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Strength evaluation of beam made of the aluminum 6061-T6 and titanium grade 5 alloys sheets joined by RFSSW and RSW

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ABSTRACT

The paper presents the strength evaluation of the beam made of the sheets from the aluminum alloy 6061-T6 and titanium alloy grade 5. The beam was made of two C-profiles connected by the webs, with the flanges reinforced by the flat bars. Channels were made by bending alloy aluminum 6061-T6 sheets with a thickness of 0.8 mm. Flat bars made from titanium alloy grade 5 having a thickness of 0.8 mm were used to reinforce the flanges. The metal sheets components were connected by Refill Friction Stir Spot Welding RFSSW and Resistance Spot Welding RSW technology. The welding parameters of RFSSW and RSW were selected on the basis of the strength of the joints with a single RFSSW and RSW spot. The joints made of two aluminum alloy 6061-T6 sheets, as in the case of the beams webs, and the joints made of aluminum alloy 6061-T6 and titanium alloy grade 5 sheets, as in the case of beams flanges, were analysed. The beam was subjected to three-point bending using the optical deformation system analysis Aramis. The load-capacity of the beam, the distribution of plastic strains on the reference surfaces and the method of beam cracking were analysed. The results of experimental studies were compared with the results of numerical analysis performed using the ADINA System based on the Finite Element Method.

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1. Introduction

The metal sheets made from aluminum and titanium alloys are characterized by low density, high strength and high corrosion resistance. Due to these advantages presented in [1,2] aluminum and titanium alloys are used by the transport industry, especially aviation. Less weight of the construction means lower fuel consumption and thereby reduces emissions and environmental pollution, as pointed out by the authors of [3–5]. According to the papers [6–8], recently the aluminum and titanium alloys are also used inter alia in the building structures, especially for the roof panels.

The aluminum alloys with the best strength are 2xxx, 7xxx and 6xxx series alloys. These alloys are hard to weld by traditional welding methods. Usually riveting is used for joining aluminum alloys. An alternative method of joining the aluminum alloys sheets is Friction Stir Welding (FSW) presented in the articles [9–11]. FSW is a thermal and deformation process occurring in the solid state of joined material. The authors of the papers [12,13] emphasize that the heat required to soften the material is generated by friction between the tool and the workpieces surface and by the strong plastic deformation. FSW is dedicated to the linear joints.

Refill Friction Stir Spot Welding (RFSSW) is dedicated for spot joints. RFSSW joints are produced by a special tool (Fig. 1). As presented in the papers [14,15] the RFSSW process is performed in following way (Fig. 2): the sleeve is plunged into the workpieces, but the pin is retracted. At the same time, the plasticized welded material is transferred to the pin location. Upon reaching the desired plunge depth the rotating tool is retracted from the welded point and the material is pressed into the welded point. The RFSSW can be used for joining the sheets made form aluminum alloys 7075-T6 and 6061-T6 what were presented in [15–17]. In the papers [18,19] the cellular beams made by using RFSSW process to join the 6061-T6 sheets were shown.

According to the works [21,22] in Resistance Spot Welding (RSW), two metal sheets are placed between two copper electrodes. An electric current is supplied to the welded sheets via the two electrodes. The spot weld is finished via solidification due to cooling through the electrodes. In recent years, researchers have attached great importance to the application of titanium and its alloys in Resistance Spot Welding. In [23] the feasibility assessment of a beam structure made of titanium alloys grade 5 and grade 2 sheets with a thickness of 0.8 mm was performed (Fig. 3).

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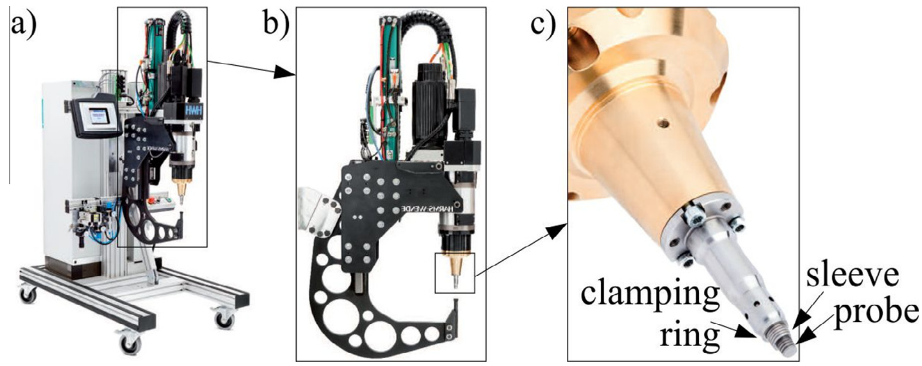

Fig. 1. RFSSW machine made by Harms & Wende company [20]: a) machine, b) operating arm, c) tool.

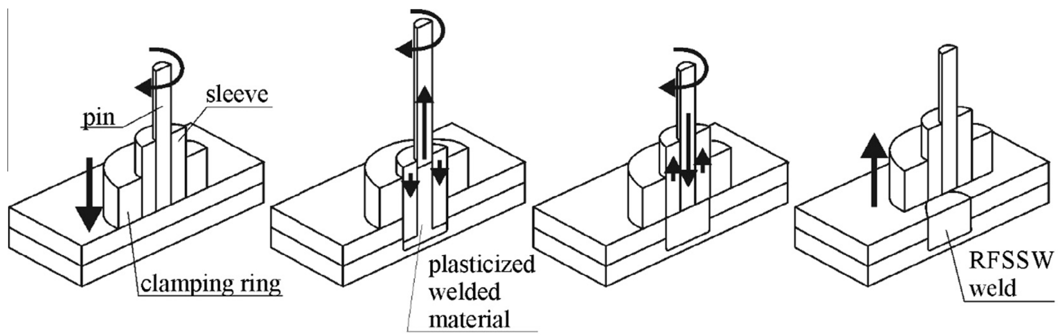

Fig. 2. Scheme of RFSSW process execution.

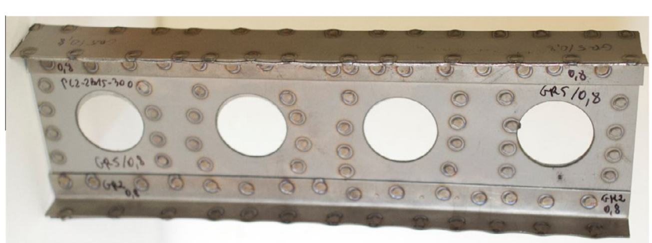

Fig. 3. Beam made of titanium alloys grade 5 and grade 2 sheets with a thickness of 0.8 mm [23].

2. Goal and scope of work

The aim of this study was to determine the load bearing capacity of composite beams. The aluminum-titanium beam was made of aluminum alloy 6061-T6 sheets and titanium alloy grade 5 sheets. The beam was made of two C-profiles of aluminum alloy 6061-T6 sheets with the flanges stiffened by the titanium alloy grade 5 sheets. The C-profiles were cold bended. Metal sheets with a thickness of 0.8 mm were used. The C-profiles were joined by Refill Friction Stir Spot Welding along the webs. The flanges of the C-profiles were connected with the titanium alloy grade 5 sheets by Resistance Spot Welding.

The aluminum-fiberglass beam was made of aluminum alloy 6061-T6 sheets and fiberglass sheets. The aluminum-fiberglass beam was made of two C-profiles of aluminum alloy 6061-T6 sheets with the flanges stiffened by the fiberglass sheets. Fiberglass sheets with a thickness of 0.3 mm were used. The C-profiles were joined by Refill Friction Stir Spot Welding along the webs. The flanges of the C-profiles were connected with the fiberglass sheets by epoxy adhesive. The properties of fiberglass sheets used for the beam are in Table 1.

The geometries of the beams were presented in Figs. 4 and 5. The composite beams were subjected to three-point bending (Fig. 6).

Analysis of the beam was preceded by preparing the RFSSW and RSW lap joints. The lap joints made of aluminum alloy 6061-T6 sheets with a thickness of 0.8 mm were prepared using RFSSW technique (Fig. 7a). The lap joints made of aluminum alloy 6061-T6 and titanium alloy grade 5 sheets with a thickness of 0.8 mm were prepared using RSW (Fig. 7b). The RFSSW and RSW joints were sheared in a testing machine.

The RFSSW parameters used to prepare the beam and the lap joints are presented in Table 2.

The RSW lap joints made with 5 combinations of welding parameters (Table 3) were considered. Three joints for each combination of RSW parameters were made. The shear tests were carried out using a testing machine and the non-contact optical 3D deformation system Aramis.

The RSW parameters used to make the beam were selected in shear tests of the lap joints. The criterion was the largest force carried by the joints.

3. Results

The shear test results of the RFSSW joints (Fig. 8a) made of the aluminum alloy 6061-T6 sheets having the thickness of 0.8 mm are show in Fig. 9. The average force was of 3.57 kN. The distributions of plastic strains on both sides of the joint are similar. Plastic strains of the sheets are evenly distributed over the analysed surface and they are around 0.004. The concentration of plastic strains occurs in the edge region of the RFSSW spot and the base material. The maximum plastic strain is 0.032. The minimum plastic strain of RFSSW spot is in the centre of the spot and its value is 0.004.

The RSW joints were formed by an adhesive connection (Fig. 11). The largest average force carried by the RSW joints made

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