THE SELECTED PROPERTIES OF POROUS LAYERS FORMED BY PULSE MICROWELDING TECHNIQUE

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Abstract

The paper describes the study of porous layers formation process made with Fe on the carbon steel base. To form the layer there was used method of consisting combination of pulse microwelding paste layer on the S235 steel surface. The paste layer was combined as a mixture of different powders like Fe_2O_3, Fe, Cu and mineral oil. The resistive pulse microwelding techniques were applied on the layer. Whole process of applying layers was controlled manually.The deposit was sintered with reduction oxides in dissociated ammonia. There was prepared mixture of iron powder ASC 100.29, ASC 100.24, Distaloy SE (source: the Höganäs company) and iron oxide in various compositions. To mixtures there were also added Cu, in order to improve the layer properties after sintering. Because the base material and the paste composition are being very similar by the chemical composition, only Cu has been recognized as the best key indicator enabling diffusion proccess study. Therefore Cu plays the role of an indicator that allows the assessment of the sintering properties, including the depth of diffusion. The layers were investigated with metallographic methods and EDS analyses. Using EDS analysis, there were identified a types of alloying elements and the extent of diffusion from Fe foam into to S235 steel. Also, there was investigated microhardness by Vicers method. Microscopic examination was carried out to examine the structure of formed layers. Image analysis methods were used to measure the size of the cross-section porosity. Studies have determined basic quality parameters of the covered layers.

Keywords: Microwelding, surface engineering, porous layers, microstructure, microhardness

1. INTRODUCTION

Highly porous open-cell materials on the base of various metals and alloys are of increasing interest as they combine structural and functional properties [1,2]. Open-celled metallic foams with their specific structural properties are attractive candidates for a wide range of applications in the field of catalyst supports, process, and energy technologies.[3,4,5] The novel low-cost technology is proposed for fabrication of foams from metals, alloys, intermetallics. Metal foam was formed by a typical base metal like Al, Cu and other. [6,7,8] The subject of the experiment was testing of the using the produced porous metal foams techniques by reduction of metal oxides during the sintering. The mixture was sintered in a dissociated ammonia atmosphere. Fe foam was prepared according to the method described in the Polish patent No. 199720.[9] This allows for compose of irregular cellular structures with pores open or closed. The range of the porosity depends strongly on the used materials - the particle size and type of particulate material. However crucial influence on the porosity has the ratio between quantity of metal oxide powder and amount of matrix metal powder, which is a basic structure of produced sinter [10]. There is a wide range of possible applications for such materials, e.g. as heat exchangers, filters or catalysts. A new and promising method to produce open- cell metallic foams on base of iron powder, low and high alloyed steel powders. The foam material can be stacked and co-sintered with top layers to sandwich structures. A porous layers were formed by microwelding technique the powder mixture and the reduction of ferrum powder ASC 100.29, ASC 100.24, DISTALOY SE and ferrum oxide of different granulation.

2. MATERIALS AND EXPERIMENTAL PROCEDURE

The chemical composition of powder mixtures:

Fe foam was prepared by mixture of iron powder ASC 100.29, ASC 100.25 and Distaloy SE (source Höganäs company) Cu powder and iron oxide Fe_2O_3 with different composition. The exemplary morphologies of powders (raw materials) are shown in **Fig. 1**.

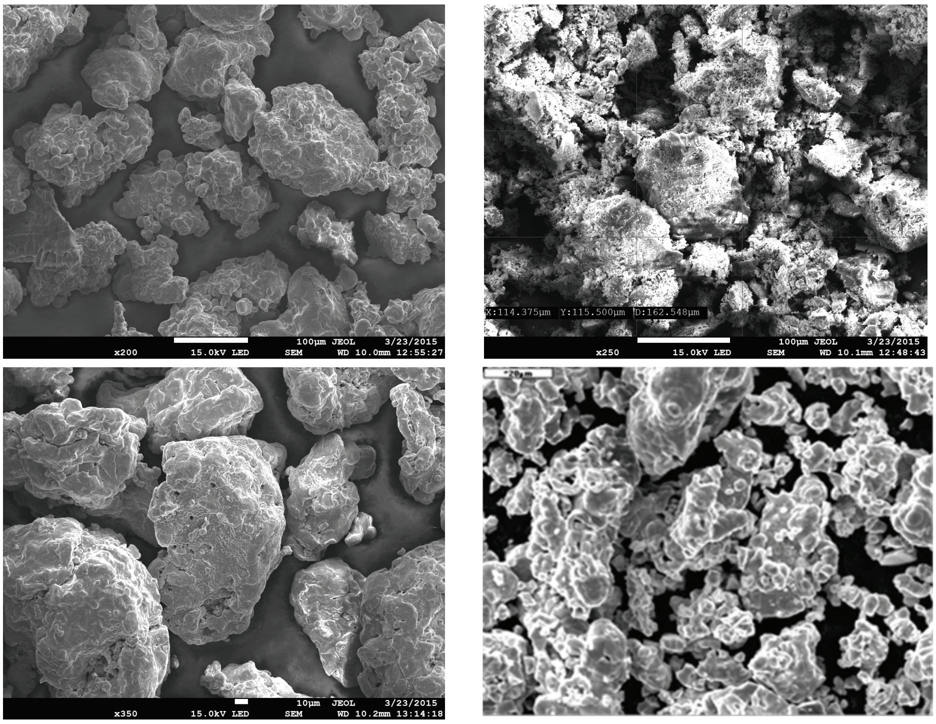


Fig. 1 Typical morphologies of raw material:
a) ASC 100.29 powder, b) Fe_2O_3 powder, c) Distaloy SE, d) Cu powder

2.1. Joining parameters

To form a porous layer, there was used composed hybrid technique consisting of creating the weld layer and its subsequent reduction with sintering. The applied layer was a composition of different powders; iron oxides and iron. The compositions are shown in **Table 1**. To unify the substrate layer steel of powders there were used microwelding technique. Depending on the progress of process two or three layers were applied adjusting the length of the pulse.

The welds were made using the microwelding device type WS 7000 S from SST France & Vision Lasertechnik. This machine welding generates pulses with an average frequency of 5000 Hz. The application of welding time ranges from 0.1 ms to 99 ms with increments of 1, 5 or 10 ms. Welding-current value generated reaches 11 900 A at a voltage of +/- 5 V. The device allows to use electrodes silver-tungsten-non-magnetic of 5 mm diameters.

Table1 Compositon fo cowering mixture

No.	The composition markings	The mixture
1.	ASC 24	ASC 100.24+12%Fe_2O_3+6%Cu
2.	ASC 29	ASC 100.29+12%Fe_2O_3+6%Cu
3.	SE	Distaloy SE+12%Fe_2O_3+6%Cu

During experiment, following parameters were used:

- welding amperage in the range of 43-73% of the power device (max. 7000 A) was applied
- microwelding time in the range of 6 ms to 8 ms;
- powder and wire-ribbon as a selected form of impulse,
- duty cycle: multi impulse welding cycle.

The parameters used for various compositions were summarized in **Table 2**.

Table 2 Overlay welding process parameters

No.	The composition markings	% of the power device	welding time (ms)
1.	ASC 24	53% powder mode	7-8
2.	ASC 29	65% powder mode	6-7
3.	SE	73% powder mode	5-3-6

2.2. Sintering

The overlay weld was sintered in a dissociated ammonia atmosphere at 1180°C for 45 minutes. After sintering the samples situated in furnace were moved to an area where it was cooled in a protective atmosphere. Cooling took place in with an average speed of about 25 degrees per minute. To determine pore size and shape from the foam specimens, the image analyzer software was used. For further study the foam with a porosity of 57% was selected.

2.3. Investigation

2.3.1. Micro and macro structure investigation

To illustrate structures of fusion researchers used the optical microscopy and SEM methods. Microscope Nikon MA 200 Eclipse with the image analysis system NIS 4.20 to metallographic specimens testing was used. All samples were mounted in a vacuum, using Buehler EpoThin resin during preparation process for the protection of the porous structure. SEM examination was performed using a JEOL JSM 7100F microscope (with field emission - Schottky) with EDS OXFORD X-MAX microprobe. The results showed that there is a possibility of obtaining the joint between the Fe foam and S235 steel.

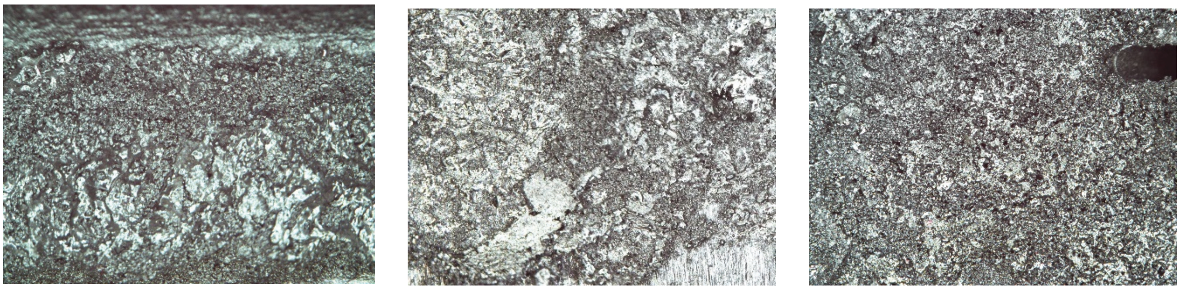
2.3.2. Microhardness

Microhardness measurements of the base material and Fe foam were made at the weld zone and formed outside the weld. For investigation there was used Matsuzawa Vickers microhardness MX 100 type. Microhardness tests were carried out by using a Vickers indenter, with an applied load of 100G(0,98 N) for 15 s.

3. RESULTS AND DISCUSSION

3.1. Macroscopic observations

After preparation, the samples were subjected to the observation naked eye and low magnification and photographed them. **Fig. 2** shows macrophotography of specimen with porous layers.



A B C

Fig. 2 Macrophotography of surface specimen with porous layers:
A) SE sample B) ASC 29 C) ASC 24

The observation with optical microscope and image analysis

The porosity was studied using an NIS 4.20 image analyzer. **Fig. 3** shows an image of the porous structure of sample SE formed on a flat S235 steel substrate by diffusion bonding.

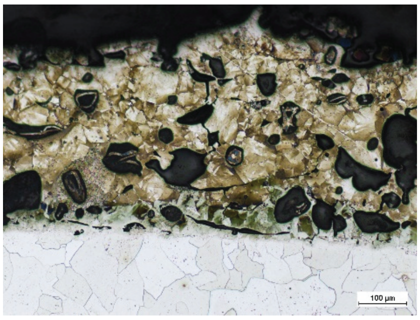


Fig. 3 The microstructures of the SE sample porous structure. Nital etchings

Considerable expansion of the surface inside the structure was achieved. It should be noted that non-uniform distribution of pores was due to diversity of the composition powder particle size. There are bridges connecting porous layer with the steel substrate surface.

A quantitative analysis of the microstructure of sample SE was conducted to determine its porosity. It was necessary to determine the number of pores per unit considering polished surface for different cross-sections. 5 areas so called *Region of Interests* (ROI) of the structure were analyzed. The average porosity was 64%. **Fig. 4**. shows location of ROI for analysed SE specimen.

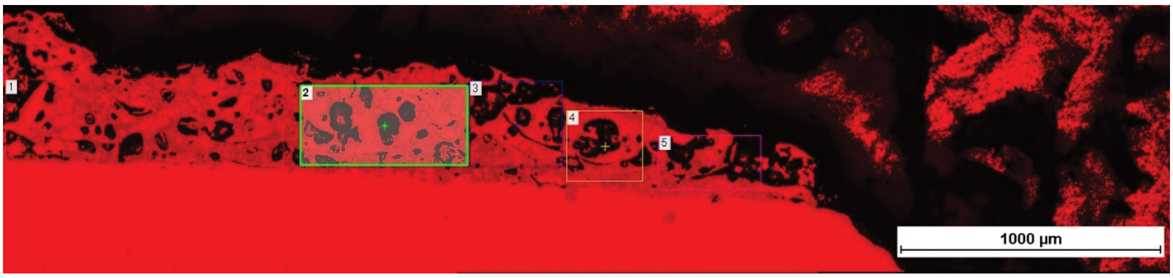


Fig. 4 Mirophotography of SE cross-section witch marked “ROI`s” on analyzed areas

For other specimens the analyses showed that the average porosity scope was from 57% for ASC 29 and from 41% for ASC 24. The differences in porosity mainly result from the behavior of powders during surfacing composition. They stem primarily from the shape of the ASC100.29 and ASC 100.24 powders grains. It was necessary for compositions based on ASC 100.24 to use the lowest amount of energy during the deposition process and the relatively long pulse. The manufacturing technology defined by the foam morphology is different from the other described structures with pore size and shape [11,12]. The most similar technology for producing Fe foam described in the literature [13,14] gives the structure of a much larger pore sizes. In this work [14,15] the authors used additional foaming agent to obtain a greater porosity. This was necessary due to the particular purpose metallic foam. Other methods for preparing porous materials also can produce macroscopic materials having pores like [16] and other.

During SEM observations and EDS microprobe examinations there was no significant diffusion of alloying the overlay weld from the SE mixture to the substrate material. Only noticeable change in the breakdown of Cu was on the overlay weld border. The SE mixture had a greater amount of Cu relatively to the ASC ASC 24 and 29 because that Distaloy SE had in its composition approx. 1.5% Cu. Diffusion occurred at a depth of about 30-40 microns. During the microwelding process diffusion of Cu took place, in S235 direction. It should be added that the diffusion zone is very small. **Fig. 5** shows microstructure SEM and EDS elements distribution for Fe and Cu.

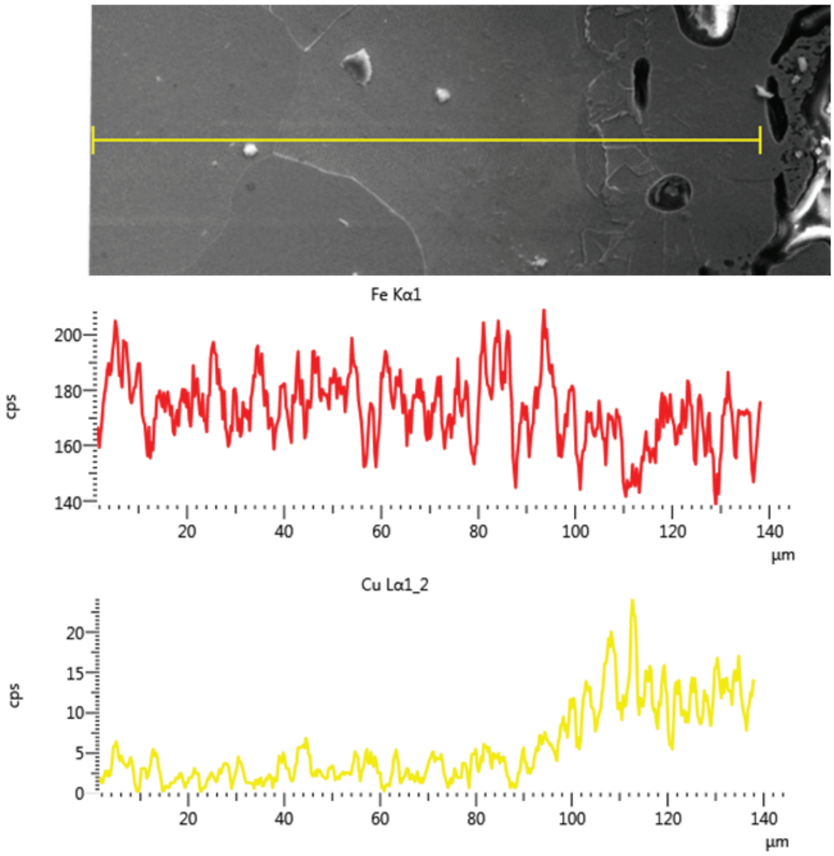


Fig. 5 The microstructure of SE cross-section specimen with Fe and Cu distribution.

3.2. Microhardness

Hardness measurements for compositions ASC ASC 24 and 29 showed no significant differences with respect to the material sintered in the classical way [Höganäs materials].

Change in the material hardness may be obtained by changing the composition powders applied during microwelding [Hogonas materials]. Attained values ranged from 120 HV100 the substrate material to 162 - 212 HV 100 of the applied layer. On the border of the base material the applied layer was approximately 180HV100. Significantly higher hardness is due to the presence of alloying elements Ni and Mo and rapid cooling of the layer formed after sintering.

4. CONCLUSIONS

There is a wide range of possible applications for such materials, e.g. as heat exchangers, filters or catalysts [17]. A new and promising method to produce open-cell metallic foams on base of iron powder, low and high alloyed steel powders as well as nickel alloy powder. Pre-foaming was performed during the layer application at room temperature, allowing a very good process control by various parameters, foams of a great metals variety is possible and a broad spectrum of properties is achievable.

Macroscopic and microscopic observations provide insight into the morphology of the structure. Compared to other reported in the literature showing that the technology Applications up leading to the formation of the microporous layer.

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