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To Study the Effect of Heat Treatment on Microstructure and Mechanical Properties of Sintered Steel SMF 2025

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ABSTRACT: High demands are set on key synchronizers made from sintered steel regarding wear, fretting, tooth fracture and pitting load capacity. The hardening obtained after the sinter process will affect the microstructure of the sintered steel so that the wear load capacity can increase to higher values. This paper shows the influence of different hardening methods on key synchronizers fabricated from SMF 2025 sintered steel and the changes induced on the microstructure, the surface and the core hardness and the wear load capacity. Case carburizing has long been a basic technique for the improvement of the wear and fatigue resistance and of PM steel components. The key to the successful improvement in carburizing however is understanding and interpreting the microstructure of the carburized case. Carbonitriding is basically the same process as Case Carburizing. The major difference is that Ammonia (NH3) is added, normally towards the end of the carburizing period. The Ammonia decomposes on the surface of the components (and also on the furnace itself) into atomic nitrogen that can penetrate the component and into hydrogen gas.

Keywords: Microstructure, Sintering, Carburizing, Carbonitriding.

I. INTRODUCTION

Sintering is a method established for making metal objects from powders and every single step of this process is having an influence on certain material property. The parts made by powder metals are the main group of products in powder metallurgy. They are very profitable products in a highly developed industry, being used in the automotive industry, machinery as well as in many other areas of the metalworking industry. Compared with other types of production, the marked share of sintered parts is not so big but it shows a constant steady growth. Over the time, the sintered parts have developed from unimportant parts to the very important functional parts like the one which is investigated here. These parts must always transfer high static loads but often dynamic loads also. Key synchronizers are used in the transmission assembly of vehicles during engaging and disengaging of gears. SMF 2025 sintered steel is used for manufacturing these components. The research presented in this paper is aimed at finding the most appropriate additional treatment which leads to higher wear load capacity as compared to the wear of sintered key synchronizers without any additional treatment.

The introduction of high density compaction technology, known as the AncorMax D process enables P/M part producers to achieve up to 98% pore-free densities in green parts [8]. This premix technology features a proprietary lubricant/binder system requires a high compaction pressure of 550 – 823 MPa (40 – 60 tons/in^2). Die temperatures must be maintained in the range 60 – 70 °C (140 – 150 °F) and this is achieved using cartridge heaters incorporated within the die. Warm die compaction, coupled with advanced lubricant/binder systems has been shown to increase green densities without the need to heat the powder [9].

Carburizing is the addition of carbon to the surface of low-carbon steels at temperatures generally between 850 °C and 950 °C (1560 °F and 1740 °F), at which austenite, with its high solubility for carbon, is the stable crystal structure. Hardening is accomplished when the high-carbon surface layer is quenched to form martensite so that a high-carbon martensitic case with good wear and fatigue resistance is superimposed on a tough, low-carbon steel core [1].

Case depth of carburized steel is a function of carburizing time and the available carbon potential at the surface [2]. When prolonged carburizing times are used for deep case depths, a high carbon potential produces a high surface-carbon content, which may thus result in excessive retained austenite or free carbides.

These two microstructural elements both have adverse effects on the distribution of residual stress in the casehardened part. Consequently, a high carbon potential may be suitable for short carburizing times but not for prolonged carburizing. In regards to fatigue properties, Low retained austenite content and fine austenitic grain sizes, which create a microstructure of finely dispersed retained austenite and tempered martensite, prevent nucleation of fatigue cracks, or retard fatigue crack initiation until very high stress levels are reached. In contrast, low-stress applications that fracture at low cycles is related to high retained austenite levels and coarse austenite grain sizes [5-6].

Carbonitriding is basically the same process as Case Carburizing [3-4]. The major difference is that Ammonia (NH_3) is added, normally towards the end of the carburizing period. The Ammonia decomposes on the surface of the components (and also on the furnace itself) into atomic nitrogen that can penetrate the component and into hydrogen gas. The nitrogen will diffuse into the part in a similar way as carbon does, driven by the concentration difference between the surface and the core. The nitrogen in solution in the austenite will increase the hardenability and therefore, the carbonitriding can be used to obtain martensite in alloy systems that would not normally transform into martensite after an ordinary case carburizing [7]. The problem with oxidation is also present in this system since the equilibria are the same with the exception of the added ammonia. The ammonia influences the carburizing equilibria to small degree only, except that the amount of hydrogen gas increases slightly. However, since the addition of ammonia is normally (at least for PM parts) added towards the end of the austenitization, the oxidation has already taken place and will not revert even if the furnace conditions should improve slightly [10].

II. EXPERIMENTATION

The test program was intended to investigate the performance levels achievable on mechanical properties and microstructure of a hybrid sintered steel by using a secondary heat treatment such as carburizing and carbonitriding. This program was divided into following steps:

(i) Preparation of samples from sintered Steel SMF 2025.First of all the test samples are made for tensile test and impact testing, test samples are made using sintering processes details of which are discussed in the paper.

(ii) Then the heat treatment processes carburizing and carbonitriding are performed on these samples. The details of carburizing and carbonitriding are discussed in the introduction part.

(iii) Then the samples are taken for tensile testing, the tensile testing is performed on UTM machine .

(iv) Microstructure examination of the treated and untreated samples was carried out. Each sample was carefully grounded progressively on emery paper in decreasing coarseness. The grinding surface of the samples were polished using Al (2)0(3) carried on a micro clothe. The crystalline structure of the specimens were made visible by etching using solution containing 2% Nitric acids and 98% methylated spirit on the polished surfaces. Microscopic examination of the etched surface of various specimens was undertaken using a metallurgical microscope with an inbuilt camera through which the resulting microstructure of the samples were all photographically recorded.

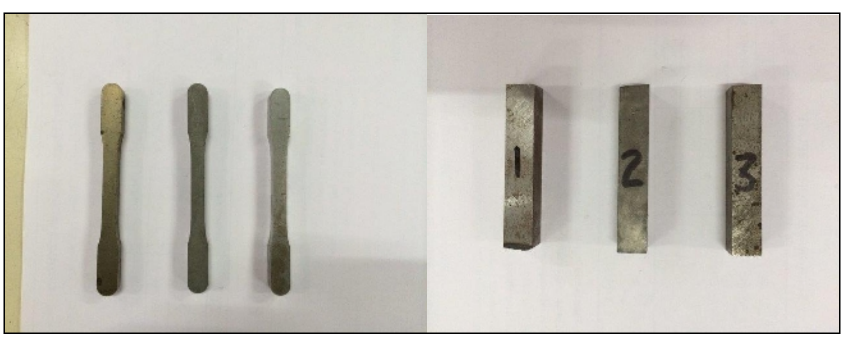
(v) Inspection of hardness of these samples is carried on Rockwell hardness tester and the results are recorded on HRA scale.

(vi) Analysis of the results carried out.

(vii) Conclusion of the results by optimizing the heat treatment which gives best results.

III. MATERIAL COMPOSITION AND TESTING CONDITIONS

The material used in the work is SMF 2025,it is a Japanese standard JIS for sintered material. The main constituent materials are Fe-Cu.
Designation: SMF 2 (Sintered material fibre)
JIS EQUIVALENT: SMF 2025
Material : Fe-Cu



Sample for tensile test Sample for impact test

Fig. 1.

A. Dimensions of sample for tensile test

Width	:	6 mm
Thickness	:	6.5 mm
Initial length	:	20 mm

B. Material composition

Table 1: Material Composition of SMF 2025 Steel.

Fe	C	Cu	Ni	Sn	Mo	Cr	Other
balance	-	3%	-	-	-	-	1%

C. Operating Conditions of SMF 2025 Steel

Table 2: Operating Conditions of SMF 2025 Steel.

SPECIFICATION Of SAMPLE	TEMPERATURE	TIME	C-P	QUENCHING OIL TEMPERATURE
Sintered	1120 degree Celsius	20 min	-	
Carbonitriding	870 degree Celsius	70 min	1.1	100 degree Celsius
Carburized	940 degree Celsius	70 min	1.1	100 degree Celsius

IV. TESTING OF MECHANICAL PROPERTIES OF SMF 2025 STEEL

Mechanical properties of the treated and untreated samples were determined using standard methods. For hardness testing, oxide layers formed during heat treatment were removed by stage-grinding and then polished, Apparent hardness measurements were performed on the surface of the bars using a Rockwell hardness tester. All measurements were conducted using the HRA scale for ease of comparison. UTM is used for checking tensile load of the test specimens. Tensile strength, and maximum elongation were obtained from the average of five dog-bone tensile samples .Impact energy was determined from the average of five un-notched Charpy Impact bars.

V. RESULTS

Tensile strength for the sintered, carburized, and carbonitriding conditions are summarized in Table I. This table also include information of elongation, surface hardness, specific gravity, Surface finish and Impact strength.

Table 3: Results of mechanical Properties of SMF 2025 Steel.

	AS SINTERED	CARBURISED	CARBONITRIDING
Tensile load	312.8 N/mm.mm	335 N/mm.mm	328 N/mm.mm
Elongation	5%	5%	5%
Surface hardness	38 HRA	71HRA	67 HRA
Specific gravity	7 .007 g/cm.cm.cm	6.996 g/cm.cm.cm	6.996 g/cm.cm.cm
Surface finish	2.63 Ra	2.01 Ra	2.16 Ra
Impact strength	40 Joule	53 Joule	49 Joule
Shear strength	271 N/mm.mm	309 N/mm.mm	307.8 N/mm.mm

As shown in the table 3 tensile load increases with heat treatment processes, tensile load in carburized test sample is highest as compared with the as sintered samples and samples with carbonitriding.

Surface hardness is also on higher side in case of carburized sample as compared with the other two samples. Shear strength increases with heat treatment,shear strength for carburised sample is 309 N/mm.mm which is highest among the all three samples and Impact strength increases with heat treatment,impact strength for carburised sample is 53 joule which is highest among the all three samples.

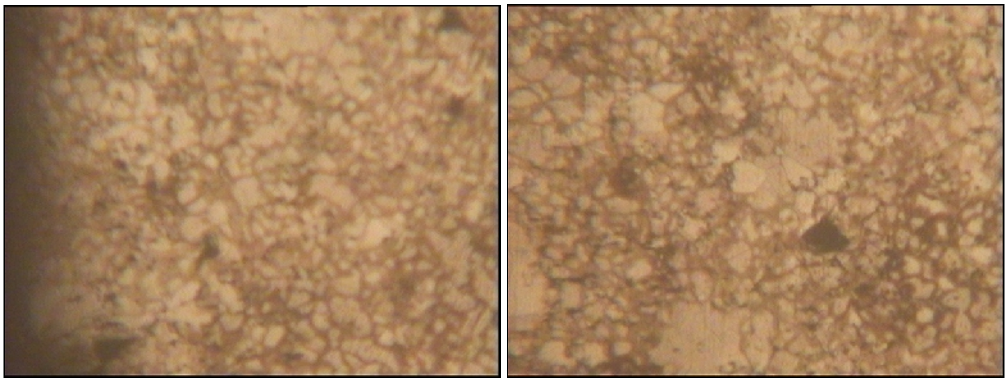


Fig. 2. Sintered Sample.

Microstructure consists of ferritic matrix.copper is uniformly diffused in iron.copper is also visible as grain boundaries interconnected porosity is distributed throughout.

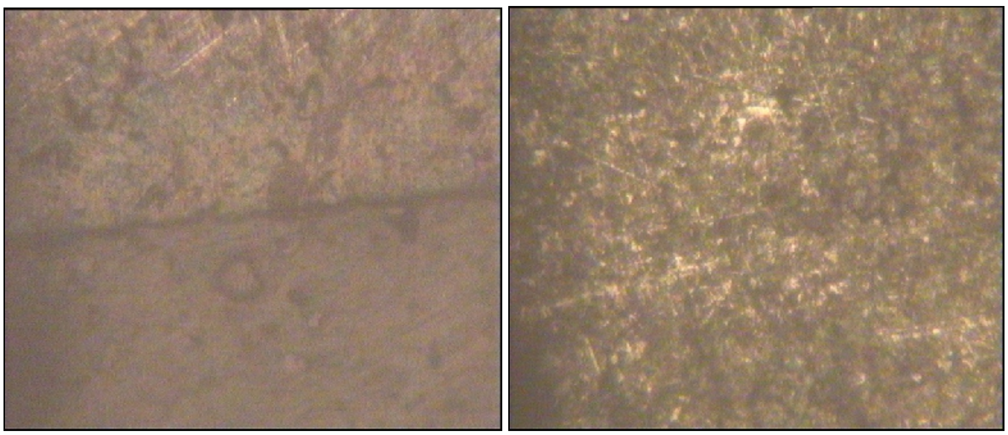


Fig. 3. Carburised Sample.

The case depth in this case is 0.7 mm and microstructure consists of a martensitic matrix at the surface and martensite and banitic structure at the core.copper particles are also present porosity is evenly distributed throughout.

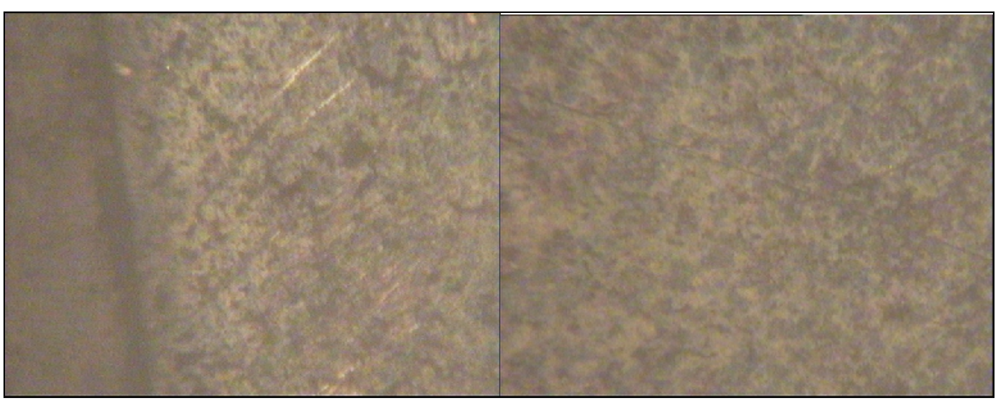


Fig. 4. Carbonitriding Sample.

The case depth in this case is 0.4 mm and microstructure consists of a fine tempered martensite at the surface and martensite and banitic structure at the core.copper particles are also present ,porosity is evenly distributed throughout.

VI. CONCLUSION

The objective of this paper is to study the effect of heat treatment on microstructure and mechanical properties of sintered steel SMF 2025 and following are the conclusion points:

- Tensile strength increases with heat treatment,tensile strength for carburised sample is 335 N/mm.mm which is highest among the all three samples.
- Surface hardness also increases with heat treatment, surface hardness for carburised sample is 71HRA, for sample with carbonitriding it is 67 HRA and for sintered it is 38 HRA.
- Surface gravity decreases with heat treatment,in case of carburised and carbonitriding it is lower as compared with sintered sample.
- Shear strength increases with heat treatment,shear strength for carburised sample is 309 N/mm.mm which is highest among the all three samples.
- Impact strength increases with heat treatment,impact strength for carburised sample is 53 joule which is highest among the all three samples.

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