The effect of "GASCARBUSINT" on tensile properties of sintered steels

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The paper presents the tensile behavior of sintered steels developed through a new process called gascarbusintering (GCS), consisting of carburizing in gas (CH_4) of a set of iron based powder compacts followed by sintering. The influence of compaction pressure and dwell time at the carburizing temperature on the tensile properties of steels processed by GCS is investigated. Mechanical tests revealed that investigated GCS steels show Rm ranging from (180-315) MPa, Young's modulus from (125-150) GPa, with values increasing with increasing compaction pressures (from 400 to 600 MPa), and with increasing dwell time of carburizing (from 120 to 240 minutes).

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1. Introduction

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The use of structural sintered materials in the automotive industry is increasing, given the increasing mechanical properties of Powder Metallurgy products and especially considering the combination of high strength and dimensional accuracy which can be achieved.[1, 2]

A new method of processing of sintered steels for structural parts was developed with the aim of reducing or eventually eliminating the use of elemental graphite [3, 4, 5], and in order to obtain a gradient of C% concentration in the component, therefore influencing the structure and properties of the product. This method was named "GASCARBUSINT" and consists in the introduction of C by a carburizing treatment of green compacts samples followed by the sintering in the same thermal cycle [6, 7, 8].

The analyses of tensile properties of GCS steels have revealed that the material shows characteristics similar to the alloyed steel with composition Fe-2Cu-2.5Ni, treated in high sintering temperature – sintered at 1250 – 1280 ^{0}C x 30 – 60 min. in N2+H2 atmosphere.

2. Materials and experimental procedure

Fe DWP200 powders, showing the characteristics reported in table 1, have been used in the research.

The Fe powder was pressed in a 10x10x55mm shape and compaction pressures were 400 and 600 MPa.

Density and porosity of green compacts are presented in Table 2.

Table 1. Fe DWP200 characteristics

PROPERTY	MINIMUM	MAXIMUM
Hall Apparent Density [g/cm^3]	2,50	2,70
Hall Flow Rate [sec/50g]	31	33
SIEVE ANALYSIS		
+212 µm (%)	---	0,1
-212/+160 µm (%)	---	15
-160/+100µm (%)	20	40
-100/+63µm (%)	20	40
Pan (%)	25	45
GREEN COMPACT PROPERTIES		
C*ompressibility* (at 600 MPa - 43.5 tsi, 0,75% Acrawax) g/cm^3 ,	6,95	---

Table 2. Densities and porosities of green compacts

	Medium density [g/cm^3]	Medium porosity [%]
400 MPa	6.62	15.76
600 MPa	7.07	9.99

The green compacts underwent the GCS treatment reported in Fig. 1.

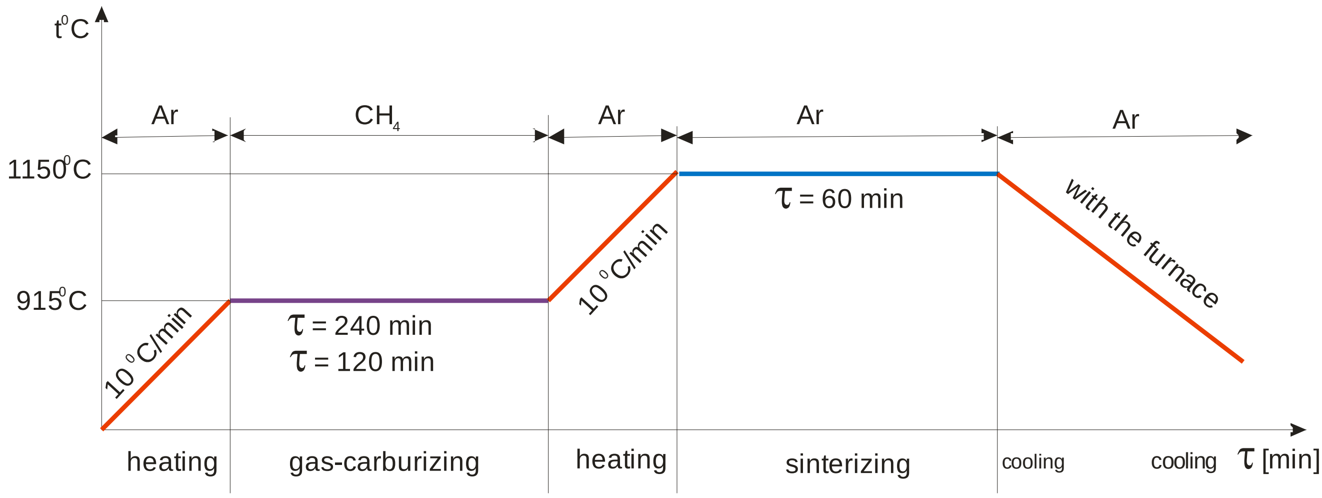

Fig 1. GCS thermal cycle.

As it can be seen, samples were carburized at 915 ^{0}C, in CH_4 with dwell time of either 120 min. or 240 min.. After carburizing the samples were sintered in Ar at 1150 ^{0}C with dwell time 60 min.

The average C% content of GCS steels is presented in Table 3.

Table .3 C% content in GCS steels

	S1	S2	S3
4.12	1.06	0.93	0.79
4.24	1.28	1.16	1.01
6.12	0.63	0.51	0.42
6.24	0.82	0.70	0.54

S1, S2 and S3 represent progressive distances from the outer surfaces and correspond to 1.5; 3 and 4 mm. The data from table reveal that the C% content in section of the sample decreasing from surface to core. Also the C% content decrease with rising of compaction pressure, as it can be observed Tab. 4. Clearly the porosity of samples decreases with increasing of compaction pressure.

Table 4. Evolution of GCS densities and porosities.

	Medium density [g/cm^3]		Relative density [%]	Medium porosity [%]	
	Green	GCS		Green	GCS
400 MPa	**6.62**			**15.76**	
4.12.	6.63	6.63	84.35	15.58	15.56
4.24.	6.62	6.62	84.22	15.61	15.62
600 MPa	**7.07**			**9.99**	
6.12.	7.07	7.08	90.07	9.89	9.88
6.24.	7.08	7.07	84.95	10.05	10.03

3. Results and discussions

Strength properties of P/M materials are closely interdependent with relative density, respectively porosity of the materials. The relation between young modulus (E) and density is approximately linear for relative densities higher than 80%.

- E value is halved (E ≅ 210 GPa for Fe) by decreasing the density in the indicated range;

- The decrease becomes steeper with porosity greater than 20%.

For Poisson's ration (v) an increase of porosity up to 15 – 20% for ferrous P/M materials involves gradual decrease of the value of v from ≅ 0.29 to ≅ 0.26.

Regarding the mechanical properties of GCS steels compared to P/M steels at tensile strength, according to data from the literature in „Guide to design of sintered parts" [9], table 5, they are similar with steels with composition Fe-2Cu-2.5Ni SH (high sintering temperature – sintered at 1250 – 128 ^{0}C x 30 – 60 min. in N2+H2 atmosphere).

The tensile test was made in conformity with MPIF 10 Standard test (ASTM E 8, ISO 2740) and five GCS samples have been subjected to tests. After that was calculated the averages of measurements. The values are listed in tab.5, and evolution of tensile strength test parameters according to compaction pressure and dwell carburizing time are presented in Fig. 2.

Table 5. Values of tensile test.

Pressure MPa	**Time min**	**Sample code**	**Modul E GPa**	**Rp $_{0.2}$ MPa**	**RB MPa**	**Rm MPa**	**ε Break %**	**ε Fmax %**
400	**120**	**4.12.**	125.64	138.82	177.23	181.58	5.66	5.73
	240	**4.24.**	126.3	172.81	239.45	241.53	4.08	4.13
600	**120**	**6.12.**	143.16	169.73	247.31	253.16	10.23	10.52
	240	**6.24.**	149.68	223.12	312.72	315.74	4.42	4.49

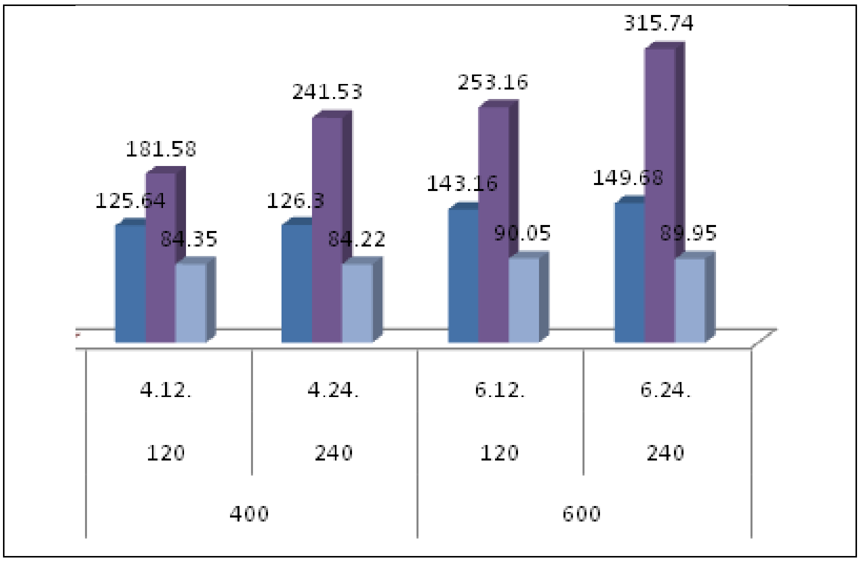

Fig. 2. Evolution of E, Rm and relative density depending on compaction pressure and dwell carburizing time.

4. Conclusions

After an analysis of experimental data results the followed conclusions:

- the values of mechanical strength of Rm and E are in accordance with relative density of GCS steels, namely they increase in value with increasing relative densities of samples;

- GCS steels compacted at the same compaction pressure (400 MPa or 600 MPa) had very closes values of relative densities (84% at samples compacted at 400 MPa) and (90% at samples compacted at 600 MPa. However, the Young Modulus especially strength at similar types of samples (4.12. and 4.24, respectively 6.12. and 6.24.) seems to be increasing with increasing the dwell carburizing time. For the samples compacted at 400 MPa the Rm increases by 25% at dwell carburizing time increasing from 120 to 240 min. Samples compacted at 600 MPa show the increasing of Rm values of about 20%. The dwell carburizing time cause increasing C% content and as in theory: the increasing of C% content increase the mechanical strength.

In conclusion, the tensile strength parameters of GCS steels increases with increasing of relative densities values according with increasing of C% content.

Regarding the mechanical properties of GCS steels compared to P/M steels at tensile strength, according to data from the literature in „Guide to design of sintered parts" [9], they are similar with steels with composition Fe-2Cu-2.5Ni, treated at high sintering temperature – sintered at 1250 – 128 ^{0}C x 30 – 60 min. in N2+H2 atmosphere.

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