturing process producing components having desirable characteristics, without subsequent machining, re- sulting in reduced cost and time. In this study, the fabrication of sintered gear and its subsequent case hardening by gas carburizing is mentioned. To under- stand the effects of carburizing on the sintered gear, both the sintered and car- burized specimens were analyzed for its microhardness, breaking load, wear rate and microstructure. The results of microhardness analysis of the carburized gear provides the depth of effective hardening to be 1.02 mm. This increase in hardness caused a minimal reduction in elasticity, causing the ultimate com- pressive strength to decrease from 40 KN to 34.4 KN. The specific wear rate (m3/Nm) was low for sintered material than carburized material, under increas- ing loads and disc speeds. This was contrary to the specific wear rate for in- creasing track radius, where the carburized specimen exhibited better wear re- sistance than sintered specimen. The images obtained from Scanning Electron Microscopy (SEM) for carburized specimen showed relatively uniform grain size and lesser pores than sintered specimen. The carburizing process was found to be beneficiary for gears used for continuous and heavy loads.***

Keywords - Gear, Powder Metallurgy, Carburizing, Microhardness, Wear, Mi- crostructure.

I. INTRODUCTION

In recent times, Powder Metallurgy (PM) has garnered attention as one of the most used technology for the manufacture of automobile parts. It also has found promi- nence in manufacturing and aerospace engineering. The powder metallurgy is a 'near net shape process' which eliminates the necessity of any major secondary operation. Reduction in number of operations for manufacturing a product, improves costs and saves time. It also addresses the concerns on energy and environment [1-3]. Also, heat-treatment is being adopted by many as a strategy to develop high stress- withstanding PM components. However, hardening of the core could occur for PM components with high porosity, causing more brittleness [4].

Research has shown that the heat-treatment of sintered components improves the mechanical and tribological characteristics. Vysotskii and Lovshenko performed car-busintering for obtaining improved mechanical properties, such as ultimate tensile strength, which showed improvement up to 50% [5]. Georgiev et al observed that sintered gears made from NC 100.24 grade iron powder showed better wear resistance when treated with C7H7 [6]. Askari et al performed nitriding and carburizing process on PM steel parts to increase surface hardness and wear resistance. For carburized specimens, wear mechanisms were influenced by brittle fracture causing abrasive wear [7]. It was reported by Nusskern et al. that, a surface densification process prior to carburizing produced martensite phase and compressive residual stresses on the surface, also increasing the fatigue strength [8]. Fe-C-Mo and Fe-C-Cr steels were sintered for different values of temperature and pressure by Lorella Ceschini et al. and their behavior under both dry sliding and abrasive wear conditions were studied. Dry sliding wear behavior was desirable for higher Mo content, reduced porosity as well as increased pore roundness and all tested steels had high abrasive wear [9].

II. FABRICATION OF GEARS

The sintered gear is prepared by using conventional PM technology. Some of the sintered gears were further subjected to gas carburizing, to obtain carburized gears. The schematic of the gear design is presented in Fig.1.

ISSN (Online): 2456-0448
International Journal Of Innovative Research In Management, Engineering And Technology
Vol. 3, Issue 2, February 2018

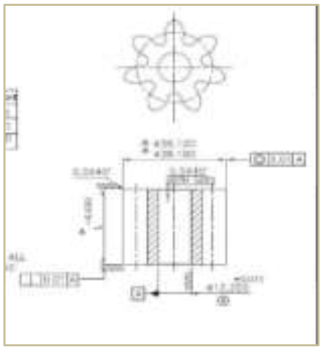


Fig.1 Gear design


Fig.2 Compacting Press


Fig.3 Sintered Gear

2.1 Fabrication of Sintered Gear

The powder metallurgy technology, primarily involves three stages. In the first stage, the required metal alloy powder is prepared and mixed with a suitable bind- er/lubricant. The mixture prepared is compacted into the required shape using a die or mould, in the second stage. Finally, the compact is sintered, in a protective atmos- phere to achieve sufficient strength of the compact and to enable it for the intended use. In the preparation of the sintered gear component, binders/lubricants were not uti- lized. Pressure of 600 MPa was applied to produce the compact from the powder mix- ture, using a mould. The green density of the compact was measured to be 6.85-7.10

g/cm^3. The compact was subjected to 1120 ^{o}C for 30 minutes in NH3 gas atmosphere. The composition of the powder mixture and properties of the sintered component are presented in Table 1 and 2 respectively. Fig.2 displays the compacting unit and Fig.3 presents the image of the sintered gear.

Table 1. Chemical composition by weight %

Chemicals	Nickel	Carbon	Copper	Molybdenum	Iron
Weight %	1.5	0.5-0.8	1.5	0.5-0.8	Remaining

Table 2. Properties of Sintered Gear

No. of teeth	Module	Pressure angle	Pitch circle diameter	Addendum	Density	Hardness
7	4 mm	20^o	28 mm	5 mm	6.4-6.6 g/cm^3	45-50 HRB

2.2 Fabrication of Carburized Gear

The gas carburization was a case hardening process. The following range of parame- ters was chosen to perform carburizing of the gears using the Continuous Mesh-belt Hardening Furnace (CMHF): Temperature of (600-800) ^{o}C; Duration of (40-60) min; Carbon potential of ((0.7-0.8) % to (0.9-1.0) %). Further, the quenching process was carried out at 60 ^{o}C using high quench oil medium grade, followed by tempering at 150 ^{o}C. The CMHF is shown in Fig.4 and the carburized gear is depicted in Fig.5.

Fig.4 Continuous Mesh-belt Harden- ing Furnace

Fig.5 Carburized Gear

III. EXPERIMENTAL DETAILS

3.1 Microhardness Analysis

Micro-hardness is determined by making static indentations with loads not exceeding 1 Kgf. For measuring the microhardness of the carburized gear at increasing distances from the surface, Vickers diamond pyramid with an apical angle of 136o, was used as the indenter at 0.1 Kg load, according to ASTM E384-17. A part of the carburized was cut and cleaned with nitric acid and ethanol. The part was used to prepare the mould shown in Fig.6. The indentations were measured using precision microscopes having a magnification of x500 and accuracy of +0.5 µm. The Vickers hardness tester used is displayed in Fig.7.

3.2 Breaking Load Analysis

In order to determine the permissible compressible stress withstood by both the sin- tered and the carburized gear, the breaking load analysis was performed. The gear load was mounted on a v-block, and increasing loads were applied on the tip of the gear tooth, as shown in Fig.8. Universal Testing Machine (UTM) having a capacity of

10,000 KN was used to apply the compressive loads.

Fig.8 Experimental setup of breaking Load analysis Fig.9 Wear testing unit

3.3 Wear Analysis

The specific wear rate (i.e. wear rate per unit load) was determined for both sintered and carburized PM material according to ASTM G99-17 standard. The pin specimens, prepared using Electro Discharge Machining (EDM), had a length of 40 mm and di- ameter of 5 mm. EN31 Steel was used as the disc material. The wear analysis was performed for the following conditions: (20-40) N load, (30-50) mm track radius, and (425-475) rpm. The duration of each trial was fixed at 10 min. The weight of the specimens was measured using a digital weighing scale of accuracy +0.01 mg. The wear testing unit is depicted in Fig.9.

3.4 Microstructure Analysis

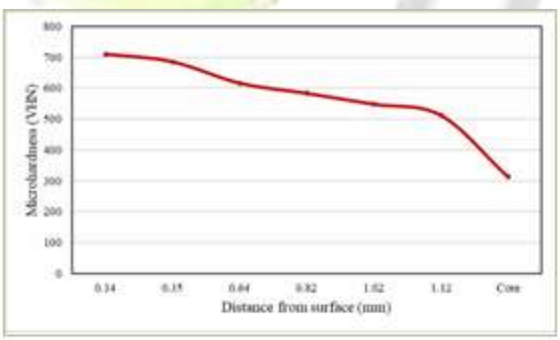
The microstructure of the surface of solid materials was analyzed using Scanning Electron Microscopy (SEM). 1cm x 1cm x 0.5cm size samples of sintered and carbu- rized material was prepared using EDM. The samples were then ground using SiC impregnated emery paper, polished using Al powder and etched using Keller's rea-gent. The images from SEM was used to determine the morphological changes during gas carburizing of sintered material. Energy Dispersive Spectroscopy (EDS), an ana- lytical technique using x-rays for chemical characterization of a sample, was used to view the chemical composition of sintered and carburized material.

IV. RESULTS AND DISCUSSION

4.1 Microhardness Analysis

When the microhardness of carburized material was measured at equal distances from the surface, the maximum microhardness attained was 710 VHN near to the surface. The microhardness value decreased on increasing distances from the surface, finally attaining a value of 313 VHN at the core. The carburizing process was found to have effectively increased the hardness of sintered material, up to a distance of 1.02 mm from the surface [10]. The variation in microhardness of the carburized gear specimen is plotted in Fig.10. The sintered component had a uniform microhardness value of

310 VHN.



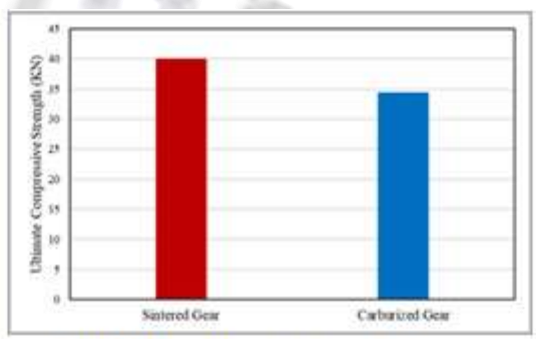


Fig.10 Microhardness values of carbu- rized specimen

Fig.11 Breaking load analysis

4.2 Breaking Load Analysis

During the breaking load analysis, the carburized gear exhibited a minimal decrease of ultimate compressive strength, compared to sintered gear. The sintered gear frac- tured at a load of 40 KN, while the carburized gear fractured at 34.4 KN. This could be due to the increase in carbon concentration in the carburized gear, thereby under- going reduction in elasticity. The breaking load of the gears are represented in Fig.11.

4.3 Wear Analysis

The specific wear rate (x10-15 m3/Nm) was calculated from the weight of sintered and carburized specimens measured before and after wear test, for varying conditions of load (N), disc speed (rpm), and track radius (mm). The sintered specimen showed less wear relative to that of carburized gear, for increasing values of applied load, maintaining disc speed and track radius constant at 450 rpm and 40 mm respectively. A similar trend was also observed when increasing the disc speed, keeping load and track radius constant at 30 N and 40 mm respectively. The increase in track radius for constant values of load (30 N) and disc speed (450 rpm), presented higher wear rate for sintered specimen than carburized specimen. This behavior of the sintered gear could be explained by its high porosity, which caused the wear debris to get accumu- lated in the pores, thus exhibiting less weight loss due to wear. For longer period of usage (i.e. for increasing sliding distance), the carburized material exhibited more wear resistance than the sintered material. The values of specific wear rate for varying conditions of load, disc speed and track radius are plotted in Fig.12.

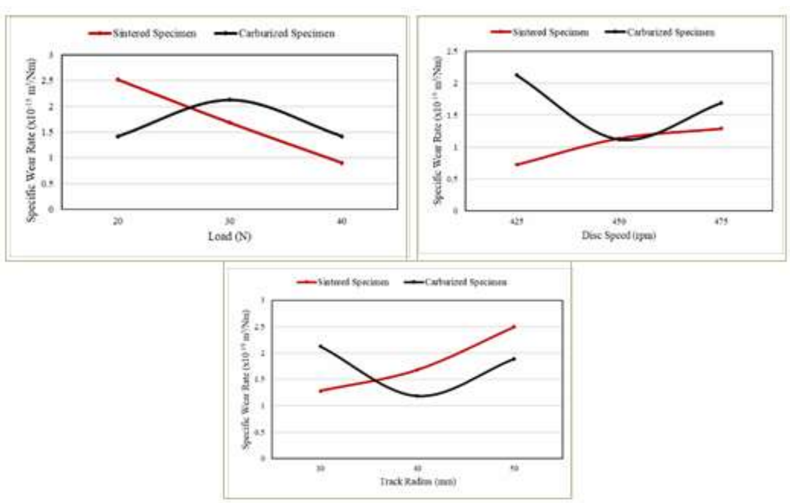


Fig.12 Specific wear rate (x10-15 m3/Nm) of sintered and carburized specimen for varying conditions of load, disc speed and track radius

4.4 Microstructure Analysis

The micrographs obtained from SEM shown in Fig.13, differentiates the grain struc- ture and boundaries in both sintered and carburized material. The carburized material presents benefits in the form of relatively uniform grain size and lesser pores, then the sintered material. When the sintered and carburized materials were observed through optical microscope, the phase in the carburized material was found to be forward transition martensite with rich nickel austenite, while the sintered material was ferrite with rich nickel austenite. The EDS results displayed in Fig.14, shows a decrease of Fe, Ni, and Cu, possibly indicating an increase in concentration of carbon.

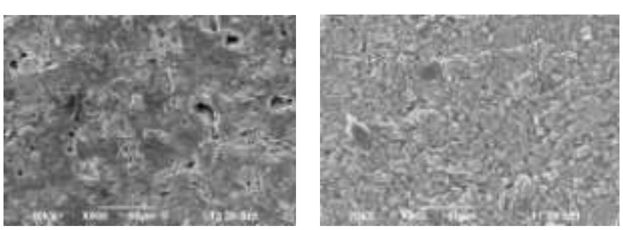


Fig.13 SEM images of sintered (left) and carburized (right) specimen

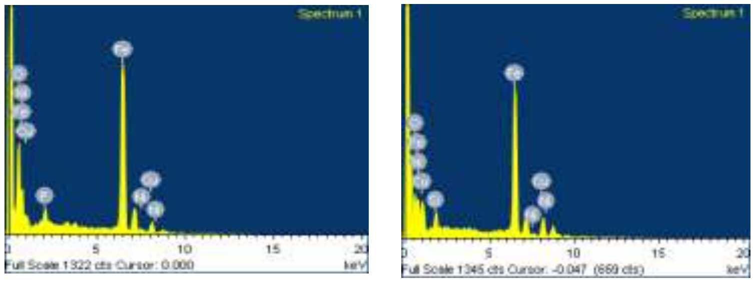


Fig.14 EDS analysis of sintered (left) and carburized (right) specimen

V. CONCLUSION

In this study, the sintered and carburized gears were fabricated successfully. The gears were subjected to microhardness, breaking load, wear and microstructural anal- ysis. From the microhardness analysis, the effective depth of hardening was found to be 1.02 mm. The breaking load analysis results displayed a decrease in elasticity of the gears due to surface carburizing. The specific wear rate stayed relatively low for sintered specimen than carburized specimen for increasing load and disc speed, which was contrary to the wear behavior of the specimens for increasing track radius. The micrographs obtained from SEM depicted relatively uniform grain and less pores for carburized specimen than sintered specimen. The carburizing process was found to be beneficiary for gears subjected to continuous and heavy loads.

References

1. K. S. Narasimhan.: “Recent Advances in Ferrous Powder Metallurgy”, Advanced Performance Materials, 3, 7-27 (1996).

2. Xinmin Li , Mario Sosa, Martin Andersson, and Ulf Olofsson.: “A study of the efficiency of spur gears made of powder metallurgy materials – ground versus super-finished surfac- es”, Tribology International, 95, 211-220 (2016).

3. S. Senthur Prabua, S. Prathibab, Asokan M.A, Anshul Jain, Neeraj Kumar Jain, Pratyush Kumar Chourasiya.: “Investigations on dry sliding wear behaviour of Sintered/Extruded P/M Alloy Steels (Fe-C-W-Ti)”, Procedia Engineering, 97, 2119-2126 (2014).

4. P. Nusskerna, J. Hoffmeistera, and V. Schulzea.: “Powder metallurgical components: Improvement of surface integrity by deep rolling and case hardening”, Procedia CIRP, 13, 192-197 (2014).

5. V. T. Vysotskii and F. G. Lovshenko.: “Feasibility of combining the sintering and carbu- rizing processes for powder alloys”, Metallovedenie i Termicheskaya Obrabotka Metallov, 1, 47-50 (1988).

6. J. Georgiev, T. Pieczonka, M. Stoytchev and D. Teodosiev.: “Wear resistance improve- ment of sintered structural parts by C7H7 surface carburizing”, Surface and Coatings Technology, 180-181, 90-96 (2004).

7. M. Askari, H. Khorsand and S.M. Seyyed Aghamiri.: “Influence of case hardening on wear resistance of a sintered low alloy steel”, 509, 6800-6805 (2011).

8. P. Nusskern, J. Hoffmeister and V. Schulze.: “Powder metallurgical components: Improvement of surface integrity by deep rolling and case hardening”, Procedia CIRP, 13, 192-197 (2014).

9. Lorella Ceschini, Giuseppe Palombarini, Giuliano Sambogna, Donato Firrao, Giorgio Scavino, and Graziano Ubertalli.: “Friction and wear behaviour of sintered steels submit- ted to sliding and abrasion tests”, Tribology International, 39, 748-755 (2006).

10. A. Vishvaksenan and Dr. S. Selvi.: “Development of High Torque gear using Powder Metallurgy”, Advances in natural and Applied Sciences, 11:6, 484-492 (2017).