CNEA EXPERIMENTS TO APPLY FRICTION STIR WELDING TO ENCASE U-MO FOILS IN AL.

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ABSTRACT

U-Mo dispersed fuel can not fulfill the U density requirements for high flux reactors. Besides, in-pile experiments have shown a large interaction between the fuel particles and the matrix. Replacing dispersed fuel by an U-Mo foil has been proposed and is currently under investigation as a possible solution to these problems. Friction stir welding is being experimented at ANL to fabricate fuel plates. Supported by the ENDE - CAC - CNEA experience in FSW, experiments have been started. Successful weld were obtained between aluminum and stainless steels (as subrogate material instead U-Mo) which allowed the selection of optimum parameters. This were applied to encase stainless steel and U-Mo foils in aluminum plates. The first objective was the implementation of the process, optimization of operative parameters and selection of the adequated tests to qualify the welding. The second objective was to apply these technic to fabricate U-Mo /Al alloys diffusion couples. First results are presented.

I. Introduction

U-Mo dispersed fuel which have being developed up to now, can not fulfill the U density requirements for high flux reactors. These fuels have also shown a large interaction between the fuel particles and the matrix presenting some doubts concerning an acceptable irradiation performance [1]. U-Mo foils have been proposed to be used instead of the fuel dispersion, and are called monolithic fuel elements. It is thought that they will contribute to solve the problems described above [2].
The usual rolling procedure applied to the fabrication of dispersed fuel elements are not adequate in the case of U-Mo foils. Several options have been suggested [2], Friction Stir Welding (FSW) and transient liquid phase bonding (TLPB) are under experimentation [3].
The Laboratorio de Soldarura at ENDE, CAC, CNEA (Argentina) has a great experience in bult welds using FSW [4], this supports the experiments that have been initiated to encase U-Mo foil in Al using this techniques.
In FSW bult welds, a cylindrical rotating tool is impinged onto the meeting surface of the edges of the pieces to be weld. As the tool is moved along the length of the pieces it produces the dispersion of the oxides, plastification of the material and the weld. In the fabrication of a monolithic fuel element, two cladding Al plates have to be welded face to face and to bond this cladding to the metallic foil in-between them, without stirring the fuel into the Al.This is possible if the tool is plunged only in the upper Al plate, Fig.1. When the

rotating tool passes close enough over the foil, smears the aluminum onto the foil giving a good interfacial contact. This characteristic of bonding without modification of the fuel surface makes FSW a potential acceptable method to fabricate monolithic fuel elements and also diffusion couples. Its remarkable features are: solid state bonding, neither gaseous protection nor third welding element is required and it is a machining process.

Experiments to implement the process started performing welds between AA6061 T6 (Al) and AISI 316 (SS). They allowed to obtain a set of optimum operative parameters [5].

This work presents the experiments in which stainless steel and U-Mo foils were encased in aluminum applying previous results. One of the objectives is the fabrication of diffusion couples to study the bond of the U-Mo foil with Al and various Al alloys out and in-pile experiments.

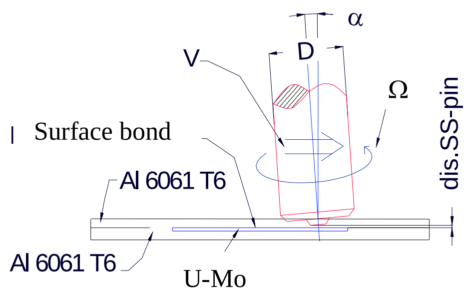

Fig.1. Experimental set up

II. Experimental

The first Al-Al and AL- SS welds were done for different operative conditions such as speed (v), angle (α) and shoulder diameter(D) of the tool, pin diameter (d), tool-interface gap (h) and constant rotating speed Fig.1.

Mechanical tests were performed to select the best parameters. They included: tensile and bend tests on normalized samples, pillow test on 150 mm x100 mm and 100mm x 100mm samples, debonding test and metallography. The selected parameters of the process related to the higher mechanical resistance of the bond were

h = 0.10mm
V = 90 mm/min.
α = 0.5 º
D = 24 mm

With this parameters SS foils and U-Mo foils were encased in Al plates.

U-Mo foils were cut from a U-7%Mo arc melted alloy and thinned with parallel faces by mechanical polishing. Two pieces of 11.5 mm x 5.5 mm x 0.93 mm with rounded corners were prepared. The foils were placed in a cavity machined on one of the Al plates. Pieces were set together as in Fig.1 and welded in overlapping laps with an overlap of 1mm. The set is machined, turn upside down and the operation is repeated.

Metallography using OM and SEM was performed in sections perpendicular to the welding plane. This was done to check the quality of the bond at the interface.

Two samples of the encased U-Mo foils were submitted to diffusion anneals, 2 hours at 530 C, to evaluate the behaviour of the weld. One diffusion anneal was quenched and the other slow cooled. Another one at 300 ºC is still on going.

III Results

It was possible to obtain satisfactory welds with no defects or debonding at the interface for SS and U-Mo foils, micrographs are shown in Fig.2 and 3

Fig. 2 Welded interface for SS encased in Al. Mechanical polishing up to 1 μm.

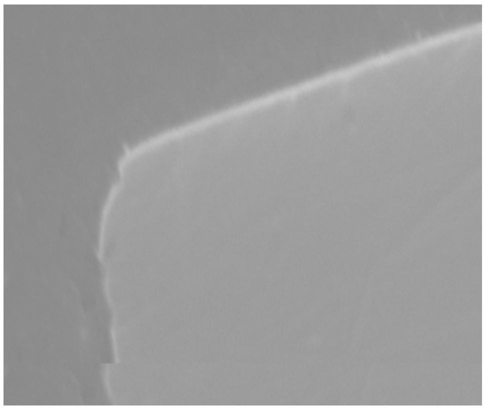

Fig.3. U-Mo encased in Al. Detail of a corner. SEM 750X

Fig.4 illustrates a failure produced when the pin got in contact with the SS. The stirring of the foil into the Al is observed and also a severe deformation of the grain microstructure has happened.

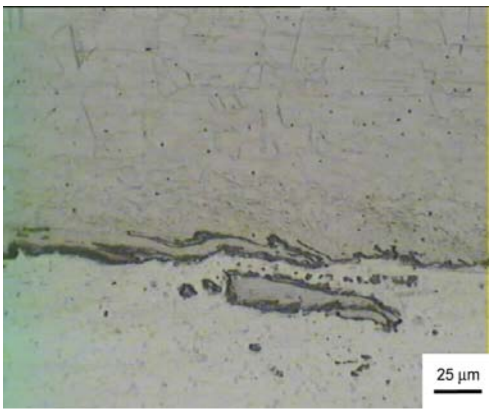

Fig. 4. Failure at the interface of a SS/Al weld due to the contact of the pin with the foil.

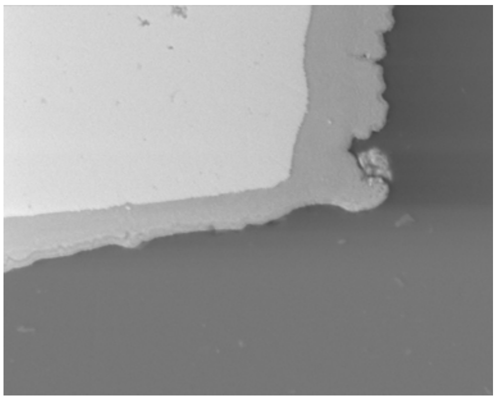

Fig. 5 Same sample of Fig 3 , annealed 2 Hs at 530°C. Backscattered electron image. 800X

The diffusion anneals of 2 hours at 530°C showed an continuous interdiffusion layer along the surface of the U-Mo foil been an indication that a good contact was obtained by FSW, Fig.5.

IV. Discussion and conclusions

FSW was applied successfully to weld face to face with no contact of the tool at the interface, Al alloys plates between them and with foils of other alloys such us SS and U-Mo. An adequate control of the operative parameters allowed to encase SS and U-Mo foils in Al cladding. As a result of this the process is considered potentially acceptable to fabricate diffusion couples and monolithic fuel elements.

From all the variables studied, the pin–interface gap is the most important related to the mechanical resistance of the bond and the most difficult to control because of its dependence on the precision of the equipment, thermal expansion of the whole set, dimensional tolerances of the foils and precision of the machining previous to the welding of the second face. Most of these are magnified if the equipment is not properly instrumented.

Aknowlegments

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