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Material Flow and Oxide Particle Distributions in Friction-Stir Welded F/M-ODS Sheets

Suk Hoon Kang *, Sanghoon Noh, Hyun Ju Jin, Tae Kyu Kim

Korea Atomic Energy Research Institute, Daejeon 305-353, Republic of Korea
**Corresponding author: shkang77@kaeri.re.kr*

1. Introduction

Oxide dispersion strengthened (ODS) steels and Ferritic Martensitic Steels (FMS) are expected to be used as a long life cladding in the future advanced fast reactor. Those materials have excellent resistance to creep and swelling as well as superior mechanical strength [1-4]. It is well known that uniform nano-oxide dispersoids act as pinning points to obstruct dislocation and grain boundary motion in ODS steel. However, these advantages will disappear while the material is subjected to the high temperature of conventional fusion welding. There is only limited literature available on the joining of ODS steels. Friction stir welding (FSW) is considered to be the best welding technique for welding ODS steels as the technique helps in retaining the homogeneous nano-oxide particles distributions in matrix.

FSW is a solid–state, hot–shear joining process in which a rotating tool with a shoulder and terminating in a threaded pin, moves along the butting surfaces of two rigidly clamped plates placed on a backing plate. Heat generated by friction at the shoulder and to a lesser extent at the pin surface, softens the material being welded. Severe plastic deformation and flow of this plasticized metal occurs as the tool is translated along the welding direction. Material is transported from the front of the tool to the trailing edge where it is forged into a joint [9, 10]. Therefore, it is highly possible that the oxide particles are segregated at the advancing side of the welds.

In this study, the distribution of oxide particles and material flow in FSWed ODS steel is investigated. The combination of tool rotating and advancing speed is critical for the regular dispersion of oxide particles.

2. Methods and Results

The material used in this study was a F/M ODS steel (Fe(bal.)-10Cr-2W-0.2Ti-0.1C-0.35Y2O3 in wt.%) and F/M steel (Fe(bal.)-10Cr-2W-0.2Ti-0.1C in wt.%). A material of the tool used in this study is a W-12wt.% Co alloy. 3 mm thick ODS and FMS sheets were subjected to FSW with a tool advancing speed of 50 mm/min. Two different rotating speeds of 1200 and 1700 rpm were used. Tempering is carried out at 750℃ for 1h after welding, by considering the characteristic of FMS and ODS steels.

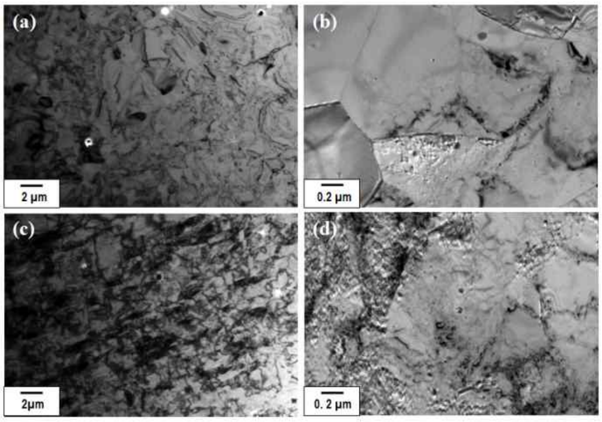

Fig. 1. TEM micrograph of FMS and ODS steels. (a), (b) before FSW. (c), (d) after FSW.

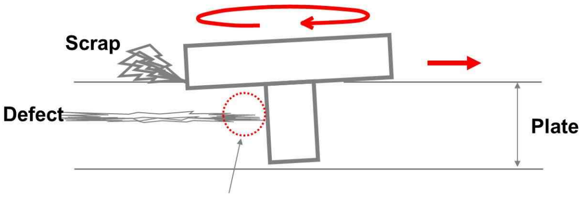

Fig. 2. A schematic of defects generation after FSW.

Most of the material flow occurs through the retreating side and the transport of the plasticized material behind the tool forms the welded joint. The defects are left behind the tool pin movement as shown in Fig. 2. Three types of flow affects the overall transport of plasticized materials during FSW. First, near the tool, a slug of plasticized material rotates around the tool. This motion is driven by the rotation of the tool and the resulting friction between the tool and the work-piece. Second, rotational motion of the threaded pin tends to push material downward close to the pin which drives an upward motion of an equivalent amount of material somewhat farther away. Finally, there is a relative motion between the tool and the work-piece. The overall motion of the plasticized material and the formation of the joint results from the simultaneous interaction of these three effects.

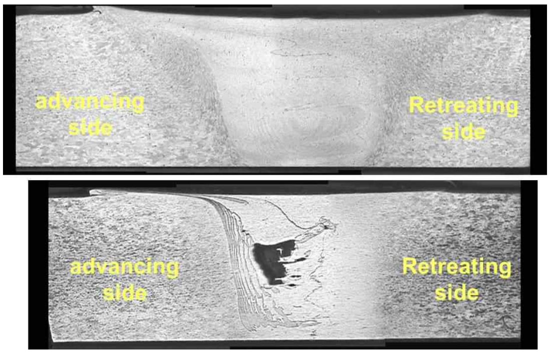

Fig. 3. The general position of defects after FSW is shown. The defects are usually formed at the end of flow; it ends at the advancing side of the weld.

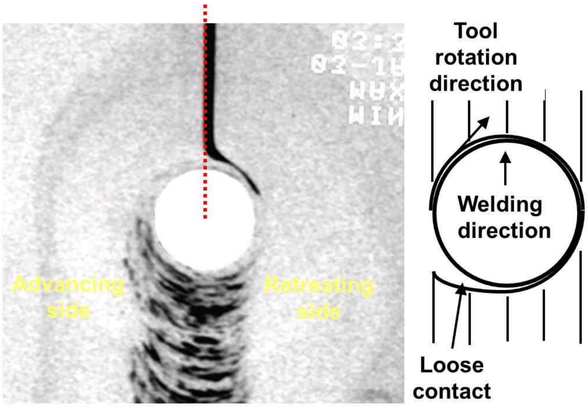

Fig. 4. The material flow inside the plates was observed in X-ray micrographs that were obtained from a marker inlay technique.

In Fig. 3, the cross section images of FSWed welds are shown. The formation of ‘‘wormhole” defect is observed at the advancing side. The lack of adequate material flow on the advancing side has been related to the formation of such defects. In order to observe the material flow inside the joined plates, a marker inlay technique was adopted, as shown in Fig. 4. Before the FSW procedure, one of the plates was carved by a grinder. After FSW, the flow of the gold inlay could be observed using X-ray micrographic imaging. Fig. 4 shows an X-ray micrograph of the FSWed aluminum plate with the gold marker. The figure shows that the gold marker is elongated around the tool pin and that its flow ends at the advancing side. The shear-deformed material flow that is transferred from the leading to the trailing side is mainly stored in the loose contact space. Considering those material flow, it is suspected that the dispersed oxide particles are asymmetrically distributed through the advancing to retreating side. The microhardness and microstructure observation will enable us to evaluate the oxide particle distributions in the FSWed welds.

3. Conclusions

Friction stir welding appears to be a very promising technique for the welding of FMS and ODS steels. This study found that, during FSW, the forward movement of the tool pin results in loose contact between the tool pin and the receding material on the advancing side. The distribution of oxide particles and material flow in FSWed ODS steel will be investigated using microhardness and TEM observations.

Acknowledgements

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