THE EFFECTS OF ADDING Cu AND SURFACE DEFORMATION ON THE PROPERTIES OF SINTERED IRON

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Abstract
The subject of the experimental research was an investigation of the influence of the amount of copper powder added to the iron powder, and also to establish the influence of a surface mechanical treatment, applied by rolling, on the mechanical properties of sintered material.
Copper powder was added to the mixture to determine the occurrence of liquid phase during sintering. Density increases through complete filling of small pores and partial of large. This increases hardness and also tensile strength, but only until a certain level of copper content. Rolling - the chosen mechanical treatment - closing pores of the material surface determines the hardening of the surface layer. A roller, pressed against the surface of the specimen to produce compressive residual stresses, increases hardness and tensile strength, and also smoothes the surface.
Keywords: iron, copper powder, mechanical treatment, rolling, mechanical properties

INTRODUCTION

For P/M components, in comparison with wrought materials, some indispensable properties as surface hardness, ultimate tensile strength, wear and fatigue resistance, are, as it is already known, weaker. This behaviour is due to their specific and complex structure, which consists of a mass of particles (the powder) and pores. The presence of pores, which may have various forms, sizes and specific areas, even, sometimes, an unfavorable orientation, enables them to be stress points, which are the basis of the origin and propagation of fissures before material failure. We can act rather easily upon the pores at the surface, but we have to use special methods upon those inside the material. Breakage will occur at the interface between the areas with high density and those with low density.

In powder metallurgy there are a number of specific operations which allow us to improve the density of the material: increasing compaction pressure, adding into the mixture of powders various elements such as copper, boron or phosphorus, to obtain sintering with a liquid phase, or nickel to activate the sintering process. Also, mechanical and thermo-mechanical treatments may be applied [1, 2].

Concerning the plastic deformation of the porous materials, this will be localized at the level of contact bridges. Generally, plastic deformation of these materials is through porosity modification, non-observing the law of the volume constancy, which is valid for fully dense materials. So, the plastic deformation of the sintered porous materials is accompanied by volume modification through density variation. During the plastic deformation process, at the same time with volume modification, because of the action of hydrostatic pressure, there appears a second process, cold straining of the material matrix. The deformation process will modify the size and shape of pores. The variation of structural parameters through plastic deformation, especially through densification and cold working,

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influences also other characteristics, such as mechanical properties of the sintered powder materials [3].

EXPERIMENTAL PROCEDURE

The aim of present work was to establish some ways to improve the mechanical properties of sintered materials.

Experimental researches were:

- a study of the influence of the quantity of copper powder added to the iron powder and
- a study of the influence of mechanical treatment applied by rolling on the mechanical properties of sintered materials.

The choice of the basic powder for production of sintered materials must take account of its availability on the market, as well as the required performance in use. In accordance with those recommendations, we chose as the basic powder iron powder NC 100.24 and a copper powder PA Cu 99, 1S.F.

The powder NC 100.24 is a powder of iron obtained by reduction, which has spongy particles. It is commonly used in the manufacture of parts that require good mechanical properties, with densities ranging from medium to high values. The powder particles have irregular shape and rough surfaces, which means a high plasticity, so a good compressibility and good resistance of green compacts. In terms of use, this powder is suitable for manufacture of sintered parts with intricate geometric shapes, which in turn requires a good edge strength [4].

Copper plays an important role in iron based sintered alloys, both for the parts with high resistance and for those with self-lubrication [5]. The powder characteristics are given in Tables 1 and 2. [4, 5]

Tab.1. Iron powder NC 100.24.

Property		Value
Apparent density [g/cm^3]	SR EN 23923-1	2.43
Fluidity [sec/50 g]	ISO 4490	31
Pressed with 600 MPa, sintered at 1120^{o}C, 30 min, in 90/10 N_2H_2		
Density [g/cm^3]	ISO 3995	6.80
Hardness [HV10]		170
Tensile strength [MPa]		530
Elongation [%]		2

Tab.2. Copper powder PA Cu 99,1S.F.

Property		Value
Apparent density [g/cm^3]	SR EN 23923-1	4.16
Fluidity [sec/50 g]	ISO 4490	15
Chemical composition [%]		
O_2 (loss in H_2) Cu Impurities	SR EN 24491-2	0.18 99.71 0.11

From these powders two mixtures were made with different contents of copper, named A and B:

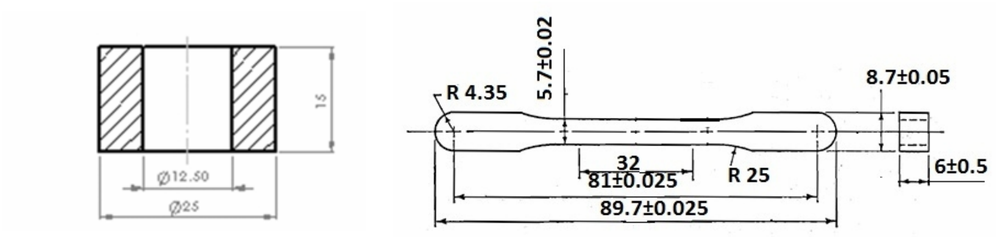
A. 98 %Fe + 2% Cu and B. 96% Fe +4%Cu

After homogenizing the powders for 15 minutes (with 1% zinc stearate) the technological properties of mixtures were determined and are given in Table 3.

Tab.3. Technological properties of powder mixture.

Property	Powder	Value
Apparent Density [g/cm^3]	A	2.67
SR EN 23923-1	B	2.74
Fluidity [sec/50 g]	A	42.62
ISO 4490	B	42.47
Density of the green compacts [g/cm^3]	A	6.396
	B	6.374

For mechanical treatment by rolling, from each mixture five roll type ® samples were tested (Fig.1a) and another five Shannon type (S) (Fig.1b). The compaction was done with 450 Mpa through bilateral pressing.



a) The roll type parts ® b) The shannon type parts (S)

Fig.1. The shape of used samples.

The sintering was done in a tunnel furnace at 1120 ± 10°C, in endogas atmosphere, for one hour. After sintering material density and mechanical properties were determined, which are given in Table 4.

Tab.4. Density of sintered materials and their mechanical properties.

Property	Powder		Value
Density after sintering [g/cm^3]	A		6.176
	B		6.196
Hardness [HB]	A	R	78
		S	87
	B	R	85
		S	95
Tensile strength [MPa]	A		294.75
	B		330.72
Elongation [%]	A		1.43
	B		2.86

To improve the mechanical properties of the sintered materials, we applied the method of surface plastic deformation through rolling.

Rolling improves the behaviour of sintered materials by interaction of the following factors: densification of the surface layer, appearance of compressive residual stresses, improvement in the surface roughness. If the surfaces are rolled, the residual compressive stresses are no longer determined by processing, but by the level of flow strength and degree of densification [2].

To quantify the improvement, comparative study was made of the mechanical properties of the sintered material and of the same material, rolled for 15, 30 and 60 min.

Rolling was done on two rolling devices:

- one which was adapted to a testing machine for fatigue strength under rotating solicitation - for the roll type parts and
- another one adapted to a planing machine - for the Shannon type parts.

For each device five samples were tested for each time from each mixture.

Rolling regime parameters were:

- for roll type parts:
  - cycle of rolling of 1976 rot/min, and the applied force was 341.36 N
  - contact length = 20 mm
  - roll radius = 32 mm
  - part radius = 25 mm
  - Hertzian pressure P HZ=59.31 MPa
  - maximum strength inside the material = 17.79 MPa
  - the depth of maximum strength = 0.014 mm

- for Shannon type parts:
  - cycles of rolling of 56 dc/min, and the applied force was 50 N.

The results are given in Table 5 and in Figures 2, 3, 4.

Tab.5. Mechanical properties of sintered and rolled materials.

Property	Powder	Times of rolling [min]	Rm [MPa]		Benefit [%]	
		0	294.75		0	
	A	15	329.55		+11.8	
		30	340.30		+15.45	
Tensile strength		60	290.83		-1.33	
[MPa]		0	330.72		0	
	B	15	332.52		+0.54	
		30	354.82		+7.28	
		60	280.34		-15.23	
			Parts roll type	Benefit [%]	Parts Shannon type	Benefit [%]
		0	78	0	87	0
	A	15	85	+8.97	91	+4.59
		30	95	+21.79	91	+4.59
Hardness		60	104	+33.33	87	0
[HB]		0	85	0	95	0
	B	15	95	+11.76	102	+7.36
		30	104	+22.35	95	0
		60	107	+25.88	107	+12.63

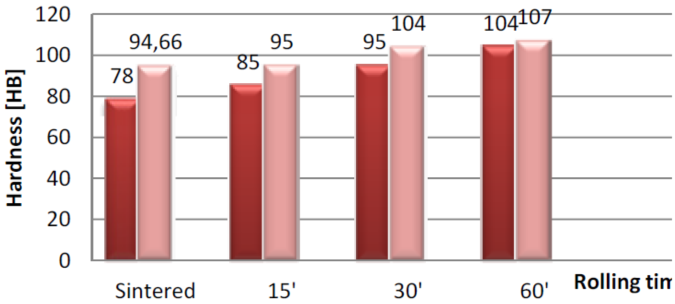


Fig.2. Hardness dependence on rolling time for the roll type parts.

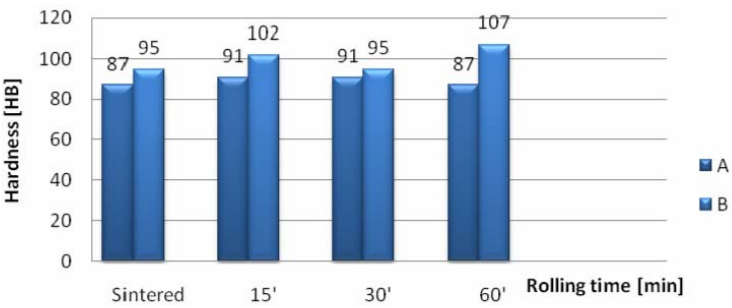


Fig.3. Hardness dependence on rolling time for the Shannon type parts.

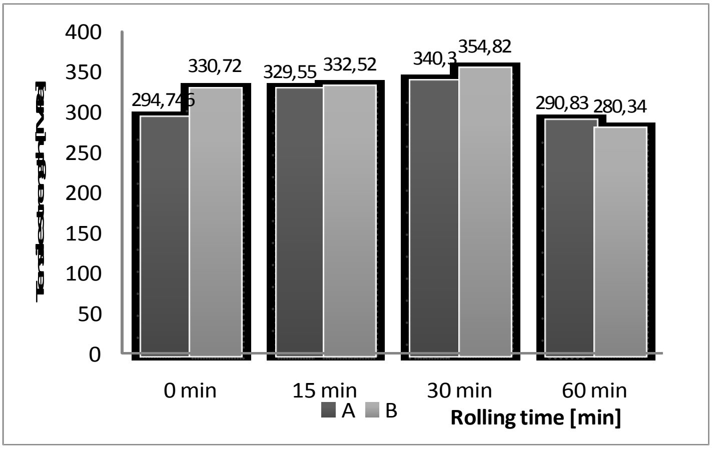


Fig.4. Tensile strength dependence on rolling time.

Fatigue tests of constant amplitude were done under bending loads through symmetrical alternate plane bending ($R = \sigma_{min}/\sigma_{max} = -1$). Plane bending was chosen because it offers the possibility to realize, with the same frequency, certain cyclic solicitation with different amplitudes and asymmetrical degree. The number of cycles to fracture (total or partial) of the materials – A and B -rolled for 30 minutes- are recorded in Fig.5 as a function of copper amount. The results confirmed the other results: the best behaviour was for material with 4 % Cu rolled 30 minutes.

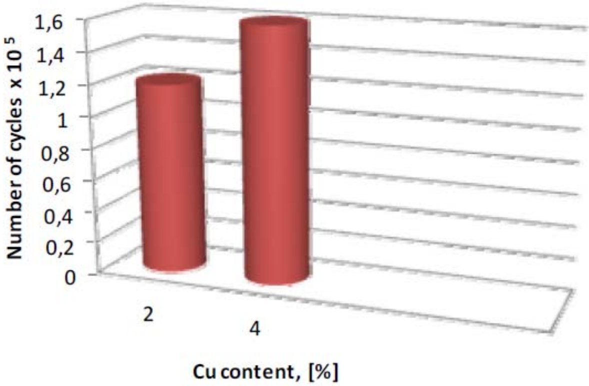


Fig.5. The number of cycles to failure of the materials rolled 30 minutes.

CONCLUSIONS

Copper added to the iron powder determines the improvement of mechanical properties of sintered materials. Improvement occurs due to liquid phase appearing during sintering, which determines the density increase by filling the small pores and partially the large ones. This has resulted in:

- density increasing by about 9% for both mixtures of powder;
- enhancing of tensile strength by about 12% for the mixture with 4% copper compared to that with 2%;

Application of mechanical treatment by rolling involves surface densification and appearance of residual compressive stresses. These phenomena result in:

- closing the pores of the material surface;
- increasing the material hardness by approximately 20 % for the mixture with 2 % copper, and by 5 %, for the mixture with 4 % copper;
- enhancing the tensile strength by:
  - 11.81 % for the parts rolled 15 minutes and by15.45 % for those rolled 30 minutes for the mixture with 2% copper;
  - 0.54 % for the parts rolled 15 minutes and by 7.28 % for those rolled 30 minutes for the mixture with 4 % copper;
- increasing the tensile strength for the parts rolled 60 minutes for both mixtures, due to the process of cold working.

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