THE STUDY OF THE CORRELATION BETWEEN THE ELASTICITY MODULUS AND THE FATIGUE OF THE SINTERED STEELS

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Abstract
The fatigue behavior of sintered steels is determined by their structure and by their static properties, specially the deformation. The deformation recorded during the fatigue test has two components: an elastic one and a plastically one. Both components, but special the plastic one, change during the fatigue testing, determining a modification of the stress-strain hysteresis loop. The plastic deformation (the width of the hysteresis loop), as component of the total deformation rises when the number of cycles increases. It may be considered as a sum of the plastic deformation of the metallic matrix and of the removals determined by the cracks initiation and propagation. The elastic components of the deformation diminish a little when the number of the loading cycle increases and, as a result, the elasticity modulus rests almost constant. To reach a greater number of the loading cycles it is necessary that the elastic deformation to be preponderant. As a result, between the elasticity modulus and the behavior of the sintered materials there is a correlation. This relation was determined also as a result of the done researches, which are the content of this paper.
Keywords: powder metallurgy, fatigue behavior, elasticity modulus

INTRODUCTION

An analysis of the sintered material mechanical characteristics shows that their density determines the static properties, as well as the dynamic ones. The tensile strength rises approximately proportional with the density increasing (Figure 1), but not the same think may be said about the dynamic properties, especially the fatigue strength. The dynamic properties diminish more intense for porosity until 5 %. Over this value, the dynamic properties are so small that the porosity influence on the fatigue strength is insignificantly.

The important diminishing of the dynamic properties is due, first of all, to the porosity, especially to the close one, localized at the intergranular bridges level, and to the presence of some clusters of pores or impurities in the sintered material. All these have a negative effect more intense on the dynamic properties then on the static ones. It is considered that the negative influence of these defects is due to their crack effect (stress concentrators), which through their presence constitute sources of cracks initiation and of their growth into the material.

During the fatigue solicitations the sintered materials suffer a continuous elastic and plastic deformation, which may be remarked on the test's hysteresis loops. For the parts fatigue solicited at a high number of cycles, over 10^3-10^4, and low loaded, the elastic

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component of the total deformation is dominant. As a result between the elasticity modulus and the fatigue behavior of the sintered materials has to be a correlation (to be influenced in the same mode by the material structure). The correlation and how much the metallic powder characteristics and the manufacturing process parameters influence these properties are very important. Their importance is given by the fact that most of the sintered parts support a high number of solicitation cycles his function [1,2].

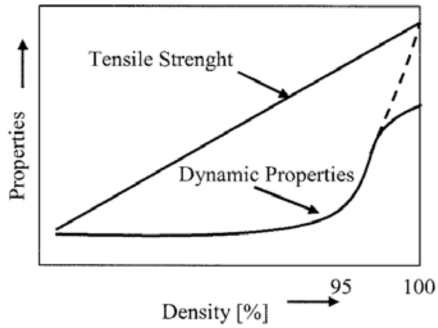

Fig.1. The variation of the static and dynamic properties with the sintered material density [3].

EXPERIMENTAL PROCEDURE

To determine the elasticity modulus and the number of cycles supported by the material until his fracture there were realized samples from reduced iron powder NC 100.24, from atomized iron powder ASC 100.29 and from atomized iron powder with 4% C added. The use compaction pressure, sintering conditions and samples symbolization is given in Table 1. The samples sintering were done in dissociated NH_3.

Tab.1. Sample’s technological parameters and symbolization.

Powder type	Sintering parameters			
	1200°C/30 min.		1250°C/60 min.	
	Compaction pressure [MPa]			
	500	700	500	700
Reduced powder NC 100.24	N5L	N7L	N5H	N7H
Atomized powder ASC 100.29	A5L	A7L	A5H	A7H
Atomized powder ASC 100.29 + 4% C	AC5L	AC7L	AC5H	AC7H

To determine the elasticity modulus for the materials obtained from these categories of powders, the samples were compacted and sintered in different conditions. Then, there were tensile tested in a loading-unloading system in elastic domain. The loading-unloading speed was the same for all tested samples: 0.1 kN/s. The obtained data concerning the applied strain and the elastic deformation suffered by the material were acquiesced in a data base file and the used to obtain the hysteresis loops for the given loading-unloading process (Fig.2). These hysteresis curves established for every material were used to determine their elasticity modulus.

To determine the fatigue behavior of the obtained materials from metallic sintered powders, there were made samples characteristics for tensile test. These samples were tested at alternate symmetrical plane bending under a loading of 623 MPa. This loading was established thus the samples fracture take place at a cycle number of 10^5-10^6 cycles. In this way it could be determined the maximum number of solicitation cycles supported by each material until its fracture. It was also possible to establish, with good results, an obvious difference regarding the fatigue behavior of each material. During the fatigue solicitation through plane bending it was also studied the behavior of each material in different steps of testing.

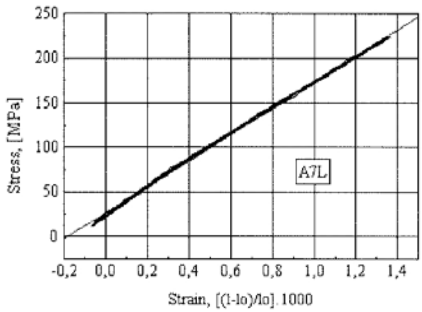

Fig.2. Determination of the elasticity modulus based on the loading-unloading hysteresis lops.

EXPERIMENTAL RESULTS

The data obtained as results of the experimental determination are presented in Table 2, and in a comparative mod, in Fig.3, 4.

Tab.2. Experimental results.

Samples	ρ [g/cm^3]	E [GPa]	N [cycles]	Samples	ρ [g/cm^3]	E [GPa]	N [cycles]
N5L	6.48	121	$12\cdot10^4$	N5H	6.5	133	$14\cdot10^4$
A5L	6.7	146	$17\cdot10^4$	A5H	6.73	146	$18\cdot10^4$
AC5L	6.68	139	$30\cdot10^4$	AC5H	6.7	146	$27\cdot10^4$
N7L	6.76	151	$90\cdot10^4$	N7H	6.78	154	$87\cdot10^4$
A7L	6.97	160	$200\cdot10^4$	A7H	6.94	165	$197\cdot10^4$
AC7L	6.9	163	$86\cdot10^4$	AC7H	6.9	167	$92\cdot10^4$

The elasticity modulus and the fatigue behavior of the sintered materials depend on the powder particle’s size and shape, on the density, on the porosity, on the pore’s size and shape and on material structure. Because of that the study of the correlation between the two mechanical characteristics is oriented through the materials obtained from the same powder.

As it can be seen in Figures 3 and 4 when the compacting pressure rise up, increase the elasticity modulus and, in the same time, the number of cycles supported by the material until its fracture, no matter the powder use for its obtaining. The elasticity modulus, as well as the material density, doesn’t modify in very large limits. The growth of the elasticity modulus in the same time with the increasing of the compacting pressure vary for each material from multiplied by 1.1 to multiplied by 1.23, indifferently the sintering temperature. For the materials sintered at a higher temperature and for a longer period of time, the rising of the elasticity modulus from a compacting pressure to another it’s almost the same. The phenomenon it's due to the fact that in the same time with the rising of temperature and of sintering period the pores will spheroids, their surface became smooth and the section of the intergranular bridges became almost the same for all materials compacted with the same pressure. The density of the obtained sintered materials changes with the growth of the compacting pressure between 6.48-6.94 g/cm^3, and almost insignificant with the temperature rising and with the increasing of sintering period.

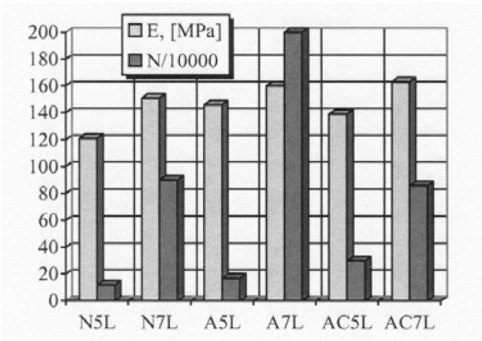

Fig.3. Elasticity modulus (E) and the number cycle (N) supported by different materials until their fracture.

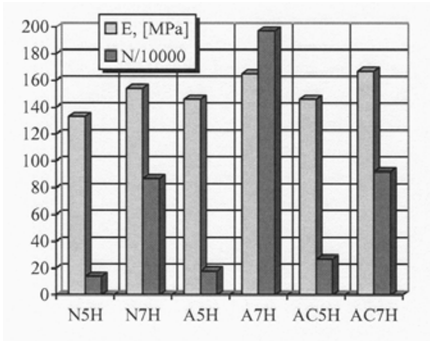

Fig.4. Variation of the elasticity modulus (E) and of the number of cycle (N) versus the compacting pressure.

If the compacting pressure, the temperature, the sintering period grow up, and grow of the elasticity modulus it's smaller, then the number of cycles supported by the material until its fracture increases significantly: from multiplied by 2.9 for the materials obtained from powder ASC 100.29 + 4 % C, until multiplied by 7.5 for the materials obtained from powder NC 100.24 and multiplied by 11.8 for the materials obtained from powder ASC 100.29. Almost the same rising of the cycle's number it's recorded for the materials sintered at higher temperature and for a longer period of time. This growth of the cycle's number strengthens the conclusion that, for the fatigue behavior, the increasing of the material density, respectively the porosity diminishing, it's very important. In the same time the pores shape it's important: the best fatigue behavior correspond to their spherical aspect. As result, during the manufacturing process of sintered parts fatigue solicited, for the porosity diminishing it's necessary to use adequate compressing and sintering process.

The greatest rising of the cycle's number with the compacting pressure increasing was recorded for the materials obtained from atomized iron powder, indifferently the temperature and sintering period. There was obtained an increasing of multiplied 11.8 times for materials sintered at 1200°C/30 minute and of multiplied 10.9 times for materials sintered at 1250°C/60 minute. This is due to the fact that the surface of the powder spherical particles is matted and as a result of the compacting and sintering process, at the level of the intergranular bridges don't appear micropores, which are fissures generators. In the same time, the irregular form of the particles lead to the apparition of some spherical pores, with a smaller negative effect on the fatigue behavior of the sintered materials.

The comparative analysis of the results (Fig.3, 4) concerning the temperature effect and the sintering period on the elasticity modulus and on the number of cycles supported by the material until its fracture, show that this is insignificant.

CONCLUSIONS

The analysis of the experimental data show that both the elasticity modulus and the number of cycles supported by the material which is fatigue solicited through symmetrical alternate plane bending, rise with the compacting pressure growing. The increasing of the cycles number is greater then that one of the elasticity modulus. The improvement of the fatigue behavior is more significant for the materials obtained from atomized iron powder.

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