Selected properties of porous layers formed during the microwelding resistive-pulse process

Wybrane właściwości warstw porowatych powstałych podczas mikrospawania opornościowo-impulsowego

WOJCIECH DEPCZYŃSKI
PIOTR MŁYNARCZYK
EWELINA ZIACH *

DOI:https://doi.org/10.17814/mechanik.2017.1.10

Presented was the way of forming a porous surface layer on steel with microwelding resistive-pulse using a device WS7000S. Porous properties of the resulting layer were characterized. Mechanical properties were studied and the microstructure was observed.

KEYWORDS: microwelding, surface engineering, porous layers, microstructure, microhardnes

Production of porous outer layers is a relatively little developed field of surface engineering. The acquisition of such layers is subject to many technological and material problems [1, 4, 6, 7]. Open-cell metal foams are characterized by particular structural properties and can be widely used in catalyst carriers, energy processes and technologies [2, 8, 9]. Methods for obtaining the acceptable porous coatings are based primarily on bonding of the porous components.

Fe foam was prepared in the manner described in Polish Patent Publication No. 199720 [3], which allows the composition of irregular cellular structures from open or closed pores. The porosity range largely depends on the materials used - particle size and particle material type. However, a significant effect on porosity is the ratio of the metal oxide powder to the matrix powder weight, which is the basic structure of the produced sinters [5, 6, 7].

Materials used for the experiment

The top layer, on which various types of powders were applied, was made of S235JR steel. Silicone oil and powder mixtures were used to make the paste:

- iron NC 100.24,
- iron ASC 100.29,
- Distaloy SE.

Resistive-impulse micro-welding process

The experiment consisted of making a porous overlay on a steel plate using three different pastes. To get the right connection, it was necessary to thoroughly prepare the surface. The steel sheet has been cleaned and degreased, also at the place where the bulkhead was connected.

In addition to silicone oil and powders (NC 100.24, ASC 100.29, Distaloy SE), additives such as iron oxide Fe2O3 and copper Cu powder were admixed. The micro-welding process was performed using 50÷70% of the pulse intensity; the pulse duration was approximately 7 ms. All parameters were experimentally selected.

Microstructural studies using optical microscopy

Samples were housed in an epoxy resin to perform metallographic prints. Then the samples were ground, polished and etched with nital. Exemplary metallographic structures were observed using the Nikon Eclipse MA200 optical microscope along with the NIS 4.20 image analysis system.

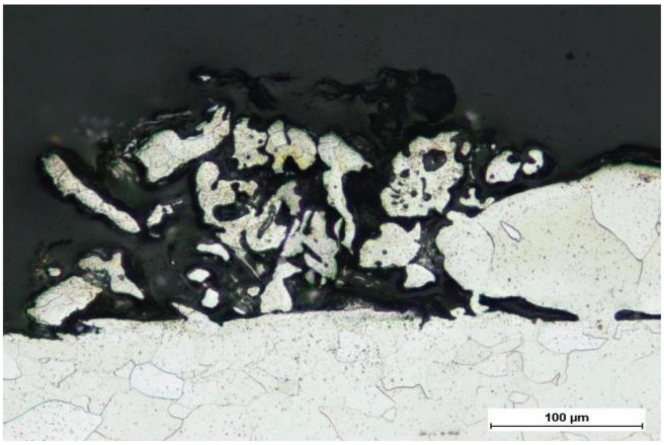

Fig. 1. Microstructure of porous layer made of silicone oil paste and NC 100.24 powder after nital digestion

* Dr inż. Wojciech Depczyński (wdep@tu.kielce.pl), mgr inż. Piotr Młynarczyk (piotrm@tu.kielce.pl), mgr inż. Ewelina Ziach (ewelina.ziach@gmail.com) – Politechnika Świętokrzyska w Kielcach

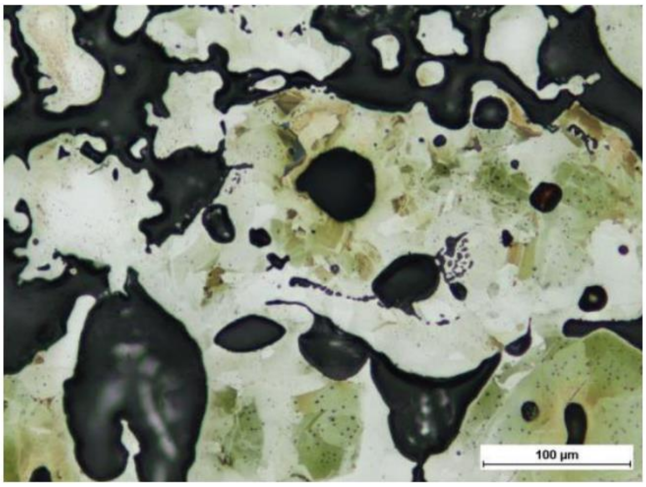

Fig. 2. Microstructure of porous layer made of silicone oil paste and powder ASC 100.29 after nitrile digestion, magnification 200×

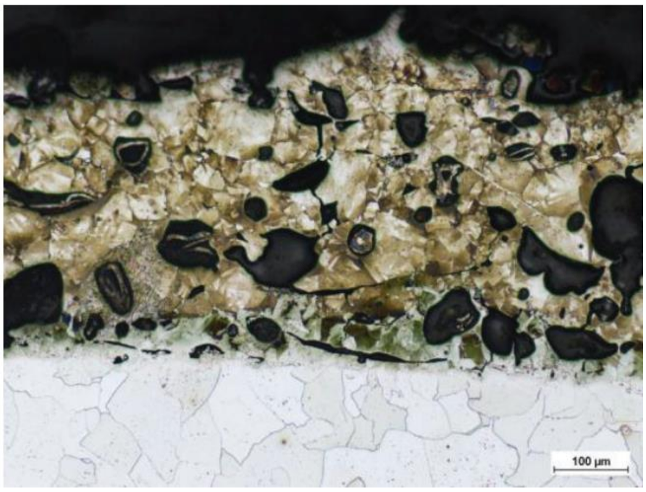

Fig. 3. Microstructure of porous layer made of silicone oil paste and Distaloy SE powder after nital digestion, magnification 100×

Micro-hardness tests

During the micro-hardness test by means of Vickers, measurements were made under 100 g (0.98 N) for 15 s. The results of micro-hardness measurements are shown in the table.

TABLE. Results of micro-hardness measurements

Powder	NC 100.24	ASC 100.29	Distaloy SE
Native material (average)	151 HV	159 HV	149 HV
Porous layer (average)	118 HV	219 HV	395 HV

Study upon porosity of top layers

The surface porosity study was performed using a digital image analysis system NIS 4.20. The porosity was measured using the Nikon Eclipse MA200 micro image. Individual fragments, so-called *region of interest* (ROI), were marked, so that the area does not go beyond the test material, because then the result would be wrong. Each of the selected areas was analyzed individually, and then the results were transferred to MS Office Excel.

Cross-section of the microporous powder-based Distaloy SE coating is the most promising seen from the perspective of further experiments.

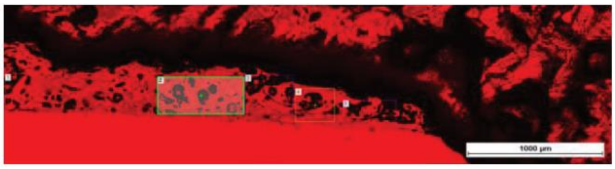

Fig. 4. Porosity study of the surface layer with the indicated porosity test site

Results of porosity testing of porous outer layers:

- samples with NC powder 100.24: 41%,
- samples with ASC 100.29 powder: 57%,
- samples with Distaloy SE powder: 64%.

Summary

Based on the study, it can be concluded that it is possible to obtain porous surface layers by means of resistive-pulsed micro-welding. One of the decisive factors is undoubtedly the selection of process parameters - too low intensity of the pulses can only cause gluing of the top layer, while too high may cause deformation and damage of applied materials. Another decisive factor is the selection of materials to make the paste. The admixtures that were introduced into the pastes were designed to achieve the highest porosity of the applied material (12% Fe_2O_3 and 6% Cu). This had the intended effect, because porosity of the surface layer was 40÷65%.

The best properties were obtained with a paste composed of silicone oil and Distaloy SE powder with Fe_2O_3 and Cu addition. The top layer made with this mixture was characterized by the highest porosity with a fairly even distribution of pores and the highest hardness.

Linear analysis was also performed, which showed no diffusion of the surface into the base material. The only noticeable change in Cu distribution occurred at the border of the top and bottom layers. Micro-hardness test showed that the obtained top layer showed satisfactory mechanical properties.

REFERENCES

1. Ashby M.F., Evans A.G., Fleck N.A., Gibson L.J., Hutchinson J.W., Wadley H.N.G. „*Metal Foams: A Design Guide*". Buterworth-Heineman 2000.

2. Calvo S., Beugre D., Crine M., Léonard A., Marchot P., Toye D., "Phase distribution measurements in metallic foam packing using X-ray radiography and micro tomography". *Chemical Engineering and Processing.* 48 (2009): pages 1030–1039

3. Chatys R., Depczyński W., Żórawski W. Sposób wytwarzania struktur porowatych, Patent RP nr 199720.

4. Davies G.J., Zehn S. "Review Metallic foams: their production, properties and applications". *Journal of Materials Science*. 18 (1983): pages 1899–1916.

5. Depczyński W. "Sintering of copper layers with a controlled porous structure". *Metal 2014: 23RD International Conference on Metallurgy and Materials*. (2014): pages 1219–1224.

6. Depczyński W., Młynarczyk P., Spadło S., Ziach E. „Wytwarzanie warstw porowatych przy użyciu mikrospawania". *Technika Transportu Szynowego*. (2015): pages 378–380.

7. Depczyński W., Młynarczyk P., Spadło S., Ziach E. „Analiza mikrostruktury warstw porowatych nanoszonych w procesie mikrospawania”. *Technika Transportu Szynowego*. (2015): pages 374–377.

8. Wójcik T.M. “Experimental investigations of boiling heat transfer hysteresis on sintered, metal-Fibrous porous structures”. *Experimental Thermal and Fluid Science.* 33 (2009): pages 397–404.

9. Wójcik T.M. “Heat transfer enhancement and surface thermo stabilization for pool boiling on porous structures”. *EPJ Web of Conferences.* 25 01100 (2012). ■