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High Cycle Fatigue Behaviour of Friction Stir Lap Welded 6061 Aluminium Alloy to Coated Steel Sheet Joint

H. Das · T. K. Pal

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Abstract Multi-material fabrication such as joining of steel and aluminium has become prominent now-a-days in automotive industries. Friction stir welding being a novel solid state welding process, has already established good joint strength between steel and aluminium; but fatigue strength of such dissimilar joint has not yet been explored. In the present study, the friction stir lap welding was performed at each rotation speed of 500, 1000, 1500 for two different travel speed i.e. 50 and 100 mm min^{-1} at a constant probe depth of 2.5 mm. Among the six different joints, joint strength achieved of maximum (5 kN) and minimum (2 kN) under two parameter combination i.e. 1000 rpm, 50 mm min^{-1} and 500 rpm, 100 mm min^{-1} respectively, have been exclusively characterized by high cycle fatigue at R ratio 0.1. Furthermore, R ratio has been varied from +0.5, +0.3 to −0.5, −0.3 at a particular load amplitude which shows the endurance limit (10^6 cycles) for both combination of parameters. The experimental results show that fatigue strength at 10^6 cycles for both the FS welded lap joint is about 20 % of their respective failure load. Thus better fatigue strength is associated with the lap joint performed with the joint of maximum load. The fatigue behaviour of two FS joints has been correlated with the thickness of intermetallic compound and accumulation of dislocations observed by TEM.

Keywords Friction stir welding (FSW) · High cycle fatigue · TEM · Fracture path · R ratio

H. Das · T. K. Pal (✉)
Metallurgical and Material Engineering Department, Welding Technology Centre, Jadavpur University, Kolkata, India
e-mail: tkpal_ju@gmail.com

1 Introduction

Recently, the automotive industries are concentrating on multi-material fabrication which can make vehicles much lighter and crash resistant etc. Its adoption in practice is closely linked with the development of efficient methods of joining for dissimilar materials such as steel sheets with aluminium alloys for light weight [1, 2]. But, from practical point of view sound joints between dissimilar materials with low cost fabrication process have to be established [1–3]. Joining of dissimilar metals by conventional fusion welding techniques is very difficult due to large differences in thermo physical properties i.e. melting point, thermal conductivity; thermal expansion which leads to high distortion, residual stresses etc. and also in metallurgical characteristics resulting in the formation of brittle intermetallic phases that generally form by solid state reaction [4]. These intermetallics (IMC) generally results in mechanical degradation of the joint [5, 6]. Friction stir welding (FSW), being a novel solid-state joining process invented by TWI, UK in 1991 has offered excellent welding quality to the joining of aluminium, magnesium etc. over the last decades. With the success in FSW of light metal alloys coupled with lower operating costs due to improved energy efficiency and virtual lack of a consumable has emphasized the need to examine aluminium and coated steel. However, the interfacial region of dissimilar joints produced by FSW is very complicated due to the introduction of complex deformation and the lack of diffusion time leading to formation of very thin intermetallic layer thickness. The analysis of the interfacial region has still remain limited and unclear.

Very few literatures are available globally on FSW of aluminium alloys to coated steel sheet lap joint. The feasibility of friction stir welding of aluminium to steel and

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