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INFLUENCE OF THE PRESSING FORCE ON THE MECHANICAL CHARACTERISTICS OF AN IRON MATRIX OF WATER- DISPERSED POWDERS ALLOYED WITH NICKEL

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ABSTRACT

In this publication the influence of the pressing force on the mechanical characteristics of sintered materials based on water-dispersed iron powders alloyed with nickel is studied. An iron matrix based on water-dispersed powders type AHC 100.29, to which up to 4% nickel was added, was studied. After pressing with a force of 300 ÷ 800 MPa, they were sintered at a temperature of 1150ºC for 1h in a dissociated ammonia medium. Experiments were performed to determine tensile strength, yield strength, elongation, Young's modulus, hardness, impact energy and dimensional changes. In determining the mechanical characteristics in order to prevent the influence of porosity, five measurements were made for each type of samples, and in the graphical interpretation of the results the arithmetic mean values were used.

INTRODUCTION

In powder metallurgy after graphite and copper, the next most common alloying element is nickel. Like copper, it has a weak affinity for oxygen. Its introduction makes it possible to obtain appropriate values for strength and ductility.

The Fe-Ni system refers to the case of unlimited solubility of components in the solid state [2,3,4]. Iron and nickel form a continuous series of solid solutions without brittle compounds. Unlike the Fe-Cu system, here the partial diffusion coefficients differ insignificantly and the effect of volume increase is almost imperceptible. Nickel has a high activating ability during sintering, which manifests itself at relatively high temperatures - above 1150ºC, and a longer process duration. Alloying iron with nickel slows down the growth of crystals during sintering, which helps to increase shrinkage during the final stages of the process.

The method of alloying has a great influence on the structure of iron - nickel products [1,6]. When working with ready-alloyed powders during sintering, the structure remains homogeneous, single-phase and is externally similar to the structure of non-alloy iron powder products.

When using mechanical mixtures of iron and nickel powder, the final structure depends exclusively on the sintering mode. At temperatures up to 850ºC, regardless of the duration of sintering, there is practically no interaction between the nickel and iron particles of the matrix.

As the temperature rises, nickel dissolves in iron. The alloys obtained under such conditions are characterized by a spotted, inhomogeneous structure. Only when the temperature rises to 1250ºC and the sintering duration exceeds 120 min the alloy acquire a single-phase structure.

In the present study, the aim is to trace the influence of the pressing force and the concentration of nickel on the mechanical properties of iron samples based on water-dispersed powders type AHC 100.29.

EXPOSURE

Iron powders AHC 100.29 were tested. – fig. 1. They are obtained by water dispersion of a melt of iron scrub heated to temperatures of 1650 ÷ 1700ºC. Nozzles with a diameter of 14 ÷ 16mm were used for spraying.

After spraying, the main technological properties of the powders are determined, which are presented in Table №1.

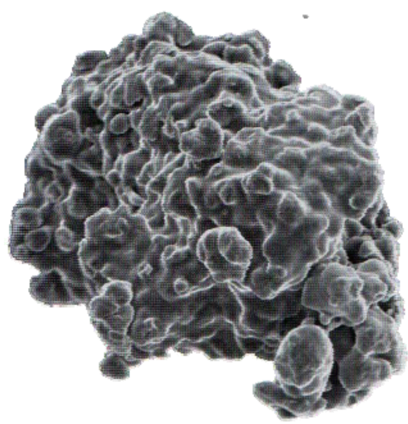

Fig. 1. Particle of iron powder AHC 100.29

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The iron matrix of the tested samples was alloyed with 2 ÷ 4% nickel.

Table 1 *Technological properties of iron powders*

Powder mark AHC 100.29	Max. particle size, μm	Apparent density $.10^3 kg/m^3$	Flowa-bility, s	Compaction at 420MPa, $.10^3 kg/m^3$	O_2, %	. C, %
min	170	2,98	25	6,75	0,10	0,01
max					0,20	0,02

After homogenization of the powders, they are pressed bilaterally with a force of 300 ÷ 800 MPa in closed molds according to the scheme of Fig.2.

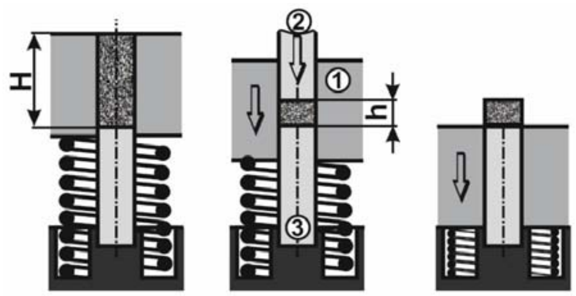

Fig.2. Scheme of double-sided pressing with movable die and fixed lower punch
1 - matrix, 2 - upper punch; 3 - lower punch

An 8% Lubricated PS plasticizer was added to compress the samples to improve compaction. [7,8]. The samples thus formed were sintered at 1150 ° C in dissociated ammonia medium for 1 hour.

The strength characteristics tests were performed according to EN 10045-1 on a universal testing machine ZD 40PU, with a range of applied force 100 ÷ 1000kN. In the process of testing the strength characteristics, specially made test specimens for powder metallurgical materials according to BSS 1086-88, with a rectangular cross section, with an area of 700 mm^2 and basic dimensions according to Fig. 3 [3, 4,5] were used.

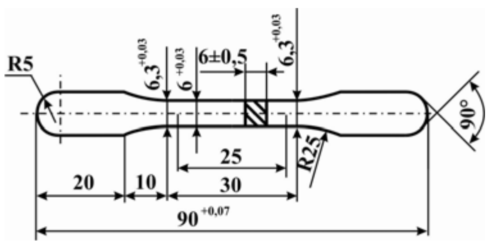

Fig. 3. Drawing of a tube of powder material to study tensile strength

In order to prevent the influence of porosity in determining the studied characteristics, five measurements were made for each type of samples, and the average values were used in interpreting the results.

Tensile strength was studied; yield strength, elongation, modulus of elasticity, impact toughness, stiffness and relative change in the dimensions of the test specimens.

The experimental results are presented in Table 2, and the graphical interpretations in Fig. 4 ÷ 10.

From the obtained experimental results in the study of the tensile strength it was found that with increasing the compressive force from 300 to 800 MPa the values increase by 95 ÷ 130 MPa.

Table 2 *Experimental results for the mechanical properties of an iron matrix of AHC 100.29 alloyed with nickel*

Mechanical characteristics	Pressing force, MPa					
	300	400	500	600	700	800
AHC 100.29						
Rm, MPa	169	187	196	222	248	264
Re, MPa	93	105	119	133	142	151
E, GPa,	108	122	145	157	166	173
A_5, %	7,1	10,4	11,9	13,2	14,7	15,6
HV10	39	53	64	71	76	81
KCU, J	18	19	22	39	52	75
D/D_0, %	-0,23	-0,21	-0,23	-0,17	-0,18	-0,21
AHC 100.29 + **2,0%Ni**						
Rm, MPa	171	192	199	225	253	267
Re, MPa	95	107	121	133	144	152
E, GPa,	103	117	141	152	164	169
A_5, %	4,7	5,9	7,6	9,3	10,1	11,8
HV10	51	65	76	83	91	105
KCU, J	11	14	16	32	49	71
D/D_0, %	-0,35	-0,34	-0,32	-0,31	-0,30	-0,29
AHC 100.29 + **4,0%Ni**						
Rm, MPa	183	198	224	262	297	311
Re, MPa	99	111	124	135	147	154
E, GPa,	97	114	137	146	158	162
A_5, %	2,7	3,5	4,6	5,3	6,8	8,7
HV10	63	78	96	103	112	127
KCU, J	8	9	12	28	42	64
D/D_0, %	-0,42	-0,41	-0,40	-0,39	-0,38	-0,37

This increase is most significant in the samples alloyed with 4% nickel - 170%, it is higher by 15% compared to samples of pure iron.

The results of the study of the yield strength show that, regardless of the chemical composition of the samples, with an increase in the pressing force from 300 to 800 MPa, its values increase by 55 ÷ 58 MPa.

As the compression force increases, the values for the modulus of elasticity (Jung's modulus) increase on average by 65GPa. The addition of 2 ÷ 4% nickel to the iron matrix leads to a decrease in its elasticity by an average of 10%.

The addition of nickel to the iron matrix reduces the relative elongation of the tested samples by 7 ÷ 8% regardless of the applied pressing force.

The most significant is the influence of nickel on the hardness values of the tested samples. With increasing its concentration from 0 to 4%, the hardness increases by 25 ÷ 50 units in all studied pressing efforts. This is most pronounced in samples compacted with 800 MPa.

The addition of nickel to the iron matrix significantly reduces the impact toughness. In the case of samples containing 4% nickel, the values for impact toughness are significantly lower than in the case of samples of pure iron, and in this case the pressing force is also essential. When pressing with a force of 300 ÷ 400 MPa, the impact toughness decreases by 50%, and when pressing with 700 ÷ 800 MPa by 15%.

The addition of nickel to the iron matrix leads to an increase in the shrinkage of the samples, which is 50% greater in samples containing 2% nickel compared to samples of pure iron, and in those with 4% nickel is twice as large as that. for samples of pure iron.

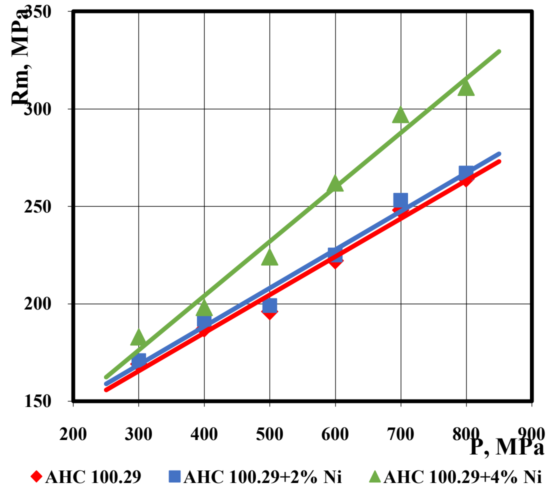

Fig. 4. Influence of the compressive force on the tensile strength of samples of water-dispersed iron powders AHC 100.29 alloyed with nickel

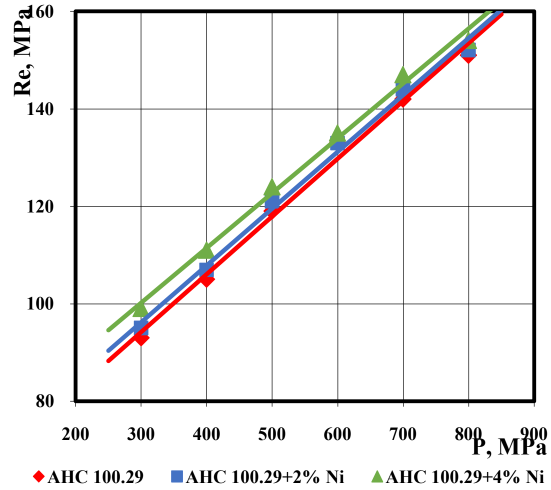

Fig. 5. Influence of the pressing force on the yield strength of samples of water-dispersed iron powders AHC 100.29 alloyed with nickel

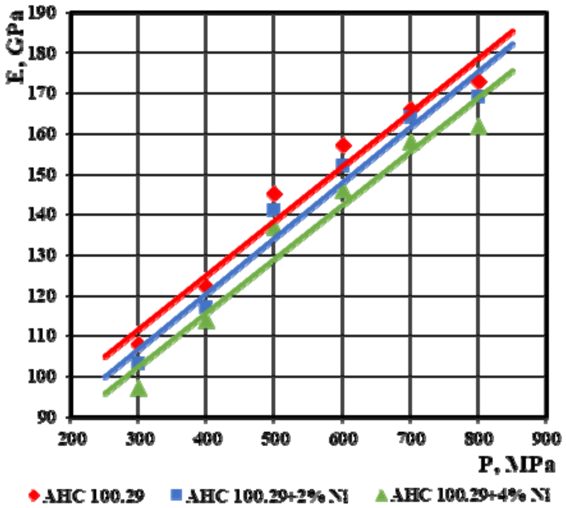

Fig. 6. Influence of the compressive force on the Jung modulus of samples of water-dispersed iron powders AHC 100.29 alloyed with nickel

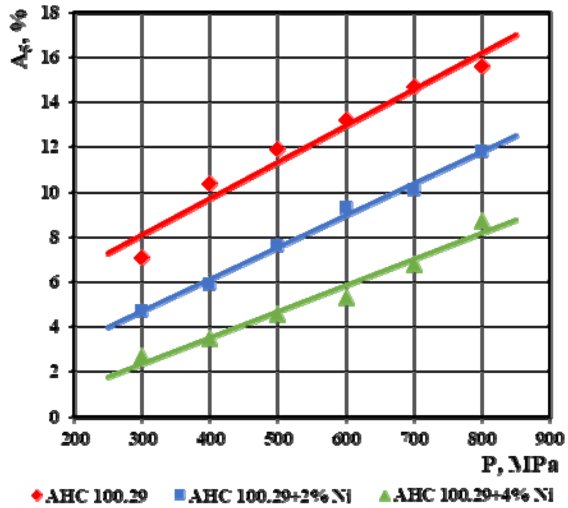

Fig. 7. Influence of the pressing force on the relative elongation of samples of water-dispersed iron powders AHC 100.29 alloyed with nickel

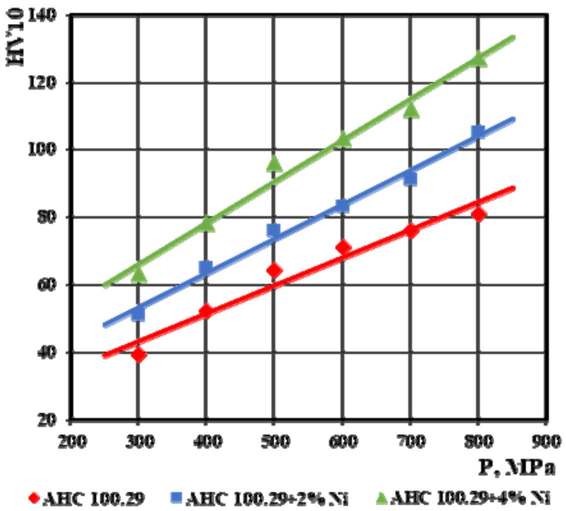

Fig. 8. Influence of the pressing force on the hardness of samples of water-dispersed iron powders AHC 100.29 alloyed with nickel

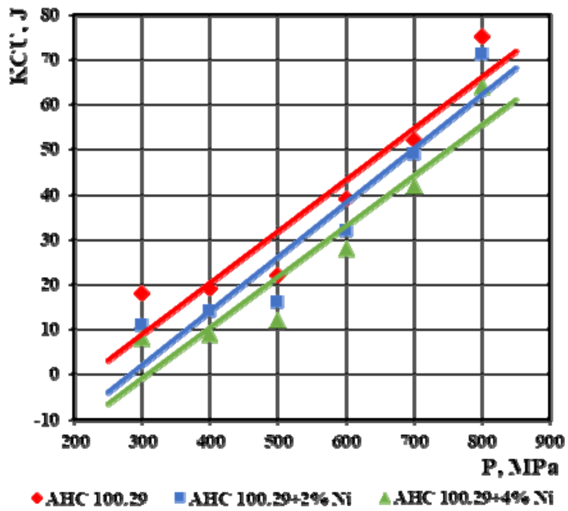

Fig. 9. Influence of the pressing force on the impact toughness of samples of water-dispersed iron powders AHC 100.29 alloyed with nickel

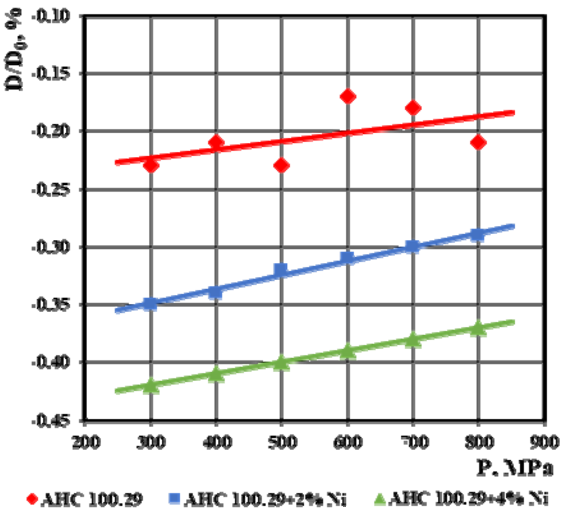

Fig. 10. Influence of the pressing force on the dimensional changes of samples of water-dispersed iron powders AHC 100.29 alloyed with nicke

CONCLUSION

From the conducted research and the obtained results we can formulate the following more important conclusions:

With the increase of the pressing force from 300 to 800 MPa due to the decrease of the porosity and the increase of the density of the samples the values of all mechanical characteristics studied by us increase - tensile strength, limit of proportionality, modulus of elasticity, relative elongation, impact toughness and hardness.

Nickel is an element that lowers point A3 and shrinks the alpha region of the Fe-Ni diagram. and due to its unlimited solubility in iron it forms a continuous series of solid solutions. It is denser than iron and therefore with increasing its concentration in the iron matrices increase mechanical properties such as hardness, tensile strength and yield strength. Compared to samples of pure iron in those alloyed with 4% nickel with increasing compressive strength, the tensile strength increases to 50 MPa, the limit of proportionality by 5 MPa, and the hardness by 25÷45 HV10.

In parallel with the increase in the hardness of the studied specimens, their elastic properties decrease - Jung's model, relative elongation and impact toughness. As the concentration of nickel in the iron matrix increases from 0 to 4%, the modulus of elasticity decreases for all studied values of the pressing force by an average of 10GPa, the elongation decreases by an average of 7% and the impact toughness by 15 ÷ 50%.

At a sintering temperature of 1150°C, nickel has a high activating ability, and with a longer process time of 1 h, nickel-doped iron slows down the growth of crystals, which helps to increase shrinkage during the final stages of sintering. This explains the fact that with the addition of 2% nickel to the iron matrix, the relative shrinkage of the parts is 50% higher, and at a nickel concentration in the matrix of 4% the relative shrinkage is twice as large as that of pure iron samples.

REFERENCES

[1] Kovachev J., Miteva I., Mitev I., Influence of Pressure Force on Density Before sintering of Iron Powder Materials Obtained by Reduction, AJ Industrial Technologies, Issue7/2020, ISSN 1314-9911, pp. 23÷27

[2] Mitev I.N., Industrial Materials, ECS-PRESS, Gabrovo, 2017, ISBN 978-954-490-556

[3] Mitev I.N., Modern Industrial Technologies - Part III (Progressive Methods for Mechanical Formation), ECS-PRESS, Gabrovo, 2016, ISBN 978-954-490-511-8

[4] Mitev I.N., Powder Metallurgy - Part I (Obtaining Powder Metallurgical Materials and Products,) UP „V.Aprilov”, Gabrovo, 2004, ISBN 954-4683-233-2

[5] Mitev, IN, Structural Analysis, EX-PRESS, Gabrovo, 2013, ISBN 978-954-490-363-3.

[6] Miteva I., Perculiarities of the technological process in the preparation of metal powders, IJSTII „Machines technologies materials“, XIV, Issue 2/2020, pp.93÷95 ISSN 1313-0226

[7] Miteva I., Mitev I., Kovachev T., Influence of the pressing force on the strength properties of sintered materials based on water-dispersed iron powders alloyed with cooper, IJSTII “Machines technologies Materials”, years XV, Issue 1/2021, ISSN PRINT 1313-0226, ISSN WEB 1314-507X, pp 34÷37

[8] Miteva I., Vinev I., Mitev I., Features of Alloying Matrix of Water-dispersed Iron Powders, 13th International Scientific and Practical Conference, 15.06.2021, Rezekne Academy of Technologies, Rezekne, Latvia, pp.226÷231