THE ANALYSIS OF TRIBOLOGICAL AND EROSIVE PROPERTIES OF SINTERED MATERIAL ON THE BASE OF X2CrNi18-9 STEEL MADE WITH VARIOUS TECHNIQUES

STRADOMSKI Grzegorz *, WRÓBEL Arkadiusz, SZAREK Arkadiusz, DYJA Henryk

Technical University of Czestochowa, Faculty of Production Engineering and Materials Technology, Institute of Plastic Forming Processes and Safety Engineering, Częstochowa, Poland, EU, gstradomski@wip.pcz.pl

Abstract

The aim of the paper was to determine the influence of used technology on the tribological properties and the erosive resistance of X2CrNi18-9 base sintered materials. In the work was made the analysis of processes the high temperature isostatic pressing and sintering in deep vacuum. For researches were made two sets of samples with variant SiC content in range 0-5 %. To the erosive resistance analysis was used the designed in Czestochowa University of Technology device. To the tribological properties analysis was used the pi on disc test.

Keywords: Sintered stainless steel, HIP, erosive resistance, tribological properties

1. INTRODUCTION

The dynamic development of technology, the increasing requirements for material produce entail a need to search for new, often alternative ways of producing and improving of current [1-6]. Powder metallurgy is a field giving extremely many possibilities and ways of development of material technology. Modern composite materials often require joining together of materials with completely different properties. The combination of often completely different materials and appropriate production technology give the best results [7]. Among the materials made in powder metallurgy technology an important group are those with improved erosion resistance. Hot isostatic pressing uses the right Pascal, and as compression medium is use inert gas (eg. He, Ar, N). The gas pressure acts uniformly on all sides of the form allowing obtain triaxial stress state. This phenomenon provides a uniform density distribution into the retaining molding regardless of the part shape. This is not available with classical die pressing. The temperature at which the process is carried out is in the range from 1100 °C to 1650 °C. Thanks to the combined action of heat and pressure the sintering process is accelerated in comparison to traditional sintering technology. By using such technology can be sintered products nearly theoretical density at lower temperatures than in conventional processes [8].

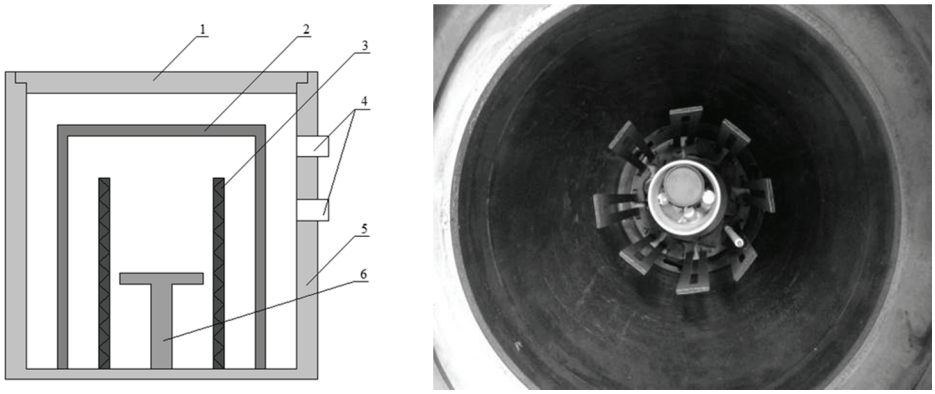

Figure 1 Scheme of chamber for hot isostatic pressing and the actual appearance of the device chamber [7] (1- chamber cover, 2 armor, 3-heating elements, valves 4, 5-chamber wall, 6 - table)

The construction of hot isostatic pressing devices must meet high requirements regarding the selection of materials and the strength of the pressure chamber. Improper construction can cause an explosion due to the huge energy accumulated in the chamber. It is therefore necessary to take extra precautions during the operation to minimize risk [8]. **Figure 1** presents a schema of the chamber to the hot isostatic pressing. Technology hot isostatic pressing is expensive due to the high cost of specialized equipment and installation. Therefore, the products also are more expensive than those produced by conventional methods. This difference represents offset by higher strength, longer exploitation life and improve the quality of the workpiece [8]. In addition, there is a significant group of products such as jet engines turbine blades requires specialized thermo - pressure treatment, which can be done only in devices such as HIP.

2. MATERIAL I METHODOLOGY OF RESEARCH

The material used during research was the sintered steel X2CrNi18-9 made two techniques: hot isostatic pressing and sintering in a deep vacuum. The aim was to determine the effect of silicon carbide on the properties of erosion and tribological properties of investigated steel. Samples were prepared from the X2CrNi18-9 steel powder of the chemical composition described in **Table 1**. Particle size of both the silicon carbide and the steel was 0.1 mm. Steel powder was purchased from an outside company, and according to data provided by the manufacturer has been obtained by grinding in a ball mill.

Table 1 The chemical compositions of tested steel X2CrNi18-9 according PN-EN 10088-1:2014-12 (mass %)

Steel X2CrNi18-9							
Element	C	Si	Mn	P	S	Cr	Ni
Content, %	<0.03	<0.80	<2.0	0.045	0.030	17.0÷19.0	10.0÷12.5

For process of vacuum sintering, and hot isostatic pressing were prepared two identical sets of powder which differed in silicon carbide content in sample. The composition of each sample is presented in **Table 2.**

Table 2 Mass composition of samples

No. samples	The weight percentage of silicon carbide, %	The mass of steel powder, g	The mass of the silicon carbide powder, g	No. samples	The weight percentage of silicon carbide, %	The mass of steel powder, g	The mass of the silicon carbide powder, g
0	0	20.00	0.00	6	0	20.00	0.00
1	1	19.92	0.08	7	1	19.92	0.08
2	2	19.84	0.17	8	2	19.84	0.17
3	3	19.75	0.25	9	3	19.75	0.25
4	4	19.67	0.33	10	5	19.58	0.42
5	5	19.58	0.42	*11*	*4*	*19.67*	*0.33*

Sample after vacuum sintering containing 4 % of silicon carbide was given the last number in **Table 2**, because the sample is dissolved before the start of the research that was omitted in the research.

After weighing the appropriate amounts of powders material was mixed for a period of two hours in a mixer shown in **Figure 2a,** and then sintered using an HIP AIP8-30H-PED shown in **Figure 2b.**

The set 1 of loosely backfilled into molds powder sintered in a high vacuum using the following parameters: temperature of 1100 °C, the time 200 minutes. The set 2 of powders was pre-compacted in a die with a force of 200 kN for 5 minutes. Then isostatic hot pressed, using argon as the pressing medium at a pressure of 2000 bar, the temperature and time of sintering were the same as for vacuum process.

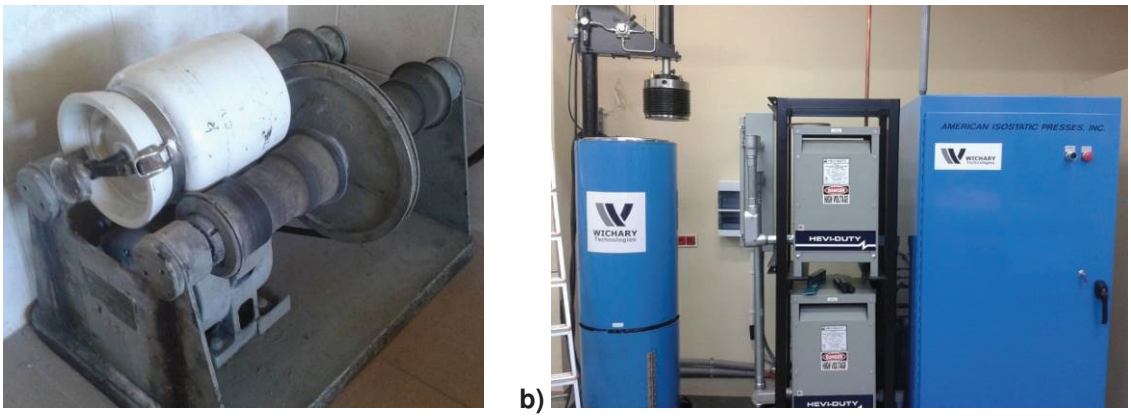

Figure 2 a) Mixer, b) hot isostatic press HIP AIP8-30H-PED

The tribological tests were performed using the "Pin on Disc" method. The "Pin on Disc" device is designed to test the wear of materials due to friction applied to the elements of friction. The test determines the intensity of wear material samples in cooperation with other material depending on the desired speed, slip and surface pressure. The scheme of the device and the actual view is presented in **Figure 3.**

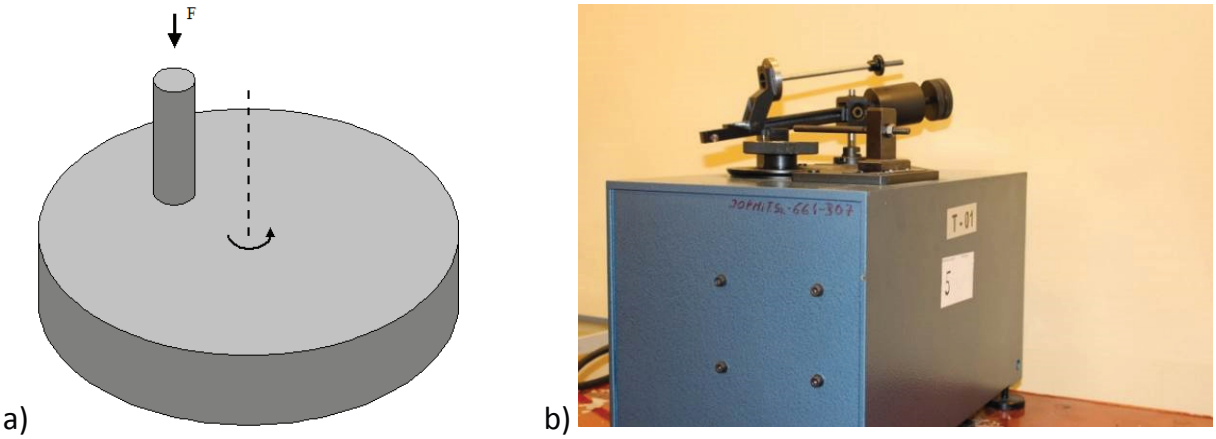

Figure 3 a) The scheme of the "Pin on Disc" device, b) Test stand

Tests of resistance to erosive wear were performed on a designed at the Technical University of Czestochowa device. Scheme and the actual appearance of the device are presented in **Figure 2**. The test site has a smooth speed control and the ability to study at the same time up to 4 samples.

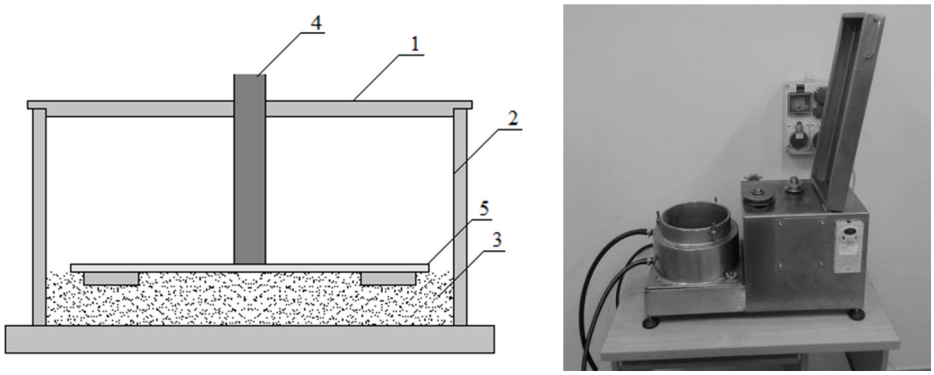

Figure 4 The scheme of the erosive wear tests device and appearance of the actual device (1 cover, 2-tank, 3-medium erosion, 4-rotor drive shaft, 5-disc spinning with inserted samples) [9]

3. RESULTS AND DISCUSSION

Erosion resistance test consisted of four measuring cycles. The duration of a single cycle was three hours. The samples were weighed before the test and after each cycle. The test results on the erosion resistance are shown in **Table 3** and **Figure 4**. The erosion test was performed at a speed of 250 rpm. The erosion medium was dry quartz sand with a 20 % addition of silicon carbide. After each test cycle the sample was weighed with an accuracy of 0.00001 g. To evaluate the erosion resistance was adopted relative weight loss of the sample. **Figures 4** and **5** show the results obtained in the form of graphs purpose of easier analysis.

Table 3 The erosive wear results

No. samples	Weight before the test, g	Weight after 3 h, g	Weight after 6 hours, g	Weight after 9 hours, g	Weight after 12 hours, g	Loss of weight, g	Loss of weight, %
0	4.91996	4.90853	4.90499	4.90235	4.90072	0.01924	0.39
1	4.52227	4.47248	4.47060	4.46699	4.46643	0.05584	1.23
2	4.91025	4.84907	4.84256	4.82413	4.82226	0.08799	1.79
3	4.72087	4.64679	4.64025	4.62890	4.62375	0.09712	2.06
4	4.86812	4.77245	4.76770	4.75969	4.75772	0.11040	2.27
5	5.49096	5.38603	5.35891	5.35473	5.35272	0.13824	2.52
6	5.20189	5.13227	5.10827	5.09133	5.08512	0.11677	2.24
7	4.92468	4.91786	4.91467	4.91311	4.91065	0.01403	0.28
8	3.76293	3.73275	3.72027	3.71007	3.70467	0.05826	1.55
9	4.42578	4.37486	4.32963	4.29814	4.29084	0.13494	3.05
10	4.98728	4.95612	4.94390	4.93402	4.92634	0.06094	1.22

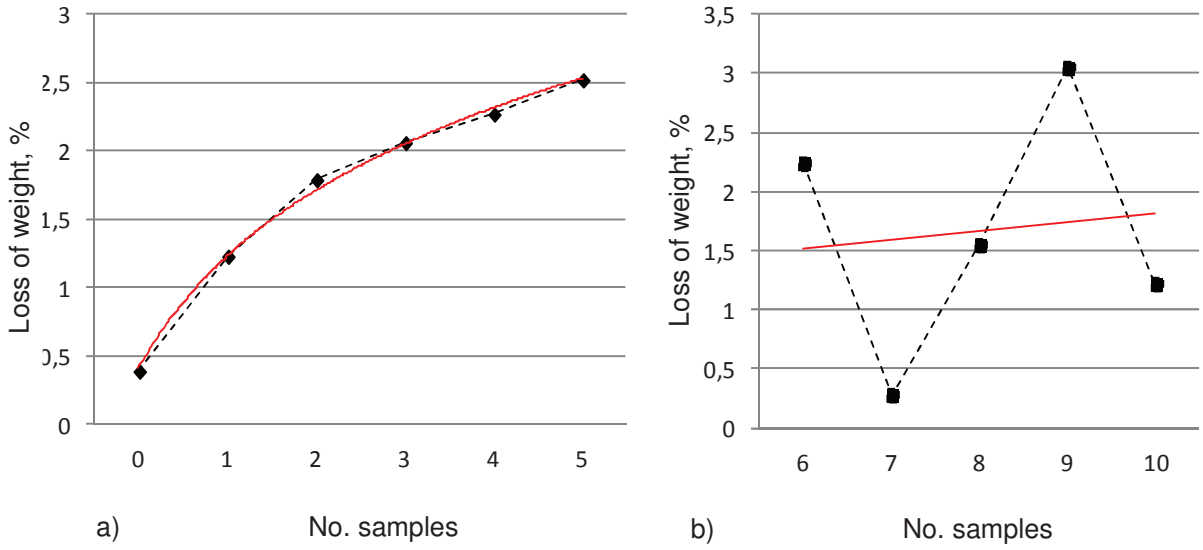

Figure 5 The value of percentage weight loss of the samples after a) hot isostatic pressing, b) the deep vacuum process

Erosion resistance test showed that in the material after the HIP process, the increase of the silicon carbide content in the sample, resulting in increased susceptibility to erosive wear. The reason is the lack of a strong bond between the silicon carbide and the matrix. For samples sintered in vacuum the increase in the content of silicon carbide does not cause clear, strong effects and shows the random nature.

In the work were performed also tribological tests using "Pin on Disc" method. The results are presented in **Table 4.**

Table 4 The results of the "Pin on Disc" test

sample No.	Before test g	The friction road mm	Weight after test g	The loss of weight g	The loss of weight %
0	10.687	301440	10.681	0.006	0.06
1	14.972	301440	14.935	0.037	0.25
2	16.701	301440	16.684	0.017	0.10
3	17.581	301440	17.578	0.003	0.02
4	17.335	301440	17.304	0.031	0.18
5	19.263	301440	19.255	0.008	0.04
6	14.583	301440	14.562	0.021	0.14
7	12.446	195936	11.787	0.659	5.29
8	Not tested				
9	Not tested				
10	13.869	301440	13.815	0.054	0.39
11	Not tested				

The samples after vacuum sintering containing 2-4 % of silicon carbide cannot be tested using the "pin on disc", since at the time the task of force were damaged. The sample sintered in vacuum containing 1% of silicon carbide could not be carried the full test using the "pin on disc" due to excessive wear of the sample under the action of the penetrator.

4. CONCLUSION

The experimental material was sintered samples based on the X2CrNi18-9 steel, which is widely used austenitic eg. in building facades, in the industry to elements resistant to corrosion and pressure vessels. The samples consisted of a steel powder and powder of silicon carbide with different contents from 0 to 5 percent. The given research material from two different processes, vacuum sintering and hot isostatic pressing (HIP), was characterized by different tribological properties and erosion resistance. Samples after the HIP process are characterized by a greater density, which results in improved tribological properties. The best tribological properties, determined by the percentage of the weight loss during in the "pin on disc" test, were the sample number 3 and the worst sample 7. For the test materials was observed that the tribological wear resistance is not proportional to the increase in the percentage of silicon carbide. For samples after the process of hot isostatic pressing can be observed a logarithmic decrease of erosion resistance with increasing silicon carbide, which is related to the chipping of the hard material particles of silicon carbide which are poorly connected to the metal matrix. This effect was not observed for the samples after the vacuum process. The biggest loss of weight after the test samples erosion of the HIP process was found for the sample No. 5. The smallest loss of weight was found for the sample without the silicon carbide. Samples after the vacuum sintering process are characterized by non-linear resistance to erosion with respect to the logarithmic nature of the change which are characterized by a sample of the HIP process.

REFERENCES

[1] GARSTKA, T. DOBRAKOWSKI, R. KOCZURKIEWICZ, B. DYJA, H. The system of automation for controlled cooling of the shapes. Journal of Materials Processing Tchnology, 2004, vol. 157, pp. 159-164.

[2] MROZ, S., SZOTA, P., KOCZURKIEWICZ, B. Modelling of rolling and cooling processes of the bulb bars HP220. Materials Processing and Design: Modeling, Simulation and Applications. 2007, vol. 908, pp. 1243-1248.

[3] LABER, K., DYJA, H., KWAPISZ, M. Numerical Modelling of the Cooling Ability of Device for the Plain Round Bars Accelerated Cooling Process. Archives of Metallurgy and Materials. 2011, vol. 56, no. 2, pp. 385-392.

[4] KWAPISZ, M., KNAPIŃSKI, M., DYJA, H., LABER, K. Analysis of the effect of the tool shape on the stress and strain distribution in the alternate extrusion and multiaxial compression process. Archives of Metallurgy and Materials.2011, vol. 56, no. 2, pp. 487-493.

[5] SZAREK, A., STRADOMSKI, G., WŁODARSKI, J: The analysis of hip joint prosthesis head microstructure changes during variable stress state as a result of human motor activity. Materials Science Forum, 2012, vol. 706-709, pp. 600-605.

[6] SZARE, K. A., POSTAWA, P., STRADOMSKI, G. Assessment of Biochemical Processes and the Influence of Cyclic Loads on the Strength of PMMA Used for Attaching the Prosthesis to the Bone. Steel Research International Spec. Edition Metal Forming, 2012, pp. 1263-1266.

[7] Missol Witold. Spiekane części maszyn. 1st ed. Katowice: Wydawnictwo Śląsk, 1978, 28 p.

[8] OSTROWSKI, T. Metalurgia Proszków. 1st ed.Lublin: Uczelniane Politechniki Lubelskiej, 1978, 87 p.

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