Microstructure and mechanical properties of Multimetal “Stahl 1018” Composite

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Abstract. The Stahl1018 composite is a multiphase material containing steel and ceramic particles placed in a polymer matrix. The scanning microscope and X-ray microanalysis techniques were used for chemical analysis, which allowed for the identification of elements in particular areas of tested samples. Then, a series of tests was performed to determine the mechanical strength depending on the temperature, hardness and impact strength. The results of the experiments show that the composite material Stahl1018 can be used for maintenance of machine parts in the temperature range 20-80 °C.

1. Introduction
Composites cover a numerous group of materials differing in their matrix and type of reinforcement [1]. The structure of composite materials depends on the production technology, material from which the matrix was made, properties, type and participation of reinforcement material. It is also conditioned by the matrix/reinforcement interface and distribution of the reinforcement phase. It is typical for the correct composite structures to have a uniformly distributed reinforcement [2-8].

The properties of composites can be shaped and designed to meet the actual needs. Composites have properties unattainable in conventional monolith materials. The former ones have increased parameters, i.e. strength, Young modulus, fatigue characteristic, wear resistance, tribological characteristic, resistance to corrosion both in room and elevated temperatures [9-11]. The main applicability area of modern composites is space technology, military industry, communications and production, e.g. sport equipment. 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. Among the filler materials are stainless steel powder, ceramics as well as additives improving surface tension and chemical resistance parameters. This composite has maximal compressive strength equal to 60 N/mm², tensile strength 72 N/mm², bending strength 89 N/mm², elastic modulus 14000 N/mm² and thermal resistance up to 90 °C and is used for fixing construction objects and worn away machine parts [12-14].

2. Microstructural analysis of samples
The composite MM stahl1018 is a complex and multiphase material, therefore it is so important to analyze its content, filler fraction (steel 1018) as well as the distribution of that fraction in the composite. As the properties and application of the composite depend on intermolecular distances, any changes in these distances may cause high local tensions and formation of compressive stress zones.
Hence, it is vital to analyze both the filler phase distribution and the matrix/filler division surface. The chemical and phase composition of the filler and components’ interface is important in the aspect of mechanical properties and may also be an element of a structure favoring premature decaying of the material. For this reason the microstructural analysis of composite MMStahl1018 is justified. The analyses were performed on 3 samples of the material compressed in plastic moulds. The microstructure of unetched surfaces has been presented in images. The basic SEM analyses were preceded with optical microscopy analyses – Microscope Nicon ELiver LV100 (figs. 1-3). The microstructure of sample 1 was presented in fig. 4, with two areas marked: 1 – elongated and fusiform area, and 2- square-like area. The experimental part is very important for further analyses, including the analysis of mechanical properties of the composite.

![Figure 1. Microstructure of sample 1 performed of MM Stahl 1018 material.](image1)

![Figure 2. Microstructure of sample 2 performed of MM Stahl 1018 material.](image2)

![Figure 3. Microstructure of sample 3 performed of MM Stahl 1018 material.](image3)

![Figure 4. Microstructure of sample 1 performed of MM Stahl 1018 material, obtained with SEM.](image4)

The results of X-ray microanalysis of phases from the marked areas are presented in figure 5-6. Point 1 is located in an elongated tapering area. The analysis revealed that Al was the main component of the analyzed phase. Area 2 has a regular geometrical shape, where metals Ti, V, Mo, Cd and Cr as well as oxygen were identified [15].
3. Strength tests on MM Stahl 1018 composite samples
The compressive test was carried out using a testing machine Zwick Roell Amsler HB 100. This machine provides close to real conditions because it has a special heat chamber and ability to add the load in vibration mode. Using a special compressive testing device (mounted on a T-slotted plate), specimens of various sizes and shapes can be determined. The integrated device can be used in a heat chamber (temperature range -80 °C to 250 °C). The maximum load 100 kN in compression; Piston stroke 250 mm. During experimental strength tests performed with Zwick Roell Amsler HB 100, the composite samples were compressed at a specified load and temperature of 20-80 °C. The pressure force equalled to 15-30 kN and the samples were d = 10 mm., h = 4 mm in size. The results are presented in table 1. Exemplary results obtained for a sample subjected to a load of 30 kN at a temperature of 20-80 °C are visualized in figure 7.
It was observed for the analyzed samples that the maximal admissible load equaled to 30 kN, and the yield point of the material depended on temperature, i.e. the higher was the temperature, the lower was the yield point.

Table 1. Results of experiments – compressive test with MM Stahl 1018.

|  | Maximum load, kN | Thickness change, mm | Temperature, °C | Yield point, MPa |
|---|---|---|---|---|
| 1 | 15 | 0.36 | 20 | 89.2 |
| 2 | 15 | 0.44 | 40 | 8.0 |
| 3 | 15 | 0.46 | 60 | 4.8 |
| 4 | 15 | 0.55 | 80 | 2.5 |
| 5 | 30 | 1.43 | 20 | 111.5 |
| 6 | 30 | 1.56 | 40 | 15.1 |
| 7 | 30 | 1.97 | 60 | 6.4 |
| 8 | 30 | 2.34 | 80 | 3.2 |
| 9 | 55 | 2.53 | 20 | 127.4 |
| 10 | 47 | 2.71 | 40 | 16.7 |
| 11 | 41 | 2.79 | 60 | 8.0 |
| 12 | 36 | 2.72 | 80 | 4.6 |

4. Hardness tests

Successively, the MM ‘Stahl 1018’ samples underwent hardness and impact strength tests were. Hardness was determined with the Brinell and Shore methods, whereas microhardness with the Hanemann method. The average hardness for three series of tests with the Brinell method was 192 HB, hardness measured with the Shoer method was similar, i.e. 97 HB. Microhardness measured with the Hanemann method equaled to 33. The differences in the obtained results can be explained with considerable nonhomogeneity of phases in the composite. Further the efficiency of the composite as an agent for binding two surfaces was analyzed. The samples consisted of two steel rods 1 cm in diameter and 2.7 cm long, and they were combined with a binder made of MM “Stahl 1018”. The following results of impact stress tests were obtained (table 2).
Table 2. Test results to be used for determining hardness and microhardness of the material "Stahl1080" by different methods.

| Sample no., № | 1         | 2         | 3         |
|---------------|-----------|-----------|-----------|
| Brinell hardness, HB | 180±2     | 195±2     | 200±2     |
| Shore hardness, HB    | 195±2     | 195±2     | 200±2     |
| Microhardness (Hanemann method), HB | 35±1     | 27±1     | 29±1     |

5. Concluding remarks

We test this material because it is very easy to use and the damaged parts of machinery and metallurgical equipment can be easily restored. Much of the fixing work has been already done with the composite material MM "Stahl1018". The presented experiments are needed to extend the applicability of this material and prove that it can be used under high temperatures and vibration loads. The conducted series of experiments concentrated on the observation of microstructure with the optical and scanning microscopy methods, identifying chemical composition of selected areas in the analyzed sample and distribution of the filler in the matrix. It was also noted that an even distribution of the filler and its form (elongated and regular particles) cause that the obtained distribution is even, which consequently affects the mechanical properties and compressive strength of the composite. The results of impact stress tests were over 100 times lower than in the analogous tests on uniform steel samples. This signifies that the material cannot be used for fixing devices exposed to strokes. The results of hardness and microhardness tests show a considerable discrepancy and this can be attributed to the presence of organic phases – polymeric matrix. Compressive tests performed at an elevated temperature showed that the material can be used for fixing wearing away machine parts at a room temperature.

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