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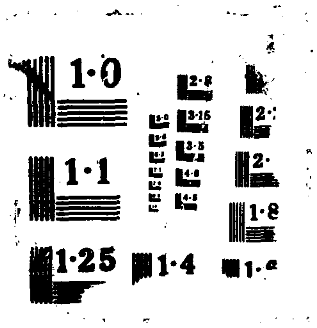
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# APPARATUS FOR PRESSURE WELDING OF TITANIUM STRUCTURES WITH A CONTROLLED RATE OF DEFORMATION

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# APPARATUS FOR PRESSURE WELDING OF TITANIUM PANEL STRUCTURES WITH A CONTROLLED RATE OF DEFORMATION

(USTANOVKA DLYA SVARKI DAVLENIEM TITANOVYKH PANEL'NYKH KONSTRUKTSII PRI KONTROLIRUEMOI SKOROSTI DEFORMATSII)

by

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*Svarochnoe Proizvodstvo*, 26, 6, p38-39 (1979)

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## AUTHOR'S SUMMARY

(from Metals Abstracts 80-11 55-1719)

A technical description is given of equipment for pressure welding of TiTANIUM panel structures of 180 × 200 × 40 mm with preheating and automatic strain rate control. A pressure ~~mechanism~~ allows the welding to be carried out in the strain rate range from (10 to the minus 5 ~~$10^{-5}$~~ to ~~$10^{-2}$~~ 10 to the minus 2)/s. Results are presented of zero-to-tension low-cycle fatigue tests on butt welded joints of TITANIUM ~~Ti~~ alloy OT4 obtained on the equipment at the temperature 950°C, deformation 3 mm, and at various strain rates. ranging from $1.2 \times 10^{-4}$ to $9.6 \times 10^{-4}$/s. A dependence of impact strength of the joints on strain rate from the range $10^{-4}$ to $10^{-3}$/s for welding temperatures of 900, 920 and 950°C is also ~~presented~~. → (to page 2)

Page 1

(from page 1)

In existing apparatus for the diffusion bonding of metals the methods used to apply the bonding pressure do not allow control of the rate at which the load is applied[1]. ~~Thus the~~ loading rate is set independently of the relaxation characteristics of the metals being welded, and it will depend only on the characteristics of the loading mechanism. However, the main factors influencing solid state diffusion bonding (SSDB) are the degree of resistance to deformation of the metals being joined and their relaxation properties, which determine the rate of the recovery processes. Apparatus for SSDB should therefore contain elements for automatically controlling the process parameters in accordance with the degree of resistance to plastic deformation of the metals and their relaxation properties.

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Some experimental apparatus has been developed which is equipped with high-precision systems for measuring the degree of resistance to and plastic deformation of the bonded components. Their methods of applying the bonding pressure enable them, during the bonding process, to control over a wide range either the loading rate with the load applied cyclically, or the strain rate according to the relaxation characteristics of the metals being bonded. On this apparatus it is possible to bond under conditions of superplasticity, and also to develop the mechanical properties of the bonds, based on the latest advances in thermo-mechanical treatment[2].

It has been found that the most reliable system for obtaining the desired deformation rates is a mechanism with an electro-mechanical drive. This enables the deformation rate to be controlled to a sufficiently high degree of accuracy over a wide range of strain rates with simultaneous control of the deformation resistance of the bonded metal during the bonding process.

Fig 1 illustrates an apparatus for the SSDB of panel-type titanium structures with a controlled rate of deformation*. It is designed to provide the technology for bonding structural elements measuring 180 × 200 × 40 mm, the selection of tooling and the deformation process, allowing for the relaxation characteristics of the bonded metal. The apparatus consists of a pressure mechanism 1, a vacuum system 2, a detachable working chamber 3, a device for positioning the tool and welded component 4 and a control panel 5.

The pressure mechanism (Fig 2) will allow bonding to be carried out at deformation rates within the range $10^{-5}$ to $10^{-2}$ $s^{-1}$, by means of a profiled disc cam 1, which sets the amount of deformation from 1 to 5 mm throughout the

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* Patent Claim No.580963

bonding cycle. The rate of deformation is controlled by a double worm gear and the electrical drive 2. The application of bonding pressure is governed by a source of elastic energy consisting of four springs 3, the characteristics of each enabling them to develop a load of up to 1.5 tonf. Pressure is transmitted to the component through the rod 4. Rotation of the disc cam relative to the support rollers 5 causes a linear movement of the body of the lock 6 relative to the fixed plate 7 at a speed determined by the profile of the disc cam and the rotational speed of the electric drive shaft 2, and this corresponds to the selected rate of loading. The resistance of the metal to plastic deformation and its creep characteristics are monitored by strain transducers, whose signals are registered by an automatic recorder during the bonding process.

Besides bonding in a neutral medium, the apparatus enables joints in ribbed structures to be obtained in a vacuum. For this purpose vacuum seals 9 and 10 are provided on the flange 8. The vacuum system permits evacuation of the contaminated atmosphere, argon-filling of the working chamber and the maintenance of any over-pressure during the bonding process.

The radiation method of heating the container (in an electrical resistance furnace) enables a steady and uniform temperature to be maintained in the welding zone. Maximum temperature does not exceed 1100°C. Temperature control is by means of thermocouples attached directly to the contact zone of the welded surfaces.

The tooling was chosen to enable correct assembly and positioning of the parts to be joined both before and during bonding. The working surface of the tools in contact with the component was coated with a thin layer of aluminium dioxide powder by plasma sputtering. Before clamping, the components were washed in acetone and dried, and the faying surfaces were repeatedly wiped with cloths soaked in alcohol to remove all traces of any contaminant. The form of the ribbed panel of titanium alloy OT4 (a sheet 6 mm thick) is illustrated in Fig 3.

Bonding procedures were chosen in two stages. In the first stage the butt welds were tested for impact toughness, and in the second for fatigue strength. In the first case a relationship was established between the rate of deformation and impact toughness. The impact toughness of joints bonded at a deformation rate of $9.6 \times 10^{-4}$ $s^{-1}$, temperature 950°C and a deformation of 3 mm was 4.3 $kgf.m/cm^2$ (Fig 4).

Testing for fatigue strength (on a basis of $2 \times 10^{-4}$ cycles) under conditions of repeated static loading demonstrated that the joints with the maximum impact toughness (4.3 kgf.m/cm$^2$) returned the maximum endurance limit of 60 kgf/mm$^2$ (Fig 5).

The results obtained however fail to give a correct idea of bond quality without taking into account the effect of strain concentrations which are formed in the transition zone from the rib to the body of the panel.

It has been found that a fillet of radius 0.5 mm will improve the endurance limit in T-joints diffusion bonded in VT20 alloy (4 mm thick sheet) from 30 to 65 kgf/mm$^2$ [3]. In order to improve the fatigue strength of joints in bonded ribbed panels, fillets were obtained whose shape is illustrated in Fig 6. These fillets were obtained by uniformly removing a metallic layer by chemi-milling. The thickness of the layer removed to obtain the required fillet greatly exceeds the depth of non-penetration at the edge, so that the formation of a fillet is at the same time an effective means of removing external defects.

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3. Matyushkin, B.A. and Shorshorov, M.Kh.: Thermal action of the arc on the shape, structure and properties of welds in titanium alloys previously welded in the solid state. Svarochnoe Proizvodstvo (1977), 6.

Figs 1-3

Fig 1 Apparatus for solid state diffusion bonding of titanium panel structures with a controlled rate of deformation

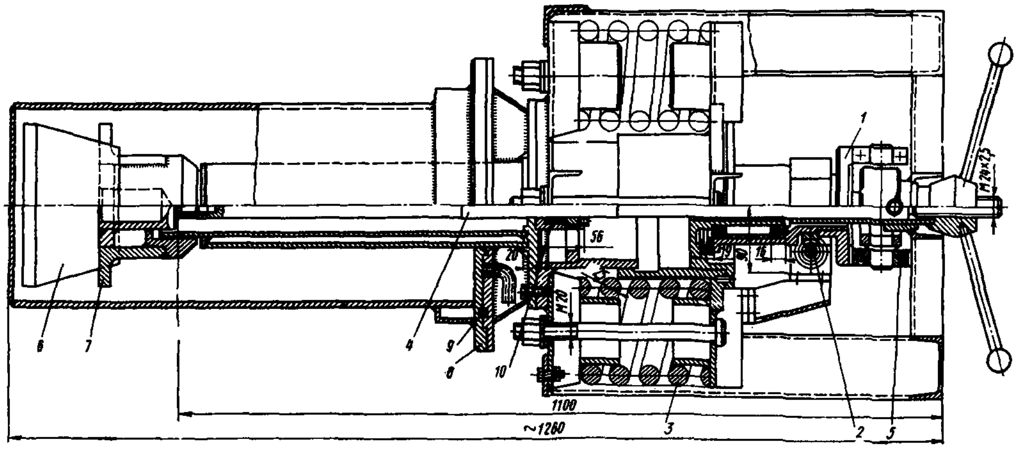

Fig 2 Diagram of the pressure mechanism

Fig 3 Ribbed panel welded in titanium alloy OT4

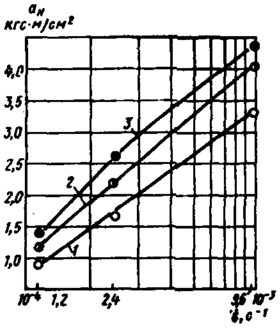

Fig 4 Impact toughness of butt welds in alloy OT4 as a function of the rate of deformation $\dot{\varepsilon}$ at welding temperatures (°C): 1. 900; 2. 920; 3. 950

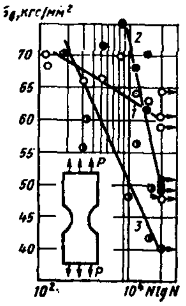

Fig 5 Variation in the limit of low-cycle endurance for butt welds in an alloy, produced at 950°C and a deformation of 3 mm, at different rates of deformation (in $s^{-1}$):
1. $9.6 \times 10^{-4}$;
2. $2.4 \times 10^{-4}$;
3. $1.2 \times 10^{-4}$

Fig 6 **Profile of a fillet in the transition zone from a rib to the body of a welded panel**

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