RESEARCHING RESULTS OF NANO-STEEL

Imre Timár, István Lisztes, Pál Horváth
University of Pannonia, Veszprém, Hungary
timari@almos.vein.hu

Keywords: grinding, hardness, spark plasma sintering, steel nanoparticle production.

Abstract: Grain refinement is an effective means for improving the strength of steel. We show test methods of the nano-steel produced within the confines of our research and some results. We compare the test results with ones of the same compound, but made other technologies. We analyse that the most important parameter of strength how to count with the using of experimental results.

INTRODUCTION

Strength property of materials is demonstrably depend on the measurement of grain. In the eighties was started to trial with the finest grained product materials and at the millenary was showed up the modern sintering machines. The literature calls the 1-100 nm grain measure materials to the nano-steels [4]. The most well-known methods of production show the *table 1* [1].

Table 1 Methods of production of powder which suitable for nano-material [1]

Method	Variant of method	Materials
Physical methods		
Evaporation and condensation	In vacuum or in inert gas	Zn, Cu, Ni, Al, Pb, Cr
	In reactive gas	TiN, AlN, ZrN, Al_2O_2, TiO_2
Fly in pieces with large energy	Grinding	Fe-Cr, Be, Al_2O_3, TiC, NiAl, TiAl
	Process like explosion	BN, SiN, TiC, Fe, diamond
	Electrical explosion	Al, Cd, Al_2O_3, TiO_2
Chemical methods		
Synthesis	Plasma chemical	Ti, TiN, Vn, AlN, SiC, Si_3N_4, W
	Laser	Si_3N_3, SiC, Si_3N_4, SiC
	Thermic	Fe, Cu, Ni, Mo, W, BN, TiC
	Spontaneously stretch on high temperature	SiC, MoSi, TaC,
	Mechano chemical	TiC, NiAl, TiB_2
	Electro chemical	WC, CeO_2, ZrO_2
	Solution	Mo_2C, BN, SiC
	Cryochemical	Ag, Pb, Mg, Cd
Thermo chemical disassembly	Condensed chemical reagents	Fe, Ni, Co, SiC, BN, AlN
	Gaseous chemical reagents	ZrB_2, TiB_2, BN

In the *figure 1* show up machine 1 MN (102 metric ton) pressing force push up the material and by the low potential with 10 000 A current intensity make a solid material. The maximal space of work is 350 mm and the dimensions of machine are 1350x1300x2670 mm.

Figure 1
The SPS 7.40 MK-V sintering machine

The weight of machine is 3500 kg. The mechanism finish about 5 minutes the sintering process, so the grain roughen could avoid.

1. THEORETICAL BACKGROUND OF WORK

The forming of the nano-steels led to the changing of mechanical quality. In the first place the increase of hardness is remarkable. Because the hardness shows the resistance of the material against to the plastic change of form accordingly is proportional relationship between the hardness of material and its yield stress (σ_y). At first examined at large the relationship between the yield stress and grain measure and as result was determined so-called Hall-Petch equation (1)

$$H_v\left(\sigma_y\right)=H_o\left(\sigma_o\right)+Kd^{-1/2}, \qquad (1)$$

where H_v is a hardness of material, σ_y is a yield stress of material, H_0 is a hardness of grain, σ_0 is a yield stress of grain, K is a material constant, so-called coefficient of Hall-Petch and d is a diameter of grain.

Figure 2 shows the relationship between the tensile strength and strain [2].

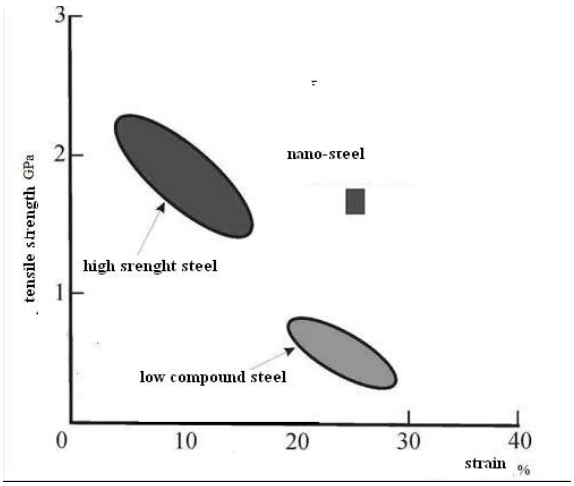


Figure 2
Different steels mechanical quality

2. SPECIMEN PRIPERING

The starting material was 316 L stainless steel powder which was made by "HÖGANÄS" Belgium S. A. by evaporation method (*base Fe, 0,017 % C, 12,6 % Ni, 17,1 % Cr, 2,5 % Mo, 1,4 % Mg, 0,7 % Si*) [3]. The average dimension 71 µm (53 %) (*Figure 3. left side*). We made 4 types of specimens. The first was made from the original steel powder. The second was grinded in propanol, in DMQ 07 attritor with 1 mm steel balls for 10 hours. The grinding speed of machine was approximately 2300 rev/min. The third material preparing was the same as second, but in the henceforth *1 % Al_2O_3* add we grinded it in dry condition for 3 hours. The fourth was grinded only *1 % Al_2O_3* add in dry condition for 3 hours. At this time the grinding speed of machine was approximately 600 rev/min. The grinded material shows on the *Figure 3* right side. The specimens were sintered in the spark plasma sintering machine which is shown on *Figure 1*.

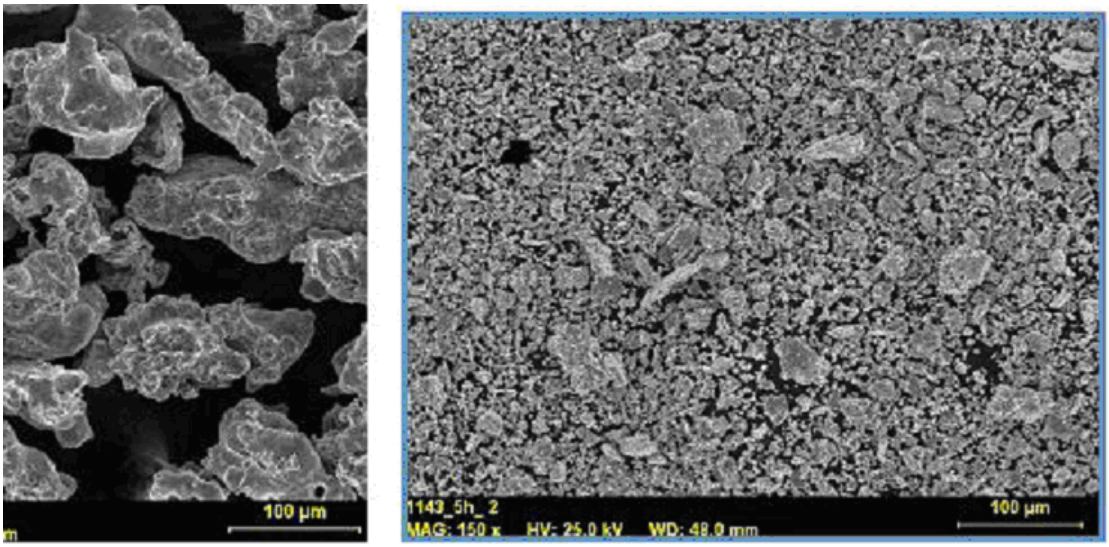


Figure 3
The original is on the left side and the grinded steel on the right

The dimensions of specimens are *Ø 100 mm x 10 mm*. To the tests we cut out the specimens with water. Because the available test material was short of we had cut down the measurement of specimen. So the measurement of tear test pieces ware *2 mm x 10 mm* and the test pieces of Charpy impact test ware 7,5 mm x 10 mm x 55 mm. We made a "control" test with the same material plate (the elements composition ware the same). This plate type was "ArcelorMittal" 316 L, 10 mm thick stainless steel.

3. MEASUREMENTS AND RESULTS OF SPECIMENS

The composition of test pieces we measured with "ArcMet 8000" device (*table 2.*). The first measurement was on the surface, after 0,1 mm inside to the centre. From the third column of table 2 is shown that the base material superabundant in carbon. The reason for this is that technical purpose the steel powder are sintering with graphite electrodes where the carbon diffuse on the surface and in to the material of specimen influence of the high temperature and the high intensity of current.

Table 2 **The composition of first specimen materials**

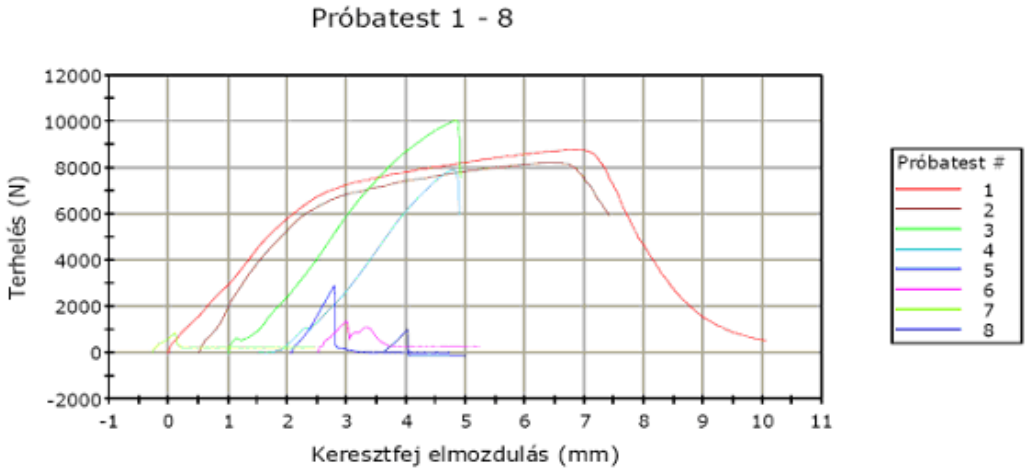
No. of test	Fe	C	Si	Mn	Cr	Ni	Mo	S	P
2341_1	62.82	(2.489)	0.569	1.258	16.59	12.92	3.225	(0.000)	0.030
2341_2	64.96	(0.857)	0.639	1.477	16.64	12.40	2.881	(0.000)	0.053
2341_3	62.61	0.348	0.725	1.717	19.94	11.58	2.857	(0.000)	0.050

Against of unfavourable influence we tray to change the technology of sintering, if it possible. The value of tensile strength, strain and hardness shows the *Table 3* and *Figure 4*.

Table 3 **Compare of the value of strain, tensile strength and hardness**

Specimen	strain ε%	tensile strength (R_m)[MPa]	hardness HB 2,5/ 62,5
No. 1 test	12,75	421	178,37
No. 2 test	7,55	449	209,55
No. 3 test	1,2	88	266,77
No. 4 test	-	-	171,92
316 L control	57,48	589,14	156,85

As the third table shows that the results of strain, tensile strength far away are behind with the control material. The tensile stress of 4 test was non valuation because it was broken. The reason for is the earlier mentioned superabundant in carbon.



	Húzó alakváltozás-nálHúzószilárdság (mm)	Terhelés-nálHúzószilárdság (N)
1	6,10235	8620,53260
2	5,89280	8224,92409
3	3,82905	10022,86971
4	3,28295	7917,28701
5	0,61595	2202,82939
6	0,50165	1294,32329
7	-3,28930	12,46988
8	0,50165	1030,99903

Figure 4
Results of tensile strength and tensile deformation

SUMMARY

We intend the heat treatment of specimens (heat to 400 ^{o}C and cooling on air). We will examine every specimen with Charpy test, additional tensile stress, composition test, gleeble test and bending stress. We study the structure of material with spectroscopic analysis using X-rays, electron spectroscopy, diffraction of X-ray (XRD) and invers microscope (1000x). The measurement of grains and the dispersion of dimensions of grains we determine with laser- granulometer.

The undesirable superabundant in carbon the results are undeveloped from the desirable, but we learn a lot about the method.

This work was supported by the Hungarian National Development Agency represented by the Ministry of Education and Culture within the frame of the TÁMOP 4.2.2.-08/1-2008-0016 project.

Literature

[1] Andrievszkij, R. a., Ragulja, A. V.: Nanostrukturnüe materialü. Moszkva, Akademija, 2005.

[2] Azarenkov, N. A., Beresznev, V. M., Pogrebnjak, A. D., Malikov, L. V., Turbin, P. V.: Nanomaterialy, nanopokrytija, nanotehnologii. Kharkovskij Nacionalnyj Universitet im. V. W. Karazina, 2009.

[3] Balázsi Cs., Timár I., Verdes S., Bálint A., Horváth P., Borbély T., Lisztes I.: Nanoszerkezetű acélporok és vizsgálatuk. OGÉT 2010, 18th International Conference on Mechanical Engineering, 2010. p.: 44-47.

[4] Kakuk Gy., Csanády A.: Nanoszerkezetű anyagok előállítása mechanikai őrléssel. Gép, Gépipari Tudományos Egyesület, 2006/1, p.: 24-28.

[5] www.scm-sps.com