RESEARCHING RESULTS OF NANO-STEEL II.

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Abstract: We show the test methods used for the nano-steel structured probes produced within a research program. We compare the test results with similar ones of the same compound, but made by other technologies. We study how the most important parameters of strength could be calculated using the experimental results.

Key words: Sintering, grinding, comparision, tensile test, hardness.

INTRODUCTION

It is well known, that the strength properties of the materials are depending on the grain size. The relationship is described by the so called Hall-Petch equation [4]. The first experiments were made in the 80's with the small size grained materials, later, around 2000 started to operate the modern sintering machineries, which were able to produce high quality, small grained nano-materilas. Literature defines the steel as nano-steel, which has a grain size of 1-100 nanometer dimensions in minimum one direction [3]. Serveral methods were developed to reach the fine grain dimension (powder metallurgy, intensive plastic deformation, controlled recristalization from atomic state, thin layer technology). This paper describes a technology, which was selected - together with the Ceramics and Nanocomposites Department of the Hungarian Scientific Academy - based on the grinding [2].
Russian scientists gave a complete summary the effect of the grain size on the different material properties, such as the yeald stress, Young modulus, heat conduction, e.t.c.) [1].

1. PREPARATION OF THE SAMPLES

The grinding operation was made in a ball and tube mill with 4,5 kg capacity. The mill has stainless steel drum wall, the material of the balls were cirkonium-dioxide, silicium-nitrid and aluminium-oxide. The speed of the drum was 4000 rev/min. The grinding operation was performed in dry and also in wet state (in propanol). The enlarged image of the grinded material is seen on the figure *1.* Four samples were prepared:

- without grinding (No. 1),
- 10 hours wet grinding (No. 2),
- with mixed grinding (No 3 with 10 hours wet grinding, than 3 hours dry grinding), and
- 3 hours dry grinding (No 4).

The fine powder was sintered and homogenized using the sintering machinery of the Istambul Technical University at a temperature of 940 ^{o}C and a pressure of 50 MPa, for 5 minutes. (with cc. 10 000 A electric current and some V voltage between carbon electrodes and pressurized in carbon form).

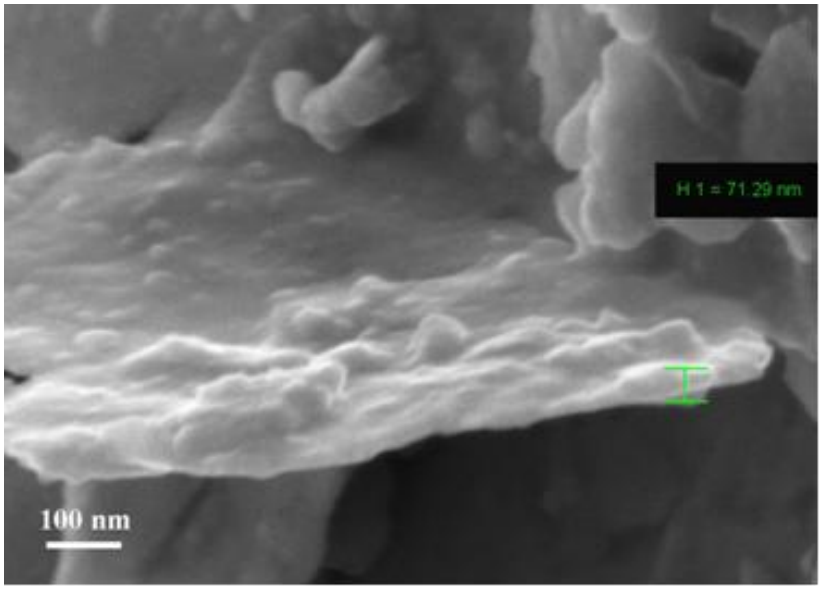


Figure 1.
The thickness of the nano steel after 10 hours wet grinding

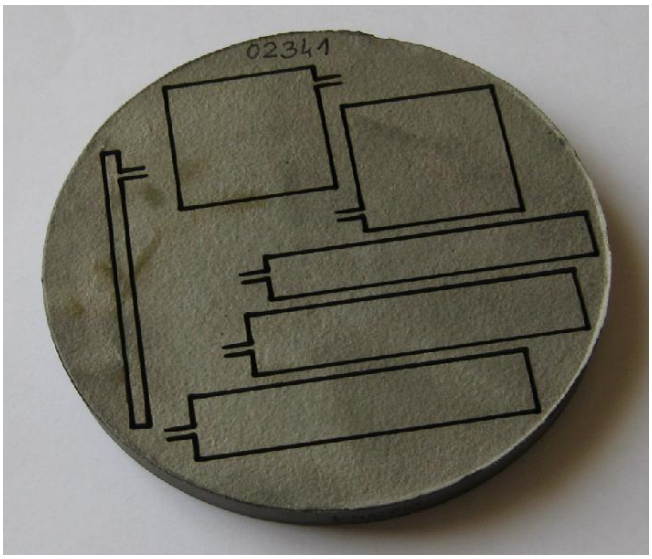


Figure 2.
The sintered, water jet cut samples ready for tests

The ready made test pieces are seen on the Figure 2. The diameter of the sample part was 100 mm, the thickness was 10 mm. Special test samples (tensile test samples, bending test samples, Charpy impact test samples, Ford-compression test samples and samples for machining tests. Similar test sample pieces were made from ordinary sheet metal with similar material composition (No. 6) [4].

2. MEASUREMENTS AND RESULTS

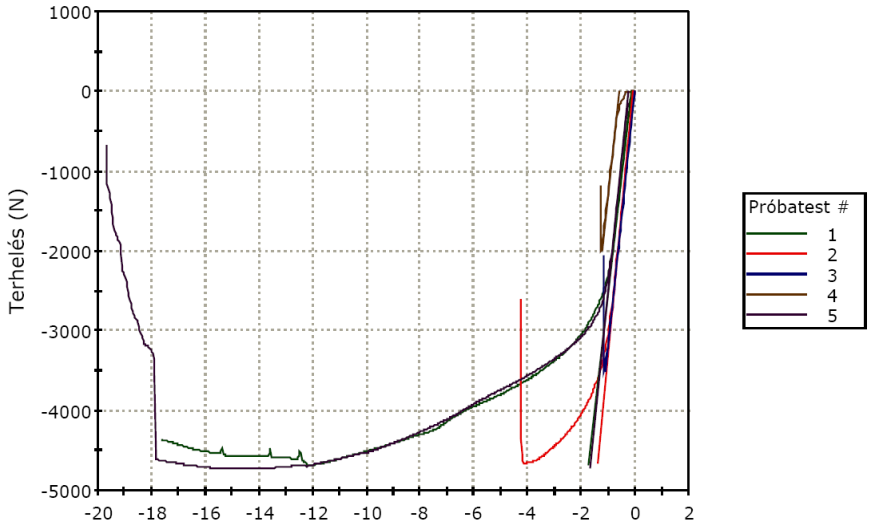
The material composition was inspected using the ArcMet 8000 equipment. (Table *1.*). The first measurement was performed on the surface of the test piece, than moving inside the measurement was done by 0.1 mm distances. It can be seen from the results in the 2nd column, that the sample was superabundant in carbon. The reason of this finding,

that the steel powder was sintered in carbon form, and carbon was entered into the metal part because of the high temperature and electric current [4].

The composition of the sample No. 1. **Table 1.**

	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

The results of the other tests.



No of samples	Thickness [mm]	Distance [mm]	Stress [MPa]
1 (2)	5,99	40,0	692,6
2 (3)	6,09	40,0	532,0
3 (4)	5,94	40,0	317,8
4 (5)	6,10	40,0	175,7
6 (1)	6,02	40,0	686,6

Figure 3.
Results of the bending test (measuring line number in brackets)

The bending test pieces (Figure 3.) were made in perpendicular direction to the surface of the sample, so the carbon content is smaller in the middle of the sample. The results are similar to the tensile test results [4], and it was surprising the good result for the base metal powder.

Figure 4. shows the microscope image of the sample No. 4 (dry grinding). It can be seen the effect of the carbon diffusion on the grain borders. All the images of the sintered samples are similar. It was more surprising the result of the machining test. The bending stress was measured in the turning knife, and also the vibrations were measured with acceleration gauge. It was noticed, that the vibrations as well as the bending stress signal were changed periodically, and the frequency was double as much as the rotation frequency. The hardness was measured again, but four places (by 90^{o} distance) this case. This result shows again, that the material is harder on the side where the metal contacted with the carbon form, and is the hardness is smaller in the middle of the sample.

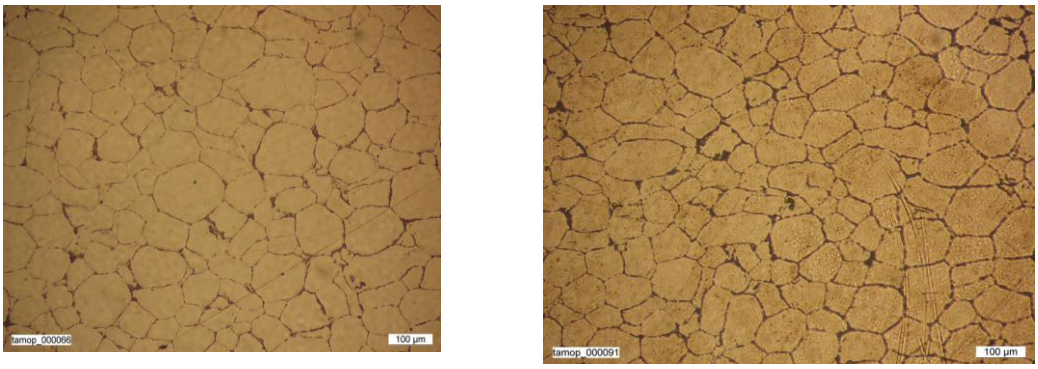


Figure 4.

Image of the sample No. 4 without acid treatment and with acid treatment at a 200 magnify

Figure 5. shows the bending stress caused by the machining force at the case of sample No. 3. The black continuous line describes the average stress value.

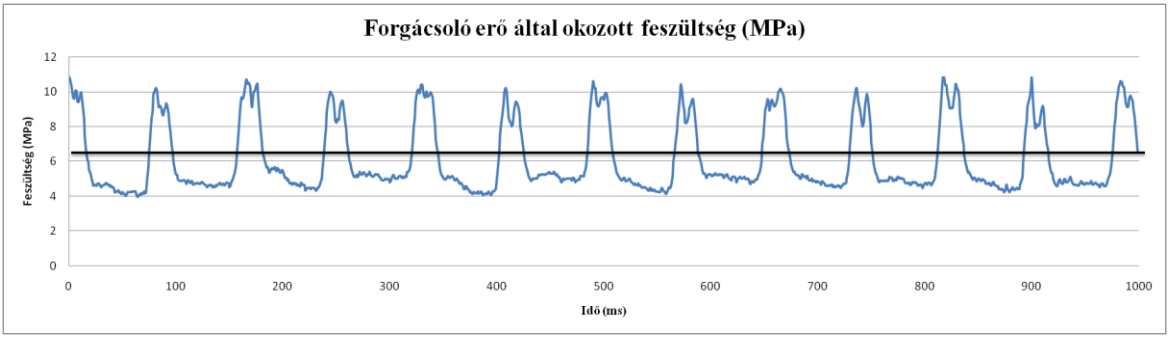


Figure 5.

The bending stress vs. the time

Although the strength properties were smaller than the planned values due to the undesirable carbon diffusion, we could reach such results using the sintering method, that we will be able to apply in other applications. The authors of the article [5] applied molybdenum foil to solve this diffusion problem, and it was useful in the case of silicon. Similar foil, or the change of the electrode material can give us a better result. We are planning to make calculations for the estimation of the strength characteristics using the results of this study.

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