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INTRODUCTION

Application of the latest developments in materials technology may greatly aid in the successful pursuit of next generation reactor and transmutation technologies. One such area where significant progress is needed is joining of advanced fuels and materials. Rotary friction welding, also referred to as friction stir welding (FSW), has shown great promise as a method for joining traditionally difficult to join materials such as aluminum alloys. This relatively new technology, first developed in 1991 [1], has more recently been applied to higher melting temperature alloys such as steels, nickel-based and titanium alloys. An overview of the FSW technology is provided and two specific nuclear fuels and materials applications where the technique may be used to overcome limitations of conventional joining technologies are highlighted.

EXPERIMENT

Overview of Friction Stir Welding Process

Friction stir welding consists of inserting a rotating pin into the material. The frictional heating and pressure act to plastically stir the material. As the tool is moved forward, the material in the weld zone is mixed and transferred from the leading edge of the tool to the trailing edge, where it cools to form the weld. Since melting does not occur, the material maintains its crystalline properties. The friction stir welder typically consists of modified heavy-duty milling machine with mutiaxial control of the tool. Tools are usually made of refractory metals or hard crystalline ceramics such as polycrystalline cubic boron nitride (PCBN). A schematic of the process of joining two plates is shown in Figure 1.

The stir zone and surrounding materials consist of four distinct zones. The first is the base or parent material, which is the area unaffected by the weld. A second zone, called the heat-affected zone (HAZ), exists where plastic deformation does not occur but the microstructure still changes due to heating of the material. The area where plastic deformation has occurred is called the thermo-mechanically affected zone (TMAZ), and if recrystallization has also occurred, it is referred to more specifically as the weld nugget.[2]. The specific nature of the microstructure will depend greatly on the welding parameters which need to be optimized to obtain the best joint quality for each type of material being welded.

RESULTS AND DISCUSSION

Joining of Oxide Dispersion Strengthened (ODS) Alloys

Core components and cladding material fabricated from ODS metal at some point will need to be joined to either itself or other structures within the reactor. For conventional metallic materials, the joints are most commonly achieved by fusion welding. However, there are many challenges associated with joining of ODS alloys by fusion welding techniques including agglomeration and coarsening of the oxide particles in the weld zone and deleterious microstructural changes in the heat affected zone. Such alterations will negatively impact the alloy creep strength. The first FSW application example will summarize results from a study to investigate the influence of FSW on the microstructure a Ni-based ODS alloy. The observed microstructural changes are highlighted in the optical and electron images provided in Figure 2 taken from various locations of a friction stir weld.

Fabrication of Low-Enrichment Uranium (LEU) Fuel Plates

In a second example, friction stir processing is being employed to fabricate LEU fuel plates for research test reactors. Aluminum cover plates, acting as a cladding, are smeared onto uranium foil surface by the rotating tool. This unique application of friction stir processing can produce bond quality not attainable by conventional joining methods. The monolithic fuel plate produced with this method exhibit a substantially lower degree of high temperature fuel cladding interaction than dispersion type fuel forms.

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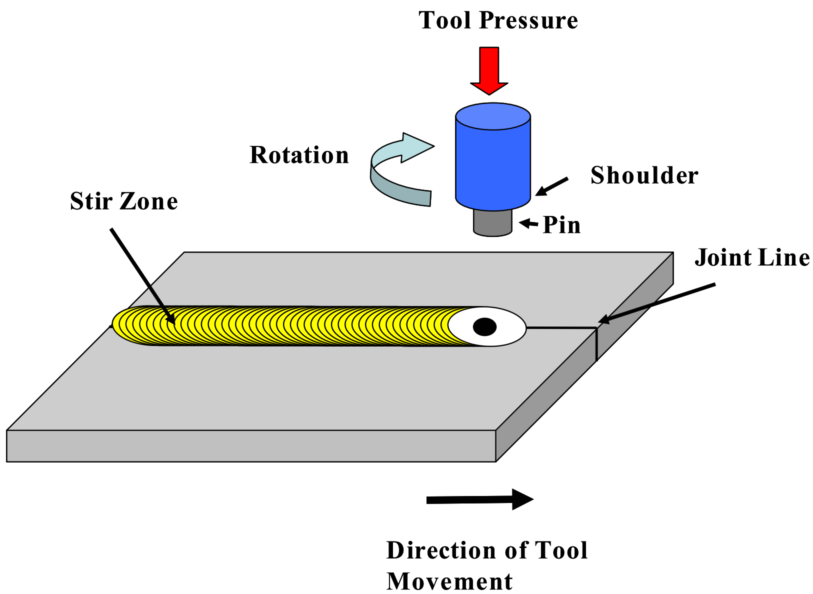

Figure 1 Schematic of FSW process.

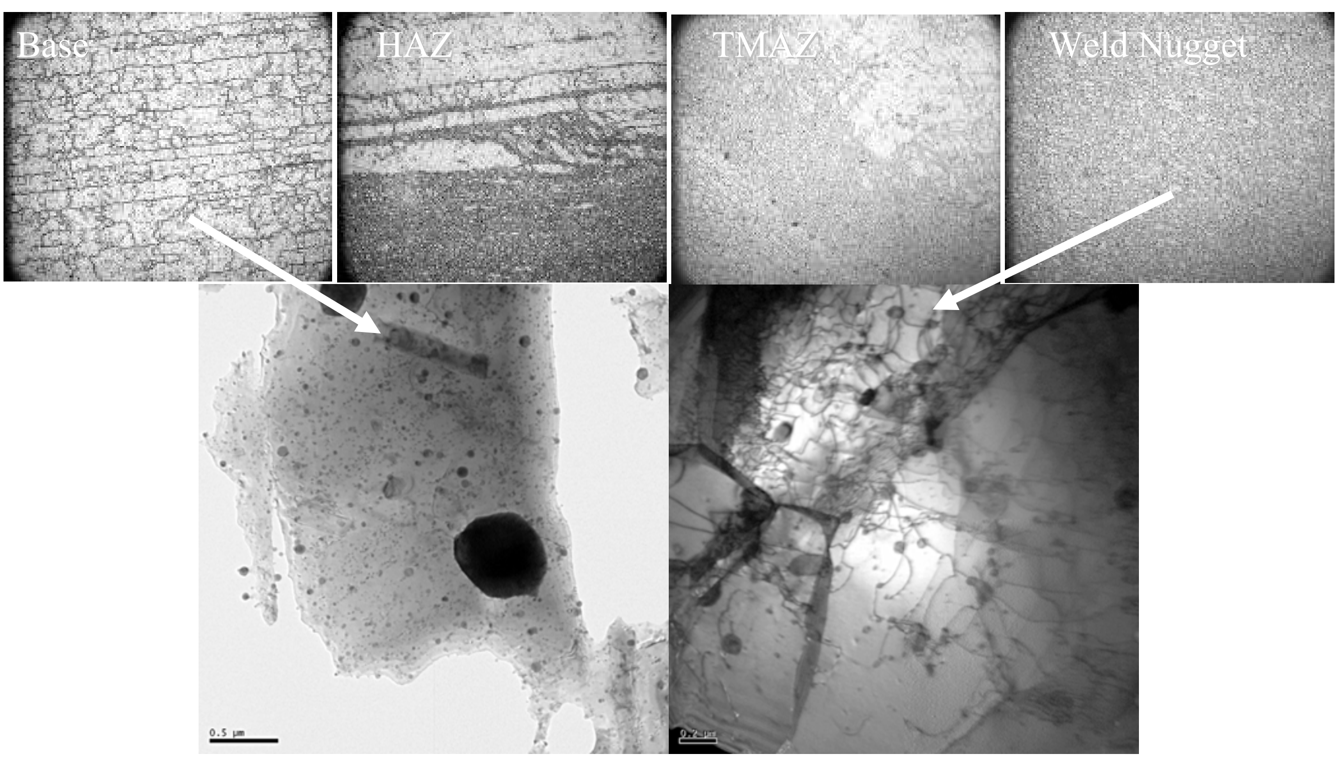

Fig. 2 Optical and TEM images illustrating the microstructure of the process zones in the FSW ODS Alloy..