EFFECTS OF THE APPLICATION OF PYROPHYLITE IN THE COMPOSITION OF PROTECTIVE COATINGS

Marko Pavlović[1], Marina Dojčinović[2], Muhamed Harbinja[3], Atif Hođić[3], Dragan Radulović[4], Mirjana Stojanović[5], Zagorka Aćimović[5]

[1] Inovation Center of Faculty of Mechanical Engineering, Belgrade, Serbia

[2] University of Belgrade, Faculty of Technology and Metallurgy, Belgrade, Serbia

[3] Innovation Scientific Development Center (INRC), AD Harbi Ltd., Sarajevo, B&H

[4] Institute for Technology of Nuclear and Other Raw Mineral Materials, Belgrade, Serbia

[5] Engineering Academy of Serbia

Abstract

In the paper, samples of protective coatings based on pyrophyllite were examined. The initial sample of pyrophyllite was obtained from the Parsovići deposit, Konjic, Sarajevo, AD Harbi BiH. Pyrophyllite samples were subjected to micronizing grinding to a filler grain size of 20 µm. XRD, SEM and optical microscopy methods were used to characterize the obtained fillers based on pyrophyllite. The optimal composition of protective coatings based on pyrophyllite and the manufacturing process were determined. The resistance of refractory coatings to the effect of cavitation was experimentally determined using the ultrasonic vibration method with a stationary sample according to the ASTM G32 standard. Based on the value of the cavitation rate, the analysis of the formation and development of damage to the surface of the samples, the possibility of applying a protective coating in the conditions of exploitation in which the occurrence of corrosion and cavitation is expected was assessed.

***Keywords**: pyrophyllite, protective coatings, cavitation, cavitation resistance*

1. INTRODUCTION

Pyrophyllite is a type of phyllosilicate mineral, from the group of layered silicates, based on a combination of two tetrahedral (T) and one octahedral (O) plates, containing no isomorphic substitution and therefore no layer charge. The basic 2:1 structure (T-O-T), with silicon in tetrahedral layer and aluminum in octahedral layer, is pyrophyllite ($Al_2Si_4O_{10}(OH)_4$). The layers are held together by weak van der Waals forces, which makes the mineral extremely soft. The hardness of pyrophyllite on the Mohs scale is 1-1.5. It is hydrophobic, electroneutral, and the pH value is between 7.5-8.5. It has the characteristic softness of phyllosilicate and crystalline structure, good grindability, low coefficient of thermal conductivity, low coefficient of linear thermal expansion. It has a great ability to stick and coat surfaces, a high melting point, high inertness, i.e. resistance to acids, alkalis and heating. The technology of processing pyrophyllite rocks is ecologically clean, and the products obtained from technological processing of pyrophyllite are not carcinogenic [3,4]. Research [5] showed the existence of a potential raw material base, which all influenced the choice of this non-metallic raw material for obtaining a wide range of products for various industrial branches [6-8]. One of the directions of research, the results of which are presented in this paper, was the application of pyrophyllite as a filler for refractory coatings. The aim of the test was to determine the quality of the coating and the possibility of application for the protection of metal surfaces in conditions of wear, corrosion, cavitation and elevated temperatures.

2. EXPERIMENTAL

2.1 Materials

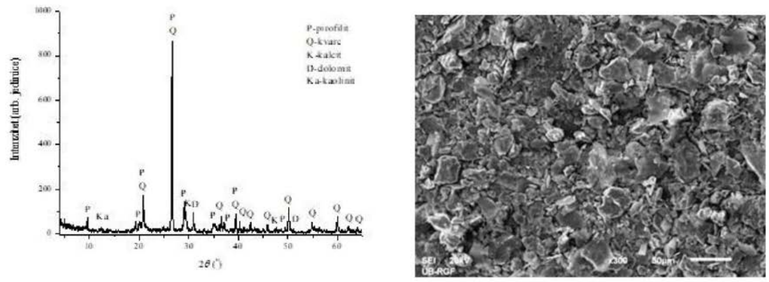
To investigate the possibility of using pyrophyllite as a filler in the composition of protective coatings, the initial sample of pyrophyllite rock from the Parsovići deposit, Konjic, Sarajevo, AD Harbi BiH, was ground to a grain size of 20 μm. In the composition of protective coatings, the following were used (%): refractory filler based on pyrophyllite (80-85); binder based on epoxy resin (14-15); organic additives (1-1,2); organic solvent to a coating density of $\rho=2.5 g/cm^3$. During the synthesis of the coating, all components from the composition of the coating were gradually added with constant mixing. For testing, the obtained protective coatings were applied in two layers to a metal plate, and then dried in the air for 60 min.

2.2 Methods

To determine the resistance properties of the obtained protective coatings based on pyrophyllite, the ultrasonic vibration method with a stationary sample according to the ASTM G32 standard [9] was applied. Testing methodology described in earlier works [5,7,8]. The aim of the test was to determine the quality of the coating and the possibility of application for the protection of metal surfaces in conditions of wear, corrosion and cavitation. Interval of exposure of samples to the effect of cavitation (min): 15; 30; 45; 60. The loss of coating mass as a function of cavitation time was monitored. The cavitation rate was determined as an indicator of the resistance of the coating under conditions of cavitation loads. The method of X-ray diffraction analysis was used to characterize the refractory filler. The morphology of the surface damage of the samples was monitored using scanning electron microscopy. Based on the value of the cavitation rate and the analysis of the morphology of the surface damage, the cavitation resistance of the tested protective coatings was determined.

3. RESULTS AND DISCUSSION

Figure 1 shows an XRD and SEM microphotograph of a filler based on pyrophyllite. Figure 1a shows that the mineralogical composition of the pyrophyllite-based filler sample is as follows: pyrophyllite, quartz, calcite, dolomite, with the most abundant minerals being pyrophyllite and quartz. Figure 1b shows a SEM microphotograph of the filler based on pyrophyllite, where it is clearly shown that this material occurs in irregular forms of different dimensions, with the presence of flaky aggregates.



a) b)

Figure 1 - Filler based on pyrophyllite: a) X-ray diffraction; b) SEM microphotograph.

Synthesized refractory coatings were applied to metal supports and tested for cavitation effects. Figure 2 shows the surfaces of the coating samples before and during the cavitation effect test. The appearance of a smaller number of dimples is observed after 30 min of exposure, which change slightly during further testing up to 60 min. The presence of shallow pits on the surface of the coating indicates minor damage to the surface of the coating, i.e. it shows satisfactory resistance of the surface of the coating to the effect of cavitation, Figure 3.

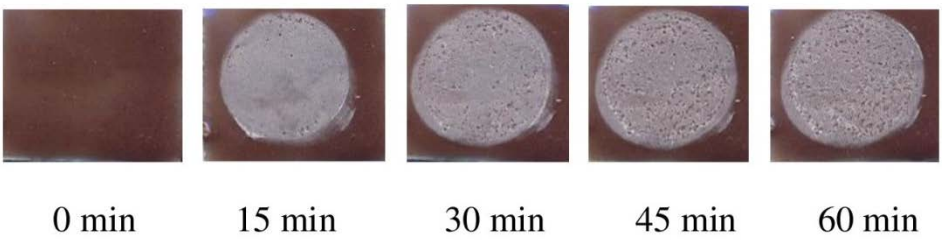


Figure 2 - Photographs of the surface of the coating samples before and during the cavitation test.

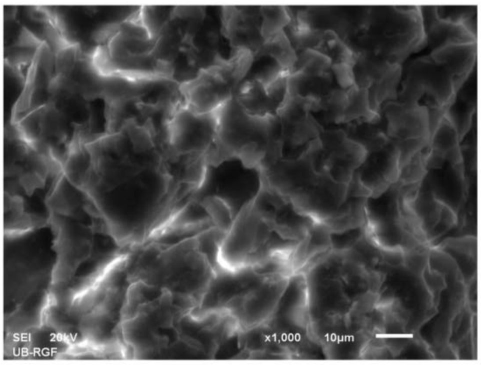


Figure 3 - SEM microphotograph of a pyrophyllite-based coating sample after 60 min of cavitation.

Figure 4 shows the cavitation rate diagram for pyrophyllite-based coatings. From the diagram it can be seen that there is no incubation period and that damage to the coating surface under the effect of cavitation begins immediately with the formation of small and shallow pits, which change slightly during exposure. Calculated cavitation rate was V=0.42 mg/min.

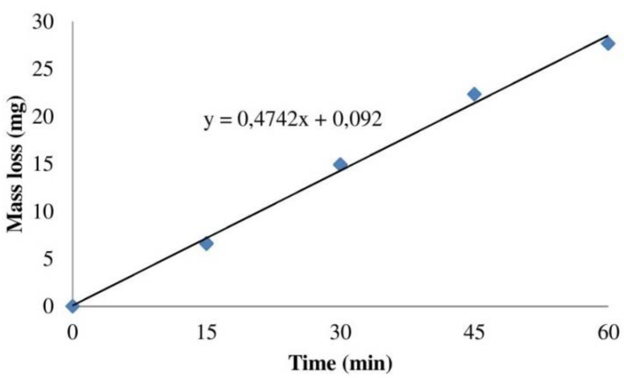


Figure 4 - Cavitation rate of pyrophyllite-based protective coating samples.

From the obtained research results, it can be estimated that the examined protective coatings based on pyrophyllite have a satisfactory resistance to cavitation.

4. CONCLUSION

These are the initial results of testing protective coatings based on pyrophyllite. Satisfactory resistance to the effect of cavitation has been demonstrated, which means that the coatings can be applied to protect metal structures in moderate cavitation conditions. In order to improve the rheological properties of the coating, to improve the stability of the coating in rigorous operating conditions, further research into the synthesis of the coating should be focused on changing the composition of the coating, applying new organic additives, and changing the procedures for making the coating.

ACKNOWLEDGEMENTS

This work was supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia (Contract No.451-03-47/2023-01/200135).

REFERENCES

[1] M.A. Ali, H.A.M. Ahmed, H.M. Ahmed, M. Hefni., Appl. Sci. 11, 2021, 11357.

[2] P. Sanchez-Soto., Thermochim. Acta 138, 1989, 267–276.

[3] Lj. Andrić, D. Radulović, M. Pavlović, M. Petrov, J. Stojanović., Journal of materials protection 61 (3), 2020, 210-219.

[4] A. Terzic, D. Radulovic, M. Pezo, J. Stojanovic, L. Pezo, Z. Radojevic, L. Andric., Constr Build Mater. 258, 2020, 119721.

[5] Elaborate on pyrophylite research, University od Banja Luka, Faculty of Science, Banja Luka B&H (2018).

[6] Lj. Andrić, M. Pavlović, M. Dojčinović, D. Radulović., Journal of materials protection 62 (2), 2021, 126-134.

[7] M. Pavlović, M. Dojčinović, A. Sedmak, I. Martić, F. Vučetić, Z. Aćimović., Synthesis and characterisation of the mullite-based protective coatings, 53 IOC Bor 2022, 3-5 October 2022, Proceedings, pp. 147-150, ISBN 978-86-7827-052-9.

[8] M. Pavlović, Z. Tanasković, M. Dojčinović, Z.Aćimović.,Quality managment of protective coating based on zirconium silicate, 13th International Scientific Conference Science and Higher Education in Function of Sustainable Development – SED 2023, VrnjačkaBanja, Serbia, Proceedings p.p. 54-58.

[9] ASTM G32-10, Standard Test Method for Cavitation Erosion Using Vibratory Apparatus, ASTM International, West Conshohocken, PA, 2010, www.astm.org, n.d.