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PARAMETRIC STUDY ON THE COMPACTING AND SINTERING BEHAVIOUR OF POWDER METALLURGICAL STAINLESS STEEL COMPONENTS

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ABSTRACT

Powder metallurgy is a flexible process capable of producing complex shapes. The powder metallurgy process is a near-net or net-shape process where a subtle change in the manufacturing process can cause a significant change in material properties. This project aims to study the powder metallurgical process of Stainless steel and to study the parameters that have significant impact on the compaction and sintering processes.

These Stainless steel alloys are to be made from elemental powders and hence an optimal blending to obtain uniform composition is essential. The properties of the PM components depend on the quality ensured in all the other steps such as compaction and sintering. In this study, a hollow cylindrical component is selected as a specimen for detailed study. The parameter namely compaction pressure is to be varied in three steps. The outcome responses in terms of green density, sintered density and hardness are to be measured.

Keywords: Powder Metallurgy, Chromium, Nickel, Compaction, Stainless Steel

INTRODUCTION

Powder metallurgy (PM) is a near net-shape technology which is commonly applied in the production of structural steel components. The PM process involves pressing powder into a compact of defined shape and subsequent heating that is *sintering* the compact so that the powder particles bond together. The shape of the compact after pressing is close to the shape of the final component and the dimensional change of the compact during sintering is relatively small. Therefore, the need for machining or other sizing operations after sintering is usually limited.

It was established that by using mixes of powders of different particle size and morphology, resulted in higher density that reduced oxidation rates at high temperature. The addition of gas atomised powders to traditional water atomised powders allowed manufacturing of high-density PM stainless steels through traditional uniaxial compaction and furnace sintering. The effect of sintering cooling rate on corrosion resistance of powder metallurgy austenitic, ferritic and duplex stainless steels sintered in nitrogen was studied, which stated that sintering cooling rate determines the microstructure of stainless steels. The corrosion resistance of any material strongly depended on its microstructural features. The type of phases and the relative amounts of constituents were the main factors to be considered. Microstructural changes took place for every sample and a strong dependency on chemical composition and cooling rate were observed.

The beneficial effect of nitrogen on corrosion behavior of solution annealed samples was established when the influence of ageing heat treatments on the microstructure and intergranular corrosion resistance of sintered in nitrogen duplex stainless steels was investigated. The cooling rate was the main factor affecting the microstructure of duplex, austenitic and ferritic stainless steels sintered in nitrogen. A low cooling rate (furnace cooling) promoted a wide process of precipitation as lamellar constituents and some intergranular and transgranular precipitated. The water cooling process avoided the precipitation. The gas cooling process showed an intermediate process of precipitation very much dependent on the chemical composition. Stainless steels sintered in argon atmosphere exhibited better densification rate than nitrogen atmosphere sintering. The microstructure of stainless steel sintered in nitrogen atmosphere revealed lamellar constituents with grain boundary Cr_2N in ferritic matrix. Composition of austeno-ferritic stainless steel in argon atmosphere showed bi-phase structure with high strength and better elongation. Sintering 316L stainless steel in nitrogen atmosphere at 1300 °C was the optimum sintering condition for compacts in terms of the mechanical properties, microstructure and density and also indicated that the compacts sintered in nitrogen atmosphere exhibited higher strength and hardness than that of the steels sintered in argon atmosphere.This project aims to study the effect of compaction pressure on 2 different compositions in the fabrication of Stainless Steel components with improved mechanical properties.

Experimental Method

Metal powders required for powder metallurgy process are generally produced by water and gas atomization, milling, mechanical alloying. Elemental powders or alloy powders could be taken and additives such as Zinc Stearate could be added to them for blending or mixing them together. The blended powder is then subjected to Compaction which could be either Cold compaction at room temperature or Warm compaction about 150°C. This compact is then passed onto sintering stage after which some optional processes such as coining, sizing could be done. In this study,2 different compositions are considered as given below in Table 1.

Table.1.Nominal Composition for considered Stainless Steels

Composition	Cr	Ni	C	Fe
SS 304	18	10	0.03	Balance
SS 410	12	-	0.26	Balance

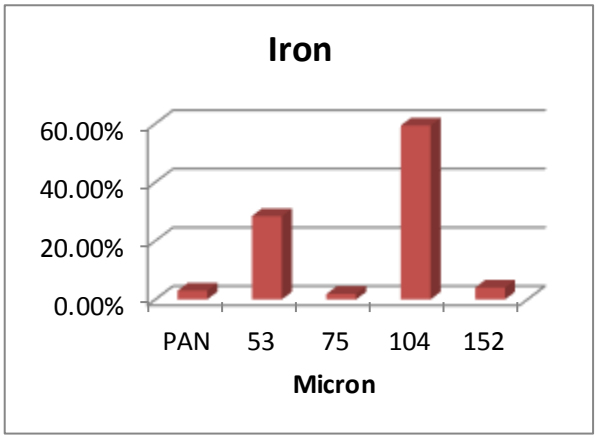
Powder shape, size, and purity are important factors in the application of a powder processing technique. For some consolidation processes or steps, powders must be smooth, spherical particles, but for other processes a much more irregular powder shape is required. In this study, conventional *press and sinter* processing is used, where an irregular powder shape and distribution of particle sizes are desired for adequate green strength and sinter response. The various powder ingredients are selected to satisfy the process constraints and still meet the requirements of the end product. For example, in cold compaction irregularly shaped powders are used to ensure adequate green strength and structural integrity of the as-pressed product. Special solid lubricants can be added to the powder blend to reduce friction between the powder particles and the tooling.

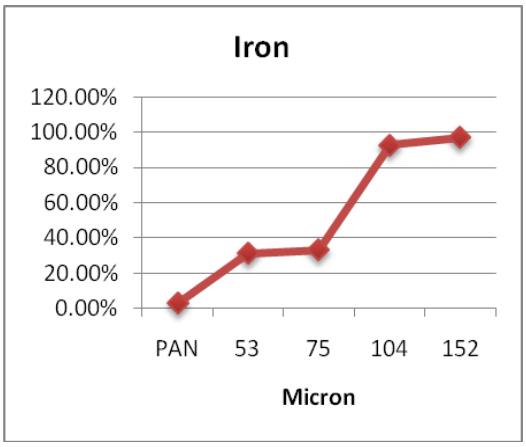
In the die compaction process, a die cavity of the desired geometric shape is filled with metal powder. Pressure, on the order of 350 to 700 MPa, is applied by the axial movement of one or more punches. In this study, pressure is varied in 3 steps – 500, 600, 700 MPa. The pressure causes the metal powder particles to mechanically interlock and cold weld together into a porous mass of the approximate shape and dimensions desired for the final component. This as-pressed shape, commonly referred to as a green part, is then heated to an elevated temperature, to sinter the metal powder particles into a solid mass. In our study, sintering was done at 1100 °C for 30 min. Dimensional tolerance control is determined by the maximum temperature of the sintering cycle and the metallurgical changes that occur during sintering. If solid-state diffusion is the primary sintering mechanism, very little densification occurs, dimensional change is minimal, and tolerance control is very good. In addition to its effects on dimensional tolerance levels, the sintering step also plays a significant role in determining the final physical and mechanical properties of the product. Higher sintering temperatures and longer sintering times promote pore rounding and increase densification, thereby improving critical mechanical properties such as tensile strength, ductility, impact resistance, and fatigue limit.

RESULTS AND DISCUSSION

Sieve analysis was done for the powder raw materials that were obtained. Each powder sample was subjected to vibration in the Sieve Shaker for 15 minutes. Fig.1 shows both individual and cumulative size distribution of the powders

For Iron, it can be observed that a majority of powders (59.4%) have stayed in the range of 104-152 μ, followed by 28.5% of the powders in the range of 53-75 μ. It is inferred that a bi-modal distribution of Fe powders is observed from this sieve analysis. For Chromium, it can be observed that a majority of powders (55.4%) have stayed in the range of 53-75 μ, followed by 36.6% of the powders in the range of 104-152 μ. In case of Nickel, almost all the powder is below 75 μ, with half of the given powders in the range of 53-75 μ, and most of the remaining powders is less than 53 μ.





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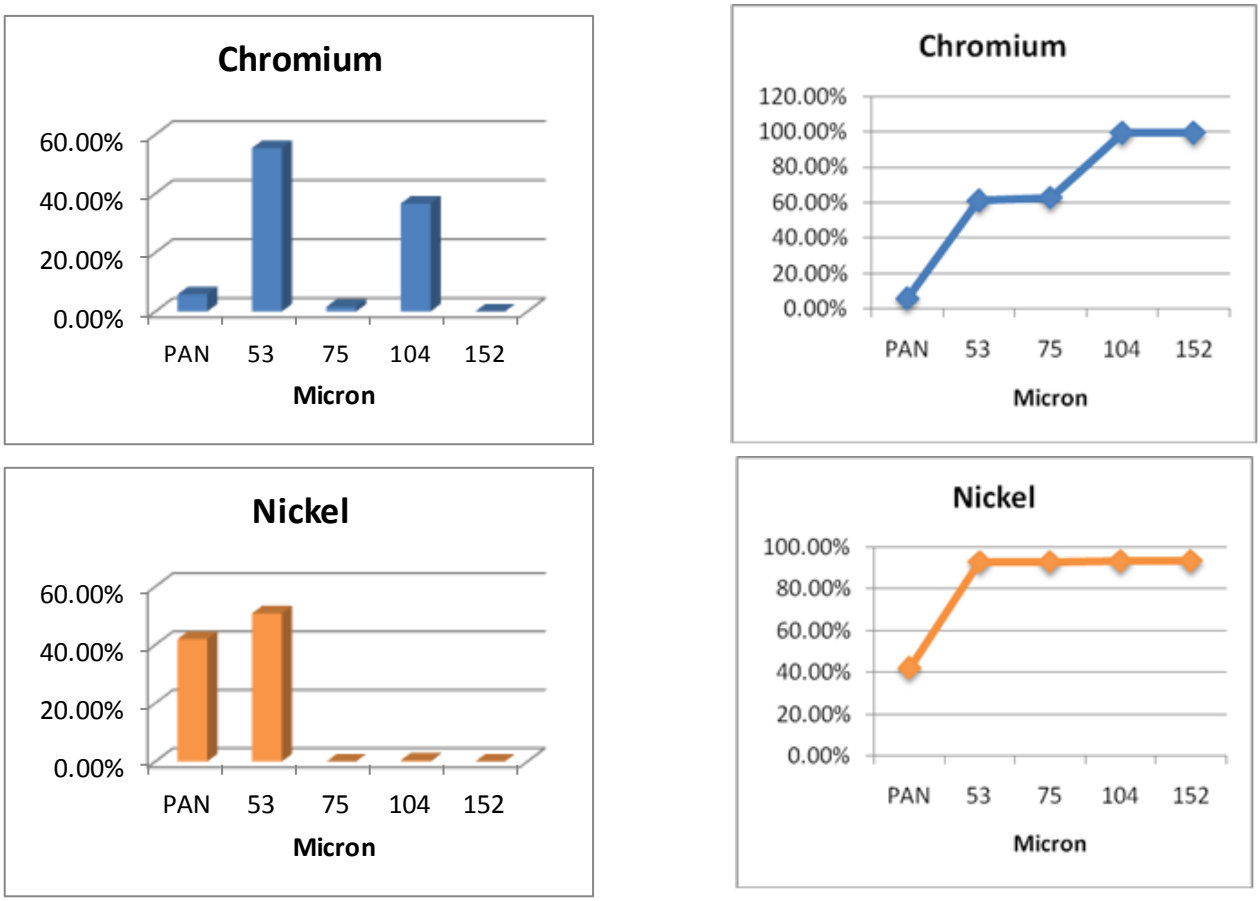

Fig.1. Sieve Analysis - Individual and Cumulative Size distributions

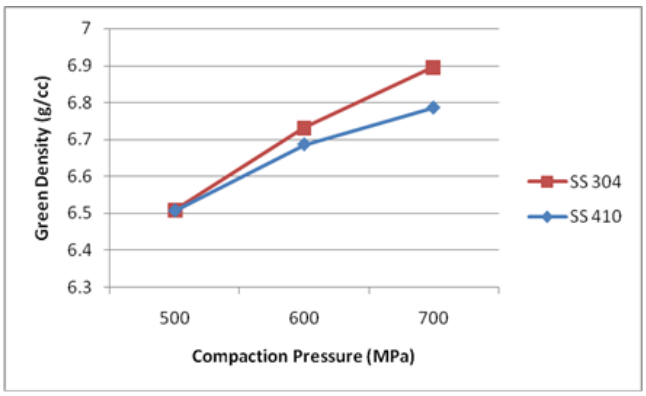

Fig.2. Green density as a function of Compaction pressure

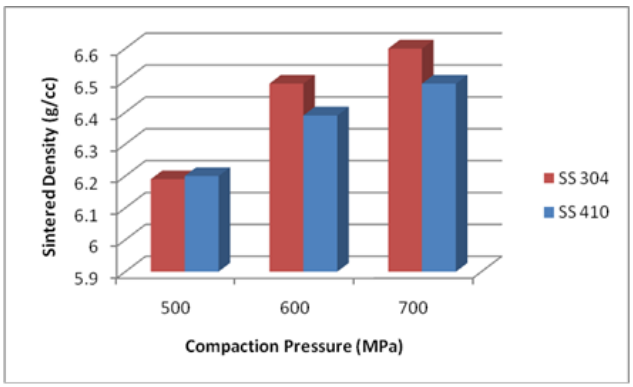

Fig.3. Sintered density as a function of Compaction pressure

The blended powders which were compacted at 3 different pressures namely 500 MPa, 600 MPa, 700 MPa resulted in different green densities respectively. The average green density for each pressure and each composition was plotted against the respective compaction pressure as in fig.2.

It was observed that densities of 6.508, 6.73, 6.89 g/cc was obtained for SS 304 and 6.507, 6.68, 6.78 g/cc was obtained for SS 410, which are plotted in fig.2. It can be seen that at 500 MPa, both compositions result in similar densities, and as pressure increases the density also increases. The response to increased pressure, by composition SS 304 is quite higher than SS 410. Similar trend could be observed in sintered density in fig.3.

Hardness values were measured for the samples with Rockwell hardness tester. SS 304 specimens were found to be harder than their SS 410 counterparts at all pressures, but the extent of difference is higher for higher compaction pressures.

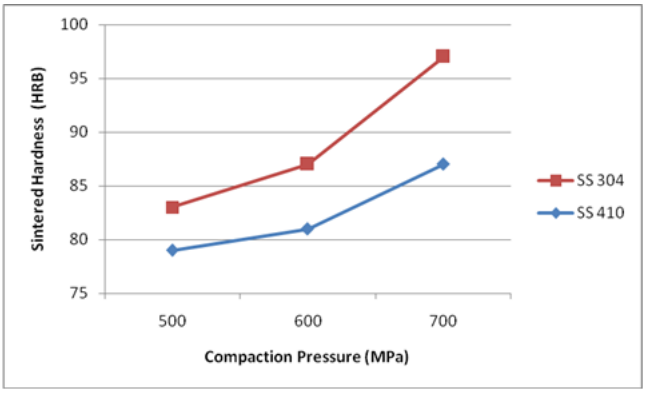

Fig.4. Sintered Hardness as a function of Compaction pressure

CONCLUSION

Within the scope of this study, composition SS 304 exhibited better Green density, Sintered density and hardness than SS 410. This could be attributed to the additional presence of Nickel in SS 304. Also it was found that these properties showed considerable increase with increase in compaction pressure.

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