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The selected properties of fusion of Fe foam and sheet metal with use of the Nd:YAG laser

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ABSTRACT

Purpose: In the paper there were presented possibilities of combining metal sheet with metallic foams using a Nd:YAG laser.

Design/methodology/approach: The research were carried out over the properties of laser welded joint of micro-welds iron foam with superalloy HYNESH230®.

Findings: The results indicated that there is a possibility of obtaining the satisfying quality joint between the Fe foam and superalloy Hynes H230®.

Research limitations/implications: The studies mainly focused on the microstructural and some mechanical properties. Example of structural applications for metallic foams, utilizing benefits in weight, stiffness, energy dissipation, mechanical damping, and vibration frequency were summarized already by many authors. The authors chose to study selected properties of fusion of Fe foam and sheet metal with new approach.

Originality/value: The studies used to determine basic quality parameters of the welded joint. Using EDS analysis, there were identified a types of alloying elements and the extent of diffusion from superalloy H 230® in the course of Fe foam. Also, there was investigated shear strength of obtained micro-welds.

Keywords: Laser welding; Fe foam; Porous materials; Superaloys

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PROPERTIES

1. Introduction

1.1. Production and properties of metal foams

Metal foams are a new type of material with a wide range of applications because of their excellent properties including light weight, impact energy absorption capacity, specific thermal acoustic properties and low thermal conductivity [1,2,3]. Nowadays open porous metallic foams are used in heat and mass transfer applications, for instance in heat pipes, vapour chambers, and loop heat pipe elements. In the past few years, there has been a growing interest in metal foams and it's new applications. Both the foam structure and the pore morphology depend on the fabrication method. M.F. Ashby et al. [1] classified the metal foam production methods according to the process and the state of matter. Nine process-routes have been developed and five of them have already been established commercially. They fall into four broad classes: those in which the foam is formed from the vapour phase; those in which the foam is electrodeposited from an aqueous solution; those which depend on liquid-state processing; and those in which the foam is created in the solid state. Each method can be used with a small subset of metals to create a porous material with a limited range of relative densities and cell sizes. Some produce open-cell foams, others produce foams in which the majority of the cells are closed. Similar classification was presented in the paper by G.J. Davis et al. [2]. The superior thermal conductivity of copper foams is particularly important. Porous sintered structures can also be produced by sintering small diameter wires [4].

The literature review in research considering combining metallic foam, points that there's constant attention paid to Al and Cu combining foam [5,6,7,8]. In the paper [9] foam deck was used to combine ceramic elements and 316 stainless steel as well as other materials such as superalloy INCONELL series 600 or titanium. While analysing existing ways of connecting metallic foams, it become obvious that the special interest is in laser welding [5,6,7]. Other methods, described in Friction Stir Welding, soldering by brazing filler to metal for example using foil as a filler metal with a metal such as Ti, Cu. Al. etc. [9,10]. Also very interesting solution is to use concentrated solar energy [8]. Taking into account above mentioned considerations it was decided to use the technique of laser welding for joining Fe foam with H230® sheets.

2. Experiment

2.1. Fe foam preparing

Fe foam was prepared by mixture of iron powder ASC 100.29 (source Höganäs company) and iron oxide Fe_2O_3 with different composition. The mixture was sintered in a dissociated ammonia atmosphere at 1180°C for 45 minutes. To determine pore size and shape from the foam specimens, the image analyser software was used. For further study the foam with a porosity of 57% was selected.

2.2. Joining parameters

The laser beam was delivered using the optical fibre. The focal length for Nd:Yttrium/Aluminum/Garnet (Nd:YAG) laser with a 1064 nm wavelength was 100 mm (Fig. 1). The diameter of the laser beam at the focus point was 300 mm.

- power of laser beam – 600 W,
- scanning rate – 250 mm/min,
- pulse rate – 44Hz,
- time of pulse – 0.5 ms.

Fig. 1. Nd:YAG laser

2.3. Micro and macro structure investigation

To illustrate structures of fusion were 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. During the preparation process for the protection of the porous structure all samples were mounted in a vacuum, using Buehler EpoThin resin.

Loss of the porous structure was not observed due to of the laser beam impact, so it can be concluded the observed structure is proper one (Fig. 2).

Regarding the properties of the foam in the view of literature, most of the studies consider the parts of foam investigated on stress compression. In the case of a welded joint foam with other elements, there seems to be important the ability of assessing of the connection durability. Therefore, studies were made on the shear strength of obtained welds. The fusion elements were stretched in a specially prepared holder.

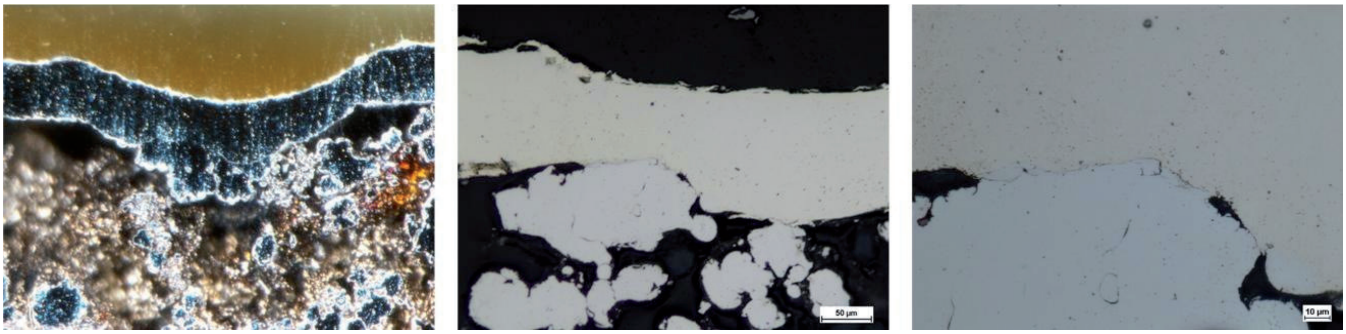

Fig. 2. Macro and micro structure of Fe foam – H230 joining

2.4. SEM

SEM examination was performed using a JEOL JSM 5400 microscope with microprobe Oxford EDS Link ISIS series 300. The results showed that there is a possibility of obtaining the joint between the Fe foam and superalloy Hynes H 230®. It was important to that did not occur significant diffusion of Fe in the direction of superalloy H 230®. As a result of EDS analysis, there was no diffusion of Fe in the direction of superalloy H 230® (Fig. 3). Fe diffusion directions H 230® would adversely affect the because the that would result a significant drop in high-temperature properties. During the welding process has taken place, diffusion of Mo and Al in the direction of foam Fe and Cu in the direction of H 230®. Additional studies are required to determine the effects of these phenomena on the properties of the alloy H 230® at the maximum operating temperatures. It should be added that the diffusion zone is very small. Other chemical analysis carried out at a greater distance from the weld not showed Cu diffusion.

2.5. Microhardnes

Microhardness measurements of the superalloys H230® 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. There was applied load 100 G (0.98 N) (Fig. 4).

3. Discussion of result

As a result of the planned experiments achieved the desired effect. The connections obtained by welding with Nd:YAG laser demonstrate morphological characteristic traits for connections of foam with open cells [5,6].

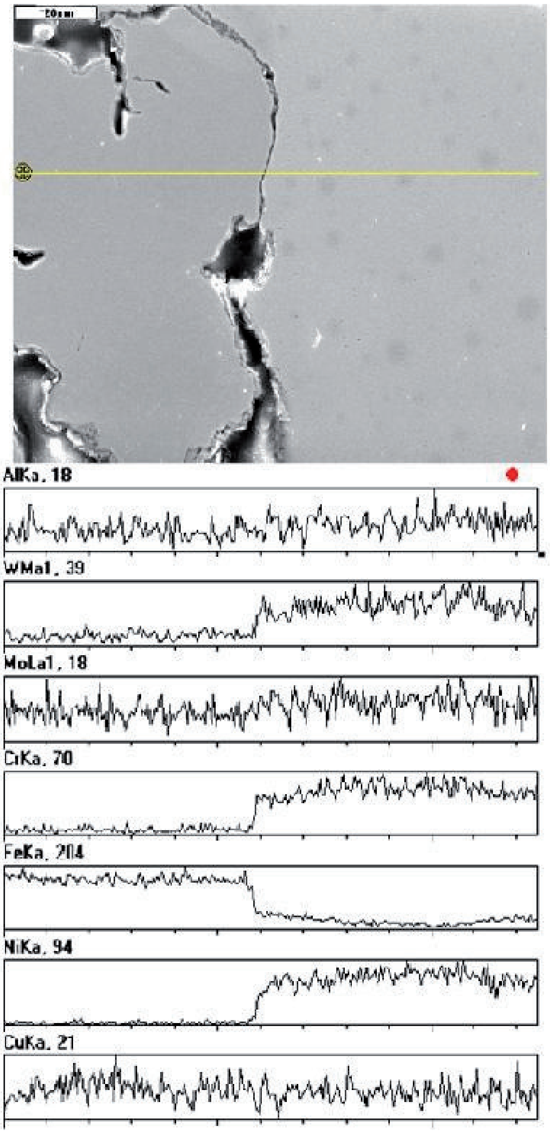

Fig. 3. SEM examination

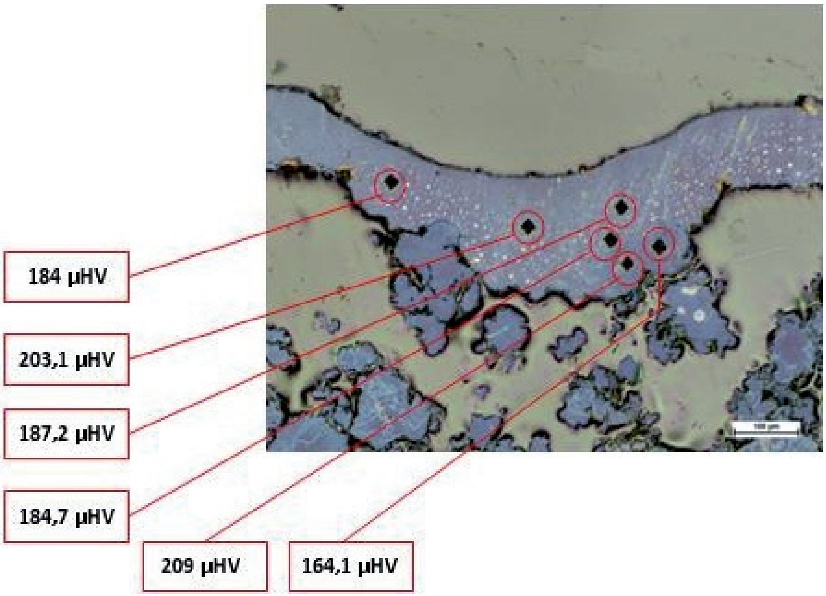

Fig. 4. Microhardness

The pores remained opened outside the weld. In case of use of techniques such as "joining metals" [9] – metal used for bonding of the foam/foams causes closing of the pores. As in the case of papers [5,6,7,8] there was obtained connection with combination of acceptable parameters. However any comparison with literature data [5,6,7,8,9] are difficult to procedure due to the significant differences in the applied materials and techniques combined. Metallographic investigations and EDS analysis demonstrated possibility of use the laser technique Nd:YAG so difficult to bond materials such as metallic foam. In the research there were observed minor changes in hardness within the bonded materials. There was no diffusion of the alloying elements in the H230® alloy within the metallic foam. This kind of connection allows fully exploit of properties H230® alloy. Combining Fe foam with H 230® will extend the study over the flow boiling in horizontal and vertical mini-channels with enhanced walls carried out so far by enhanced heating surface of H230 by laser texturing, spark erosion and sanding of the surfaces. So far, H230® film in the studies occurred as a source of heat and at the same time must have properly developed surface. However, it caused a significant limitations on modification of surface geometry [11,12]. The positive experiences from combining H230® and Fe foam provide new opportunities of controlling the processes of heat exchange by modifying the structure of the foam [13].

4. Conclusions

The results indicated that there is a possibility of obtaining the satisfying quality joint between the Fe foam and superalloy Hynes H230®. It was important, that there has not been occurred significant diffusion of Fe in course of superalloy H230®. As a result of EDS analysis shown, that there was no diffusion of Fe in course of superalloy H230®. Fe diffusion course H230® would adversely affect the parameters, and it would mean a significant decrease a high-temperature properties. During the welding process diffusion of Mo and Al in course of foam Fe and Cu in course of H230® took place. Additional investigations are recommended to determine the effects of these phenomena on the properties of alloy H230® at the maximum operating temperatures. It should be added that the diffusion zone is very small. Other chemical analysis carried out at a greater distance from the weld did not show Cu diffusion.

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