Research on solid state carburizing of sintered steels

G. Moțățeanu, C. Nicolicescu, D. Zorilă, I. Ştefan

University of Craiova, Faculty of Mechanics, Department of Engineering and Management of Technological Systems, Drobeta Turnu Severin, Romania

E-mail: gmotateanu@imst.ro

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1. Introduction

The pores inside the metal matrix represent the main characteristic of the sintered materials. The pores are advantageous when the functional characteristics are important, namely the filter capacity or self-lubricating but in the same time they provide disadvantages for the mechanical properties [1, 2].

Also, the porosity influences the heating/cooling behavior along these operations during the thermal-physical treatments. The pores diminish the thermal conductivity of the sintered steels vs. the conventional steels with the same chemical composition. On the contrary, the pores represent a great advantage when it comes about the thermal-chemical treatments, i.e. carburizing. In this case, the pores enhance the C% enrichment of the steels superficial layers by the means of the intergranular and volume diffusion [3-5]. The pores' presence favorites the formation of the saturation layer that could be thinner or thicker depending on the pores type (closed or open).

The porosity determines favorable effects on the diffusion processes during carburizing. Thus, beyond the C% enrichment on the superficial layer, in powder metallurgy this effect could provide also C% enrichments in the bulk product in order to obtain functional graded sintered steels as far as concern the concentration and physical-mechanical properties [6, 7].

Further than porosity, the thermal process type has a great influence on C% enrichment. Thus, the carburizing treatment is placed after the sintering stage (sintering + carburizing = SINTCARB) if the superficial layer enrichment in C% is the main purpose. On the contrary, the carburizing treatment should stand before the sintering stage if the C% content improvement in the bulk product is the main goal. Under these circumstances, the green parts must be carburized first and then sintered in the same thermal cycle (carburizing + sintering = CARBSINT).

By gas carburizing of Fe green samples compacted at different pressures, steels with hypereutectoid structures in outer layer and hypoeutectoid in the core have been elaborated. Similar, remarkable characteristics were obtained for the sintered steels processed by gas CARBSINT from homogeneous mixtures (Fe + graphite) with different graphite concentrations, compacted at various pressures [8-10].

Also, by CARBSINT method, sintered steels have been elaborated with remarkable characteristics, from Fe+graphite powder mixtures, compacted at different pressures and heat treated in gas state atmosphere.

The carburizing atmosphere can be solid, liquid, gas or vacuum. The conventional metallurgy for steels uses the gas carburizing and by powder metallurgy low pressure or vacuum carburizing has been developed.

The solid state carburizing used in powder metallurgy may present a special interest for CARBSINT process because, unlike other routes, it can be applied at the same temperatures for the sintering stage, meaning a single continuous thermal cycle [11].

By consequence, the research presented in this paper is focused on the study regarding the effects of the solid state carburizing treatment along the SINTCARB and CARBSINT processes applied on homogeneous mixtures of Fe+0,15%Gr and Fe+0,25%Gr, compacted at 500 respectively 650 MPa.

The carbon distribution in the steel samples surface and core after the carburizing as well as the influence of the quenching treatments in oil and water of the steels toughness are analyzed comparatively.

2. Experimental procedure

The experiments have been carried on by the research diagram presented in Figure 1.

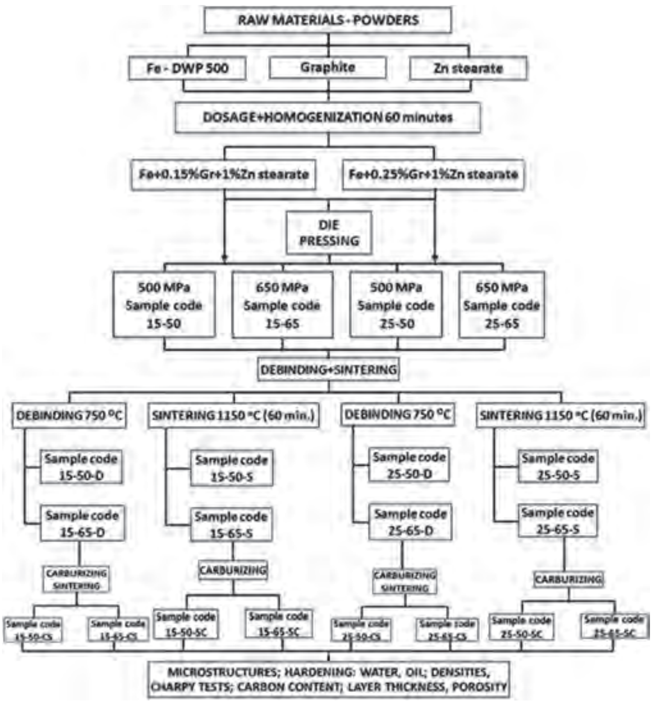

Figure 1. Research diagram.

Iron powder particles type DWP 200 – HEG5001 mixed with 0,15% respectively 0,25% graphite powders and 1% Zn stearate have been used. The mixtures have been homogenized

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for 30 minutes in TURBULA homogenizer and then cold compacted at 500 respectively 650 MPa. The samples are cuboids of 10x10x55 mm corresponding to ASTM E23, ISO 5754 for the toughness testing. Figure 2 presents the carburizing box and the samples. The green compacts have been thermal processed by SINTCARB following the thermal

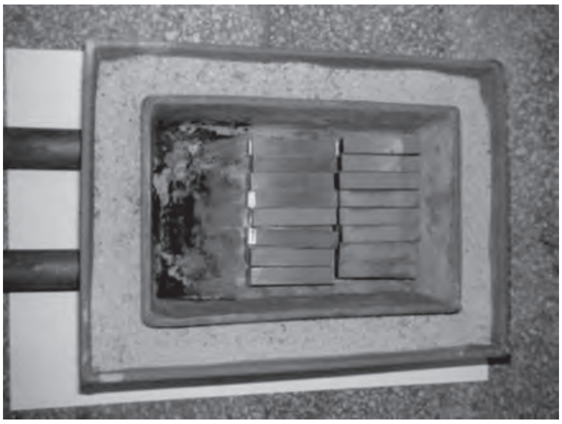

Figure 2. Samples shape and dimensions used for the experiments.

cycles presented in Figure3 respectively by CARBSINT as it is shown in Figure4. The solid state carburizing was carried on using the carburizing slurry made of 85% smut, 10% Na_2CO_3 and 5% fuel oil. The carburizing slurry was thermal analyzed by DTA and the carburizing range was determined to be (850-1150)0C. The carburizing time was 90 minutes for each process in order to reach the C% content gradient across each sample section. After the carburizing by SINTCARB and CARSINT, the samples were quenched in water respectively oil and then tested for toughness determination.

presented in Table 1 and the microstructural features, at different stages of the treatments, are presented in Figure 5-12.

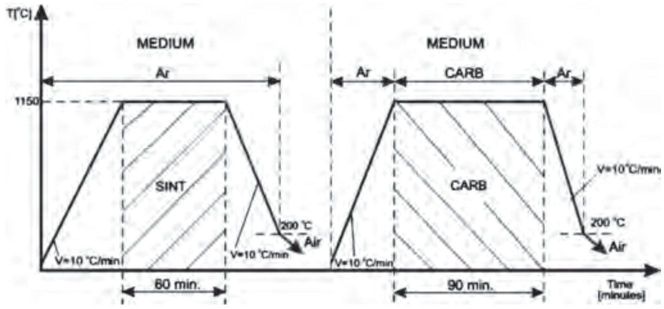

Figure 3. SINTCARB thermal cycle .

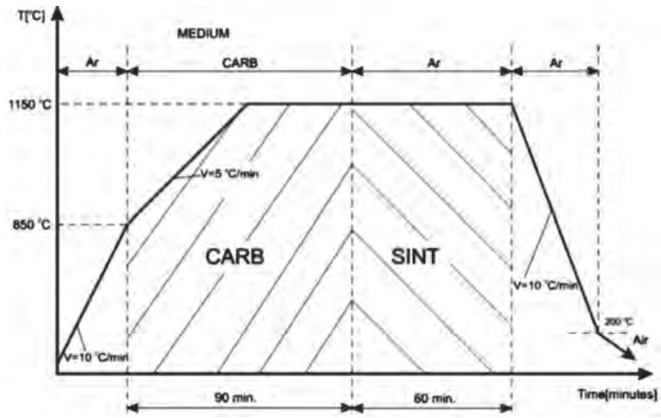

Figure 4. CARBSINT thermal cycle.

The following outlines can be stated after the analysis of the experimental results:

- Using different carburizing treatments, sintered steels with thick carburized layers respectively %C gradient in cross section can be obtained;

Table 1. Physical characteristics of the samples

Parameters		Sample															
		15-50				15-65				25-50				25-65			
		D	S	CS	SC	D	S	CS	SC	D	S	CS	SC	D	S	CS	SC
Apparent density [g/cm³]		6,85	6,93	7,12	7,19	6,9	7,04	7,3	7,39	6,75	6,79	7,29	7,34	6,84	6,86	7,13	7,3
Porosity [%]		12,15	11,19	8,75	7,88	11,52	9,74	6,46	5,26	13,41	12,95	6,54	5,88	12,35	12,05	8,59	6,42
Layer thickness x10³[µm]				1,39	0,98			1,15	0,92			1,35	0,98			0,68	0,33
%C	Layer	-	0,05	0,73	0,69	-	0,12	0,75	0,67	-	0,19	0,72	0,71	-	0,21	0,65	0,62
	Core			0,62	0,31			0,59	0,19			0,43	0,37			0,42	0,29
KC [J]	Not-quenched	-	20,5	11,7	12,3	-	23	15,7	14,7	-	21,7	15	12,7	-	23,5	17,7	16,7
	Water quenching	-	20	4	5,7	-	10	3	5,3	-	18	6	7	-	20	5	6,7
	Oil quenching	-	16	6	7,5	-	17	5	6,7	-	20	11	8,7	-	19	14	5,3

***D= de-binded green part, S=sintered; CS=CARBSINT; SC=SINTCARB

3. Experimental results

After every processing cycle, the samples have been analyzed from the point of view of density, porosity, optical microstructures and C% enriched layers. According to SR ISO 14284:2003, samples of flakes were removed from the processed steels, from surface and core areas, in order to determine the C% content. The experimental results are

- The carburized layers by CARBSINT are thicker than those processed by the conventional SINTCARB. Thus, considering the four steels type, the thickness of the carburized layers belong to (1155,35-1397,55) µm for CARBSINT respectively (331,43-985,41) µm for the SINTCARB treatment;

- The C% content is variable in the steels cross-section after the carburizing and for the core case it doesn't correspond to the graphite content in the initial mixture respectively to the diffused C during the sintering. The differences between the C% content in surface vs. the core for the carburized steels are about (0,11-0,16) % C for the steels processed by CARBSINT from homogeneous mixture with 0,15% graphite respectively (0,23-0,29)%C for the steels processed with 0,25% graphite.

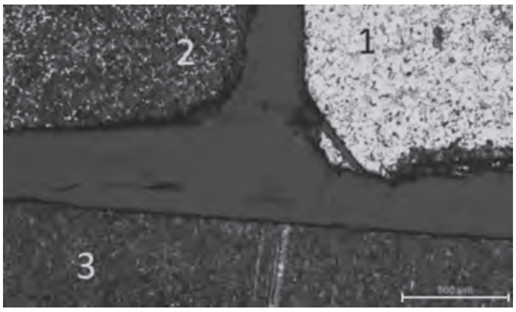

Figure 5. Samples microstructures:
1=15-50S; 2=15-50SC; 3=15-50CS (75X).

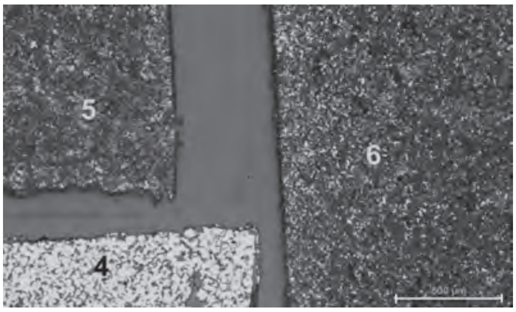

Figure 6. Samples microstructures:
4=15-65S; 5=15-65SC; 6=15-65CS (75X).

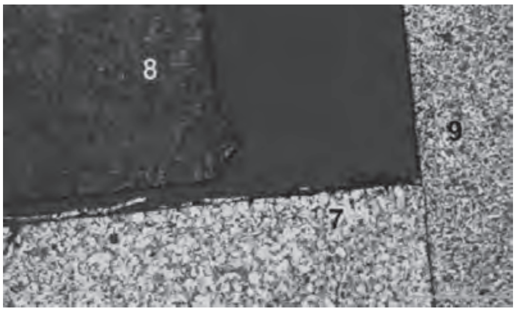

Figure 7. Samples microstructures:
7=25-50S; 8=25-50SC; 9=25-50CS (75X).

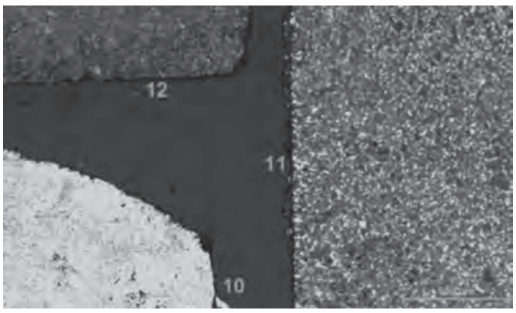

Figure 8. Samples microstructures:
10=25-60S; 11=25-65SC; 12=25-65CS (75X).

The same steels, but processed by SINTCARB, present (0,32-0,48)%C respectively (0,29-0,33)%C as differences between the C% in surface vs. the core.

- The thickness of the C% enriched layer and the C% in the steels cross section are related parameters and they are influenced by the porosity and the initial state of the samples before the carburizing. Thus, the thickest C% enriched layers respectively C% in the core case correspond to the initial porosity (11,52-13,41)% for the steels processed by CARBSINT vs. the sintered and carburized steels that, after the sintering stage, presented the porosity for (11,19-12,95)%;

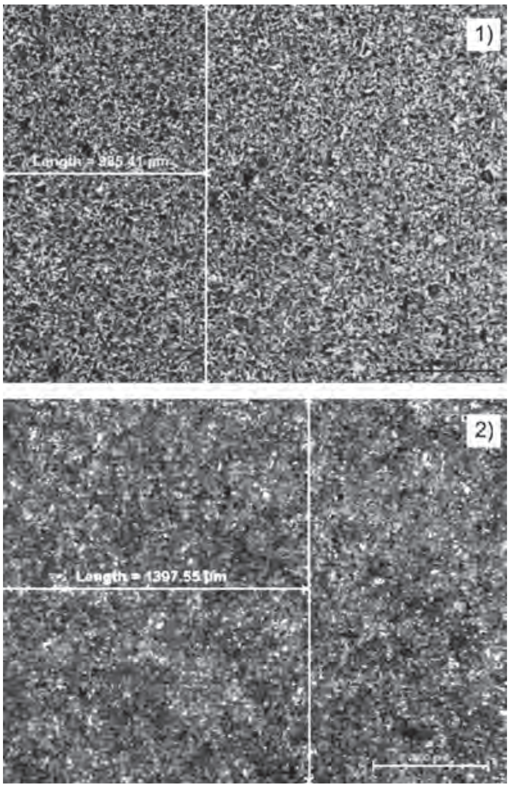

Figure 9. Samples microstructures:
1=15-50SC; 2=15-50CS (750X).

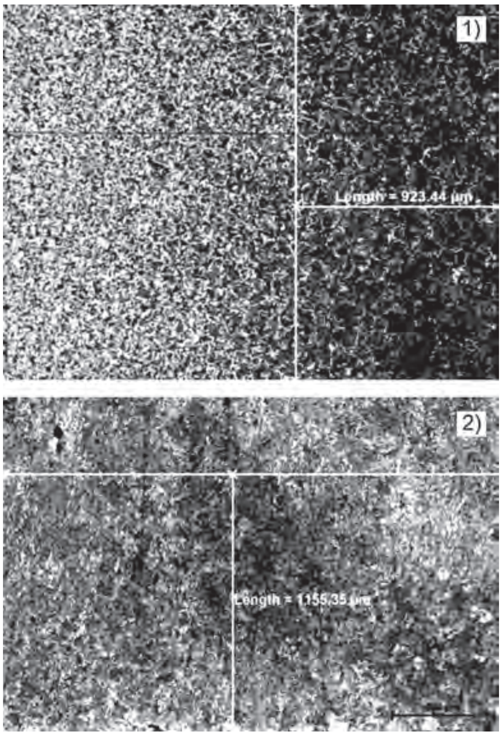

Figure 10. Samples microstructures:
1=15-60SC; 2=15-60CS (750X).

- The toughness test results for the carburized and water quenched samples confirm the experimental results concerning the C% gradient content in the cross section. Thus, the CARBSINT samples registered the toughness values of (3-6) J after the water quenching and the SINTCARB samples have (5,3-7) J. The lower toughness values of the carburized and sintered steels are due to the large bulk C% content that corresponds to the large martensite content after the quenching.

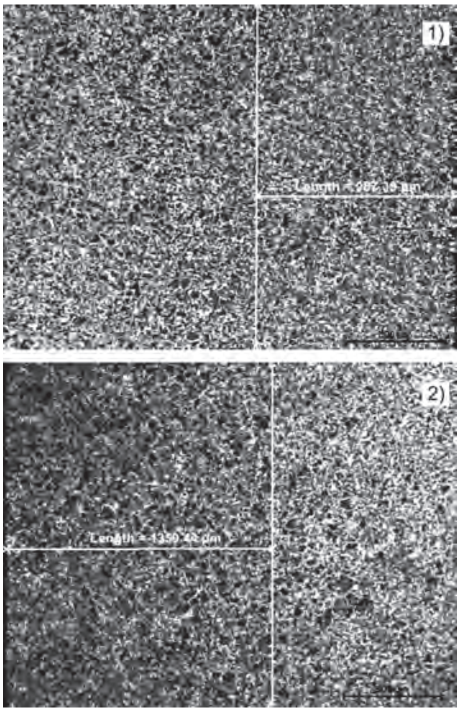

Figure 11. Samples microstructures:
1=25-50SC; 2=25-50CS (750X).

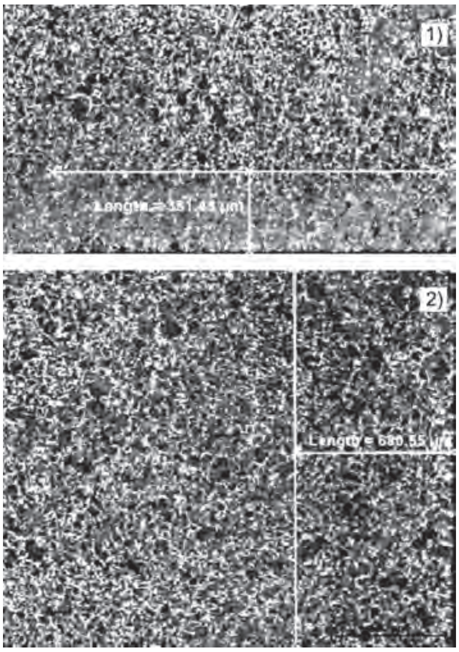

Figure 12. Samples microstructures:
1=25-65SC; 2=25-65CS (750X).

4. Conclusion

The evolution of the bulk C% content for the steels processed from Fe + graphite powder mixtures related to the porosity and thermal treatment used for the solid state carburizing by the means of a carburizing slurry represent the aim of this research.

Two carburizing methods have been approached, namely the carburizing of the green compacts – CARBSINT respectively the carburizing after the sintering (SINTCARB).

For the CARBSINT method, the C% content enrichment has been registered, the core of the samples having higher C% content of 0,4% C than the SINTCARB samples that registered (0,19-0,37)% C. As far as concern the outer layers, the C content was about 0,65%, no matter the carburizing method was used. The variation of the concentrations must be related to the C% content diffused in Fe during the sintering stage, namely (0,05-0,12)%C for the steels made of mixtures containing 0,15% graphite respectively (0,19-0,21)%C for the steels made of mixtures containing 0,25% graphite.

Considering the experimental results presented in the paper, the further research on tensile and wear behavior of these steels is recommended.

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