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DIFFUSION-CONTROLLED WEAR OF STEEL FRICTION STIR WELDING TOOLS USED ON ALUMINUM ALLOYS

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Friction stir welding (FSW) has already gained a wide field of application in particular for joining aluminum alloy components in aviation and space industries. Further expansion of this method for other materials is retarded by the necessity to have more wear resistant tools. Nevertheless, even if using steel tools on aluminum alloys there is a demand on improving both wear resistance and material transfer in the weld zone in order to avoid the so-called "Lazy S" or remnant joint line defects. Therefore, studying the FSW tool deterioration mechanisms seems to be actual task at this stage f the process development.

The objective of this paper is to disclose the steel FSW tool wear mechanisms on welding aluminum-magnesium alloys.

When examining the worn steel FSW tools one can see a transfer layer on their steel surfaces. This transfer layer is composed of aluminum alloy components and forms as a result of adhesion between plasticized aluminum alloy and steel surface during friction stir welding. The end surface of the tool shows layered structures which might have been formed when plunge force was great enough to press the tool against a substrate beneath the aluminum alloy sheet. These structures are similar to those observed in sliding tests during shear instability.

Another thin continuous layer is found between the transfer layer and FSW tool's base metal. The most part of the tool's surface area is covered by this intermediate layer even if no transfer layer spots are found. The most mechanically loaded areas of the tool are on the taper surface of the tool's pin and here one can see the so-called spikes directed inside the FSW tool metal and filled with this intermediate metal. According to the results of EDX this intermediate layer consists of intermetallic Fe-Al compound.

To characterize its mechanical strength, the nanoindentation tests have been carried out. As shown the maximum hardness of this layer was about 1700 HV as compared to 630 HV of the FSW tool steel. It is known that FeAl intermetallics possess high wear resistance, low friction and hardness at elevated temperatures. However, the problem is formation of the above mentioned spikes by diffusion on the most mechanically stressed areas, which finally leads to embrittlement and pulling out of a whole fragment of steel. The next stage will be forming a wear particle and intermixing it with the nugget zone metal.

So normal wear of FSW tools is by volume diffusion formation of continuous intermetallic film on the tools surface which serves as a protecting hard coating and keeps the wear rate minimum. However, formation of spikes by preferential diffusion along the grain boundaries of other defects must be avoided. For this purpose protective coatings must be employed.

FRICTION STIR PROCESSING ON HIGH CARBON STEEL U12

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The use of FSP for carbon steel was reported to increase the hardness of the 200 μm thickness subsurface layer up to 900 HV as a result o quenching. An order of magnitude improvement in wear rate may be obtained as well as 25% friction reduction. The literature search shows the feasibility of FSP hardening the high carbon steels in order to enhance their wear resistance. Our results relating to wear resistance of medium carbon steel after FSP show very good wear resistance improvement as compared to non-treated medium carbon steel.

The objective of this work is to study the structure formation in FSP on high carbon steel as compared to medium carbon steel.

Processing on the U12 1.2% C steel has been carried out at tool rotation rate 1500 r.p.m. and feed 23 mm/min. On processing the samples were cut, polished and etched by Nital to obtain the cross section views. Cross section view of the processed metal shows at least three zones denoted as stir zone (SZ), heat affected zone (HAZ) and base metal. The microstructure of the stir zone consists of coarse 7 -28 μm grains with cementite 0.4-0.6 μm thickness network by their boundaries. The microstructure of HAZ is represented by globular pearlite grains similar to that of base metal. However, HAZ is characterized by higher amount of globular carbide particles precipitated just below the SZ/HAZ boundary. Precipitation of both coarse and fine carbide particles is the reason