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Multimetal Stahl 1018 Composite – Structure and Strength Properties

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Abstract

The series of experiments was performed on commercial polymeric composite material MultimetalStahl 1018. Strength tests were performed to determine the yield point of the material. The composite had the highest hardness at a temperature of 20°C. Hardness and microhardness were determined in further experiments. The adhesiveness of the material to metal surfaces and impact strength were also analyzed. The scanning electron microscopy and X-ray microanalysis methods were used for analyzing the microstructure of the material. Chemical composition of selected areas was analyzed, which allowed for a preliminary identification of metallic elements content in the composite. The microstructure of composite is highly non-homogeneous and particular phases are highly elongated and angular. The analyzed phase was enriched with silicon, aluminium, magnesium, iron and vanadium other phases enriched with metallic elements, e.g. molybdenum, titanium, vanadium and also oxygen as well as traces of cadmium and chromium. The results were presented in the form of photos and illustrations. The results confirmed the applicability of the composite as a binder for fixing mechanical and foundry devices.

Keywords: Composite Stahl1018, Hardness, Impact strength, Yield point

1. Introduction

The primary applicability area of such modern construction materials as composites are space technology, military industry, communication and production, e.g. sports equipment. For over 30 years composites have been used in space as elements of truss, supports, connections, constructions, antennas, parabolic reflectors, satellite gyroscopic stabilizers, annular articulated suspensions, electronic housing. The properties of compositions can be modified and designed depending on needs. They are unattainable for conventional materials, i.e. they can have higher strength, Young modulus, fatigue characteristic, wear resistance, slip characteristics, high corrosion resistance both at the room and elevated temperature [1-11].

Composite materials based on polymers are more and more frequently applied in industry for mechanical devices, the fixing of which requires replacement of components or subassemblies. An alternative to the purchase of new parts can be the composite materials based on thermo- or chemosetting epoxy resins containing metal or metal oxide particles. Multimetal Stahl 1018 composite was worked out in the early 1990s as a result of a close cooperation with a German bridge company and a company producing metal constructions. Since that time this material has been successfully applied in Germany and abroad for fixing and replacing pillars in railway, road or canal bridges. Multimetal Stahl 1018 is based on the best polymers, which almost do not shrink after they are hardened, and which have a good chemical resistance. The composition of powder fillers covers high quality stainless steel, ceramics and additive which improve the surface tension and chemical resistance steel. Thanks to its ideal viscous consistency and Multimetal Stahl 1018 can be distributed evenly in all directions on wedge gates or bridge supports with a palette knife during installation thanks to good forming properties. The composite Multimetal Stahl 1018 can be used for fixing devices cheaply, however this should be preceded by strength tests of the composite on its ability to withstand applied loads and operate in constant dynamic loads and elevated temperatures [11-14].

This paper is a continuation of previous strength experiments on composite MM "Stahl 1018" in view of its applicability as a binder of machines operating under mechanical and thermal loads. In [14] there were performed tests on the effect of temperature on the mechanical properties of the composite. The technology of performing samples from the analyzed composite Stahl1018 and methodics of laboratory experiments, including compressive strength tests, were presented in the paper. The analysis of the obtained experimental results revealed that with the increase of temperature the yield point of the composite material decreased [12-14].

2. Materials and experimental method

The composite materials based on polymers are more and more frequently applied for fixing operational machines used in industry. The lack of spare parts for damaged mechanical devices can be a source of economic loss due to the increasing idle time. The replacement of particular components is frequently impossible or very costly because of the high price of spare parts. In some situations it is not possible at all. The Multimetal MM "Stahl 1080" composite can be used for cheap repairs of failed devices, although it should be preceded by an analysis of the material on the basis of which we can state whether or not the material can withstand the impacts, also at elevated temperatures [12-14].

For the sake of determining the properties of a given composite, a number of tests were performed, e.g. analysis of microstructure, chemical analysis, measurement of hardness and microhardness, adhesiveness of the composite to metal/steel, impact strength tests.

The testing machines allowed for performing experiments in complete thermal isolation or in given temperature conditions. A special chamber was used for heating up the sample to the required temperature and compression tests with a vibration impact. This device could be also used for testing the elasticity and strength of samples at various temperatures. The experimental temperature range was 20°C to 80°C. The tests could be performed for samples of various size and shape at maximum compressive impact 100 kN, with piston step of 250 mm.

First the strength tests of the composite samples were performed on the Zwick Roell Amsler HB 100 strength machine presented in figure 1. The results of the linear strain tests of samples 1.5; 3 and 4.5 mm high (H) at temperature 20^{o}C are presented in figure 2.

Fig. 1. Zwick Roell Amsler HB 100

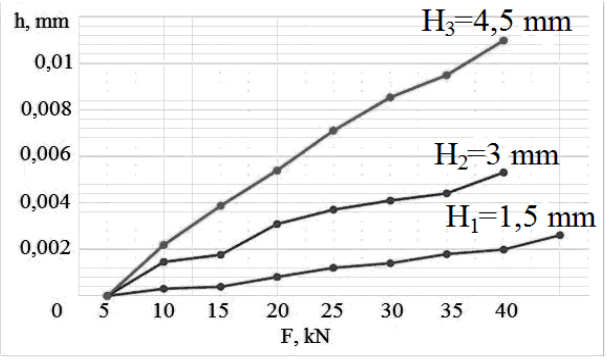

Fig. 2. Linear strain of "Stahl 1018" structure vs. axial impact at temperature 20°C

The figure indicates that the shrinkage of the material is directly dependent on the amount of sample. The higher the sample height, the greater the shrinkage. Therefore, this feature must be taken into account when using this material when developing techniques to be used in real conditions

The structure of composite material depends on the production technology, properties of matrix material, properties, type and participation of the reinforcing phase, the even distribution of which is required for the correct composite structure. The composite properties greatly depend on intermolecular distances. Any change in the distance may result in high compressive stress values. The surface dividing reinforcement and matrix is the most important parameter characterizing composites. It directly affects the quality of reinforcement and matrix interface, attenuation of vibration of cracking composite as a whole and inter crystalline cracking of the matrix itself. The chemical and phase composition of connection between components is important both in the aspect of mechanical properties, corrosion resistance and also it may also constitute and element of a structure favoring premature wearing of the material.

The chemical composition of "Stahl1080" material was determined with a microscope «JEOL JSM-5500LV» owned by the Faculty of Foundry, AGH-UST. The sample of the composite was D = 20 mm in diameter and H = 40 mm in height. The proper tests were preceded by observations with an optic microscope. Areas of possibly diversified chemical composition were searched for during the tests. Apart from this, the distribution of particular phases in the analyzed sample was also evaluated. The results of observations are presented in the successive figures. Figures 3 and 7 give a picture of microstructure, whereas figures 4-6, 8-9 are illustrations of X-ray microanalysis of indicated areas.

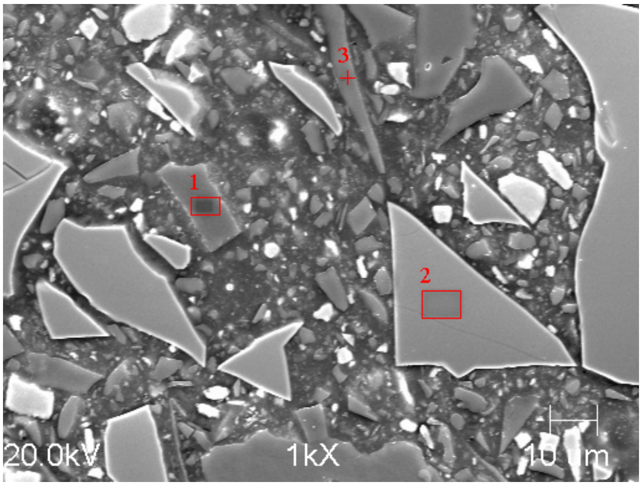

Fig. 3. Microstructure of sample no. 1 performed of MM "Stahl1080" material, obtained with SEM

The microstructure of composite presented in figure 3 is highly non-homogeneous and particular phases are highly elongated and angular. Special attention was paid to areas 1-3, which have a different morphology, shape, size and color, which may speak for the differentiated chemical composition and properties of the analyzed phases. For proving these assumptions, the chemical analyses of these areas were performed with the X-ray microanalysis method. The results of the X-ray microanalysis of indicated area 1 are presented in figure 4. The analyzed phase was enriched with magnesium and oxygen which indicated that the composite contained particles of oxided metallic magnesium or its oxide. The phase marked with 2 was enriched with chromium and contained traces of iron and vanadium. Apart from considerable differences in chemical composition the analyzed phases also had different morphology and size. The phase marked with 3 (fig. 6) had a different composition than phases 1 and 2; in this case mainly the presence of silicon and aluminum was identified.

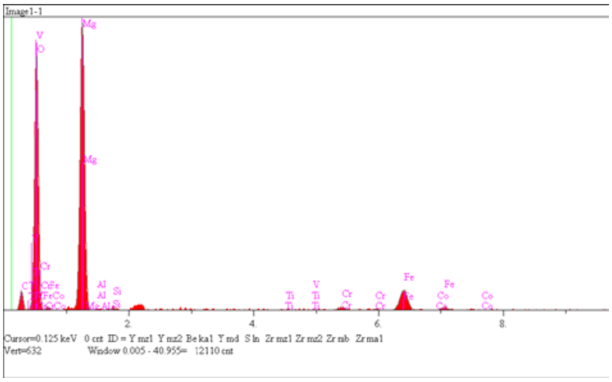

Fig. 4. Result of X-ray microanalysis of sample area 1

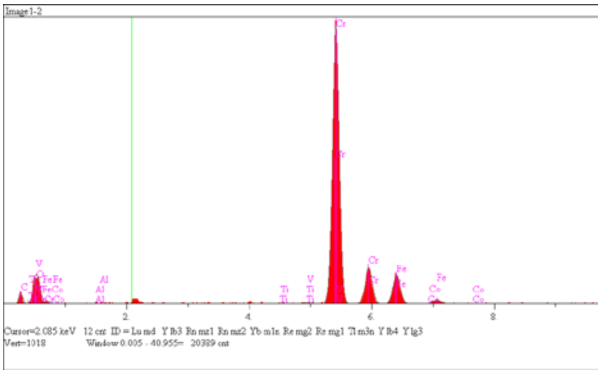

Fig. 5. Result of X-ray microanalysis of sample area 2

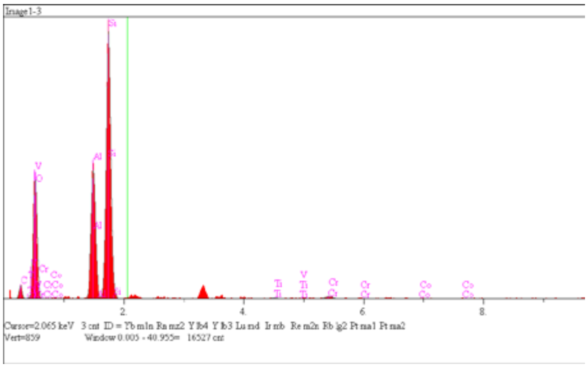

Fig. 6. Result of X-ray microanalysis of sample area 3

Analogous experiments were performed for sample no. 2. In this case the analyzed areas considerably differed in color and shape. The microstructure of sample no. 2 is shown in figure 7.

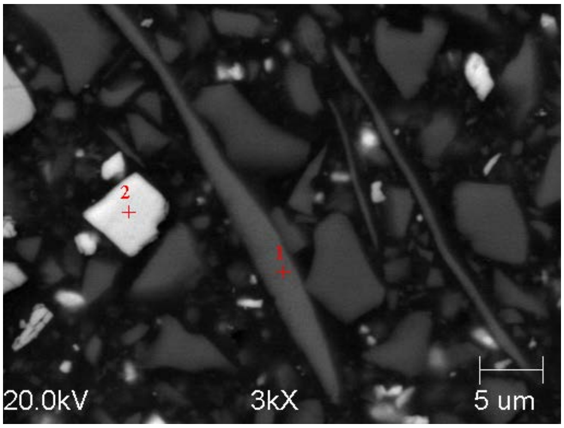

Fig. 7. Microstructure of sample no. 2 performed of MM "Stahl1080" material, obtained with SEM

In the case of an area marked as 1 (fig. 7), having elongated and pin-like shape, the results of chemical analyses revealed the presence of Al as the main component of this phase (fig. 8). The area marked as 2, with uniform geometrical shape, is chemically non-homogeneous and contains phases enriched with metallic elements, e.g. molybdenum, titanium, vanadium and also oxygen as well as traces of cadmium and chromium (fig. 9).

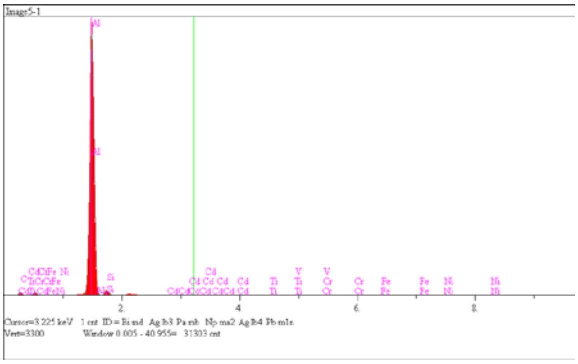

Fig. 8. Chemical composition in the first point on the surface of the sample

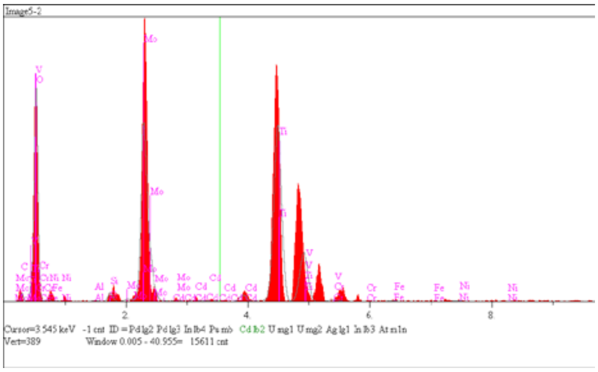

Fig. 9. Chemical composition in the second point on the surface of the sample

For the further evaluation of applicability of the composite to the maintenance of industrial tools, the samples were tested for hardness. The hardness of samples can be determined twofold: with Brinell and Shore methods. The same hardness results were obtained with both these methods, i.e. HB 180-200. This result corresponds to the low quality steel hardness scale. However, considering the fact that this material was based on polymer, the obtained hardness indices were sufficient for the planned applications. Then microhardness was determined. Microhardness was established by Hanneman. The results were much lower than previously, i.e. HB equaled to 25-30. This discrepancy was due to the considerable non-homogeneity of microstructure and chemical composition of the analyzed material. A full set of results of hardness experiments is presented in table 1.

Table 1.
Results of hardness and microhardness tests of "Stahl1080" with various methods

Number of sample,	1	2	3
Brinellhardness, HB	180	195	200
Shorehardness, HB	195	195	200
Microhardness (Hanemannmethod), HB	35	27	29

Another experiment lied in determining the adhesiveness of two steel elements connected with the composite material. The sample consisted of two steel cylinders 10 mm in diameter and 27 mm long. The cylinders were connected with the analyzed composite material, as shown in figure 10.

Fig. 10. Sample to be used for determining the shock energy

The experiments were performed for three samples. They were placed in a special device «VEB ERKSTOFFPRUFVFSCIHINEN LEIPZIG 1976» for determining their impact strength (fig. 12). The following energy results were obtained: E1=0.40 J, E2=0.45 J, E3=0.45 J. These results are over 100 times lower as for steel, which means that this material can be used for fixing devices exposed to strokes.

Fig. 11. Impact tests

For determining the adhesiveness of «Stahl 1018» to steel surfaces, other samples were prepared analogous as in the previous experiment (impact test – fig. 11). The sample was placed in a tensile testing machine «WPM Rauenstein».

The results of the experiment were not quite clear. Three experiments brought about three different results. In the case of sample 1 the steel cylinder was torn, which signifies that the adhesiveness was higher than tensile strength. In two successive experiments the samples were severed in the place where the material was connected with the composite. The differences could be caused by uneven coverage of the steel surfaces with composite material, and the different thickness of the layer.

Fig. 12. Sample after tensile strength tests

4. Conclusions

The analyses and experiments revealed that the composite material Stahl 1018 based on polymers has good strength properties at room temperature, therefore can be used for fixing damaged parts of mechanical devices. This material is non-homogeneous as far as its microstructure and chemical composition go, and the differences in its specific zones are considerable. The microhardness tests brought about a result which significantly differs from the ones obtained during hardness tests. Microhardness is much lower which is due to the facts that the material was based on organic polymers. The successive experiments showed that the composite could be used in shock conditions, though cannot be applied in machines working in impact conditions. The impact strength tests showed that energy needed to damage multimetal Stahl1018 was much lower than for regular quality steel. Moreover, the composite proved to be highly adhesive to steel surfaces, which means that it can be used for the maintenance of devices operating under dynamic and vibration load.

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References

[1] Królikowski, W. (2020). *Polymer structural composites.* Wydawnictwo Naukowe PWN. (in Polish).

[2] Rabek, J.(2017). *Modern knowledge of polymers. Volume 2. Natural and synthetics*. Wydawnictwo Naukowe PWN. (in Polish).

[3] Konopka, K., Miazga A.K. (2017). *Ceramics - metal composites.* Oficyna Wydawnicza Politechniki Warszawskiej. (in Polish).

[4] Śleziona, J. (1998). *Fundamentals of composite technology* Wydawnictwo Politechniki Śląskiej. (in Polish).

[5] Rabek, J. (2020). *Polymers and their interdisciplinary applications. Volume 2*. Wydawnictwo Naukowe PWN. (in Polish).

[6] Romankiewicz, F., Skocovsky, P., Gorockiewicz, R. (2020). *Unconventional composite materials.* Wydawnictwo Politechniki Zielonogórskiej. (in Polish).

[7] Hyla, I.(1978). *Selected issues from the engineering of composite materials*. Wydawnictwo naukowe PWN. (in Polish).

[8] Boczkowska, A., Kapuściński, J., Puciłkowski, K., Wojciechowski, S. (2000). *Composites*. Wydawnictwo Naukowe PWN. (in Polish).

[9] Grabowska, B., Bulwan, M., Zapotoczny, S. & Grabowski, G. (2012). Biodegradation of new polymer foundry binders composition of poly(acrylic acid)/ dextrin. *Polimery*. 57, 529-534.

[10] Lelito, J., Żak, P.L., Gracz, B., Szucki, M., Kalisz, D., Malinowski, P., Suchy, J.S. & Krajewski, W.K. (2015). Determination of substrate log-normal distribution In the AZ91/SiCp composite. *Metalurgija*. 54, 204-206.

[11] Ischenko, A.A. (2012). *Technological bases of restoration of the industrial equipment by modern polymeric materials.* PSTU Mariupol.

[12] Arustamian, A. & Kalisz, D. (2015). Experimental Determination of the Yield Strength of the Composite

Material "Stahl 1018" at Elevated Temperatures, *Archives of Foundry Engineering*, 15(spec.4), 7-11. (in Polish).

[13] Arustamian, A., Sołek, K. & Kalisz, D. (2016). Identification of yield point of polymer-based composite material in the conditions of increased temperatures. *Archives of Metallurgy and Materials*. 61(3), 1561-1566.

[14] Sołek, K., Kalisz, D., Arustamian, A. & Ishchenko A. (2017). Analysis of strength characteristics of composite materials under vibration loads at higher temperatures. *Journal of Machine Construction and Maintenance*. 1, 93-97.