International Journal of Applied Engineering Research ISSN 0973-4562 Volume 14, Number 11 (2019) pp. 2717-2721

Characterization of Structural Components fabricated by Compaction and Sintering of Low Carbon Content Ferrous Powders

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Abstract

In the present work, compaction and sintering methods wearre applied to fabricate structural components from the low carbon content ferrous powders. Initially, with the help of water atomization technique low carbon content ferrous powders were prepared. The powders were annealed at 1000˚C in presence of hydrogen atmosphere and allowed to mix with 2 weight percent of copper and varied weight percentages of carbon to prepare different test samples. Then the samples were subjected to compaction in the pressure range of 200MPa to 600MPa and sintering at constant temperature of 1100˚C to prepare sintered compacts. Micro-hardness measurements were taken and values in the range of 100HV to 266HV were obtained.

INTRODUCTION

Compaction and sintering processes are very useful and economical for manufacturing of ferrous based structural components with addition of different alloying elements like Cu, Ni, C etc. Also the process parameters like compaction pressure, sintering temperature etc. influence the properties of the processed components.

M.Delavari et al. (1) studied the effect of sintering temperature and compaction pressure on tensile strength of iron powder compacts. Increase in tensile strength was observed with increase of these parameters. S.Tekeli et al.(2) studied the were behaviour of Fe+0.3%graphite powder metallurgy processed steel. They inter-critically annealed the 1200°C sintered specimens at two temperatures like 728°C and 760°C and then water quenched. It was found that wear rate of inter-critically annealed specimen was very low compared to as sintered specimen. O. Coovatanachai et al. (1) conducted an investigation to find the effect of Cu and Ni addition to 409L stainless steel sintered compacts. When 2-6wt% Cu powders were added, strength and hardness increased and sintered density decreased. But when 2wt% nickel powders were added, both sintered density and strength were maximized. X.Zhang et al. (2) investigated the effect of graphite content and sintering temperature on microstructure and mechanical properties of iron based PM parts. They found that with increase in graphite content of sintered specimens, porosity decreased and hardness increased. Y.Qiu-min et al.(5) studied the effect of particle size of atomized iron powder on fluid ability, loose density, compressibility, porosity. They found that with decrease in particle size, iron powders showed lower fluid ability, higher loose density. Again with increase in particle size compressibility increased.N.Verma et al. (6) revealed the effect of carbon addition on diffusion of Copper in SH737 alloy steel. They found that carbon hinders copper growth preventing excessive penetration of copper rich liquid along grain boundaries of the iron of the alloy steel as carbon addition increased the dihedral angle between iron and copper.

In the present work, considering the demand of the industries, different sintered compacts using low carbon content ferrous powders with fixed 2 weight percent copper and varied weight percentages of carbon were prepared at compaction pressures in the range of 200MPa to 600MPa and sintering temperature of value 1100^{o}C. Growth in dimension and micro-hardness of the sintered compacts were studied.

MATERIALS AND METHODS

Production and annealing of low carbon content ferrous powders

Iron was produced by melting sponge iron and then iron was again re-melted and water atomized to prepare low carbon content ferrous powders(LCFP). All the powder particles were partially oxidized during solidification process because of presence of water. In order to remove the oxygen from the powder particles, these were to be annealed in presence of hydrogen at 1000˚C for one hour.

Characteristic studies of low carbon content ferrous powders

The chemical analysis for the said powders was done after annealing and the data are presented in Table 1**.**The shape of the powders was observed using JEOL 840 JSM Scanning Electron Microscope (SEM), which is presented in Figure 1.

The particle size distribution was carried by a particle size analyzer of model Mastersizer, Malvern make, having range 0.05-555µm. Flow meter and Density Cup were used to measure the flow rate and apparent density for the above powders. The apparent density recorded for the annealed powders is 2.75 gm/cm^3 and the flow rate is 24 sec/50 gm**.**

International Journal of Applied Engineering Research ISSN 0973-4562 Volume 14, Number 11 (2019) pp. 2717-2721

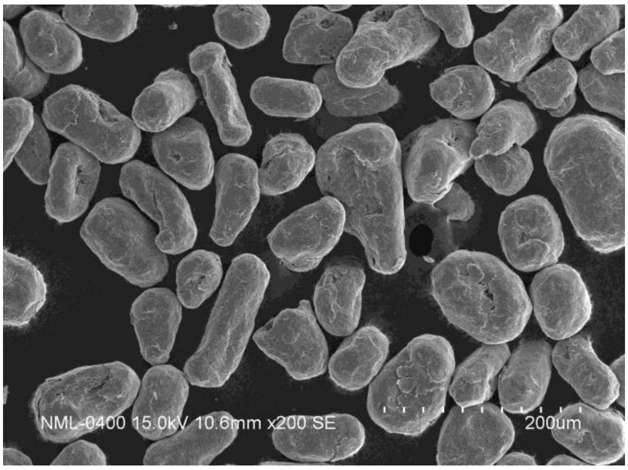

Fig.1: SEM micrograph of low carbon content ferrous powders.

Table 1: Chemical characteristics of low carbon content ferrous powders.

Elements	Annealed powder in % of mass
C	0.04
S	0.015
P	0.025
Fe	Balance

Composition selection and pre-compaction studies

In order to utilize the advantages of liquid phase sintering and to achieve higher strength, ferrous powders are to be mixed with copper (Cu). This copper addition to ferrous powders can produce dimensional growth during sintering. In order to counteract the dimensional growth of Cu additions, carbon(C) addition is to be done by which the dimensional growth caused by Cu can be reduced.

For the above produced powders several compositions of iron-copper and iron-carbon-copper have been selected for investigation. The compositions are as follows.

1. LCFP(balance)+2%Cu+1% zinc stearate
2. LCFP(balance)+2% Cu+0.2%C+1% Zinc stearate
3. LCFP(balance)+2%Cu+0.5%C+1% zinc stearate
4. LCFP(balance)+2%Cu+1%C+1% zinc stearate

The Cu powders with purity of 99%, the graphite powders (used here as Carbon) with purity of 99.8 %, were used here. The above mixtures were prepared by thorough blending using a fabricated blender.

Cold Compaction Studies of Low Carbon content Ferrous Powders.

Annealed powders below 100 µm size were taken for cold compaction studies. The powders were thoroughly blended with 1% zinc stearate to improve the lubricating behavior among the powder particles as well as to reduce the friction between powders and die during compaction. Double action die assembly and a servo hydraulic Universal testing machine of 50 Ton capacity, made by Blue Star India, were used for cold compaction of the samples. The density values were measured for the compacts at different pressures and are presented in Table 2 to Table 5.

Sintering studies of Low Carbon content Ferrous Powder Compacts

For improving strength of the above cold compacts, the sintering was done at a fixed temperature of 1100˚C for one hour in hydrogen atmosphere. Here a tubular sintering furnace, made by Therelek Furnaces Private Limited, was used. The hydrogen gas was continued to pass from starting of heating till cooling up to room temperature. After the samples got cooled down, these were collected and again were measured for their sintered densities. The sintered density data for all compacts are presented in Table 2-Table 5. The percentage change in volume after sintering (Growth/shrinkage) observed for all samples were calculated, which are presented also in Table 2-Table5.

Micro-hardness studies

The micro-hardness values were determined for the sintered samples, which had been compacted at 400MPa, 500MPa and 600MPa, by using a micro-hardness tester . The values are presented in Figure 2.

RESULTS AND DISCUSSION

Powder characteristics

From the chemical analysis presented in Table 1, it is revealed that the sulphur and phosphorous contents are quite low for iron powders for manufacturing PM components. From SEM analysis, it is revealed that most of the low carbon content ferrous powders are irregular and oval in nature. The apparent density for the above annealed powders was found to be 2.75gm/cm^3. This is quite good for manufacturing high density PM parts. The flow rate recorded for the above produced powders is 24sec/50gm.

Table 2: Gren density and sintered density of compacts sintered at 1100˚C, having composition of LCFP (balance) +2%Cu+1%Zinc Stearate, and compacted at different pressures

Pressure in MPa	Green density in gm/cm^3	Sintered density in gm/cm^3	% change in dimension
200	6.23	6.206	0.375
300	6.55	6.525	0.37
400	6.73	6.705	0.36
500	6.91	6.855	0.36
600	7.21	7. 184	0.358

Compaction and sintering studies of ferrous powder compacts with addition of copper and carbon

The behaviour of newly produced ferrous powder compacts with addition of fixed 2% copper and varied percentages of carbon(0.2%-1%) has been observed for compaction as well as sintering studies.

Table 3: Green density and sintered density of compacts sintered at 1100˚C, having composition of LCFP(balance)+2%Cu+0.2%C+1%Zinc Stearate,and compacted at different pressures

Pressure in MPa	Green density in gm/cm^3	Sintered density in gm/cm^3	% change in dimension
200	6.213	6. 182	0.495
300	6.52	6.488	0.48
400	6.705	6.674	0.46
500	6.83	6.799	0.445
600	7.214	7. 183	0.43

Table 4: Green density and sintered density of compacts sintered at 1100˚C, having composition of LCFP (balance)+2%Cu+0.5%C+1%Zinc Stearate,and compacted at different pressures

Pressure in MPa	Green density in gm/cm^3	Sintered density in gm/cm^3	% change in dimension
200	6.22	6. 196	0.38
300	6.53	6.507	0.35
400	6.71	6.687	0.34
500	6.85	6.827	0.33
600	7.20	7. 176	0.33

The green densities, which are presented in Table3-Table5, for varied amount of carbon with 2% copper, are found to be slightly less than the green densities of ferrous powder compacts with only copper of 2 wt. %, which is presented in Table 2, for all corresponding compaction pressures. This slight decrease of green densities is attributed to low density of graphite powders added as carbon.

Table 5: Green density and sintered density of compacts sintered at 1100˚C, having composition of LCFP(balance) +2%Cu+1%C+1%Zinc Stearate,and compacted at different pressures

Pressure in MPa	Green density in gm/cm^3	Sintered density in gm/cm^3	% change in dimension
200	6.221	6.209	0. 18
300	6.54	6.549	0.16
400	6.725	6.715	0.15
500	6.90	6.911	0.13
600	7.215	7.207	0.10

Here it has also been observed that the sintered density of powder compacts containing 2% copper and 0.2% carbon is slightly less than the sintered density of powder compacts containing only 2% copper for the corresponding compaction pressures. This decreasing tendency of sintered density continued for the powder compacts containing 2% copper and 0.5% carbon. However when carbon percentage increased to 1% with same fixed amount of 2% copper , for this newly developed powder compacts, the sintered density started increasing compared to that of powders compacts containing only 2% copper. This is because, carbon, in required amount, lowers the swelling caused by copper in Fe-Cu alloy during sintering by changing the dihedral angle. The growth tendency also started decreasing compared to the previous two cases for the corresponding compaction pressures**.**

Micro-hardness Studies

As observed from Figure 2 that the micro-hardness values increase with increase in compaction pressures for sintered compacts of a particular composition. For LCFP (bal)+2wt%Cu+0.2wt.% C, it is 100HV at 400MPa , 113Hv at 500MPa and becomes 125HV at 600MPa. However, with increase in carbon percentages, micro-hardness values increase for the corresponding compaction pressure. For sintered compact with composition of LCFP (bal) +2wt. %Cu+0.2wt. % C, the micro-hardness value is 125HV at 600MPa. When addition of Carbon is 0.5wt% in the compact, hardness becomes 180HV at the same compaction pressure. With 1wt.% C addition , hardness increases to the value of 266HV in the sintered compact at 600MPa. The increase of hardness is observed as carbon percentage goes on increasing. **T**his hardness value is good for using the material as structural components for various applications.

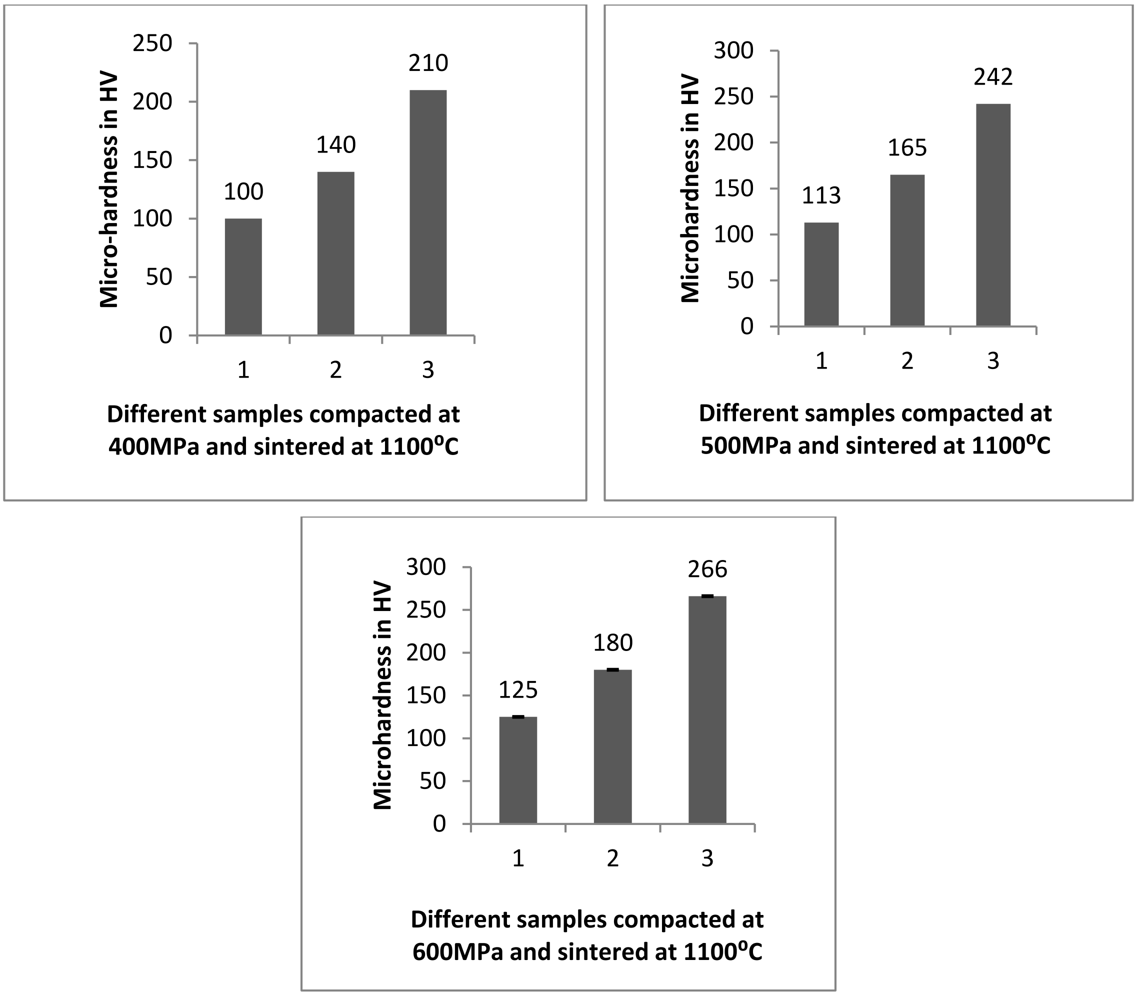

Fig.2: Micro-hardness values for different sintered compact samples : (1)LCFP(bal)+2wt% Cu+ 0.2wt%C, (2) LCFP(bal)+2wt% Cu+ 0.5wt%C (3) and LCFP(bal)+2wt% Cu+ 1wt%

CONCLUSIONS

The following conclusions are drawn

1. Low carbon content ferrous powder sintered compacts show less growth with addition of only 2wt. % copper than with addition of both 2wt. % copper and 0.2wt. % carbon, when compacted in the pressure range of 200-600MPa and sintered at 1100°C.
2. By increasing carbon percentage from 0.5wt. % to 1wt. % with the same 2wt. % copper, growth of the compacts decrease compared to that with addition of 2wt. % copper only for the same compaction pressure range of 200MPa-600MPa and sintering temperature of 1100°C.
3. Micro-hardness of the sintered compacts increase with increased compaction pressures and also with increase in carbon percentages.

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