



# Taguchi Optimisation of Friction Stir Welding Parameters for Pure Aluminium under Different Backing Conditions

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## ABSTRACT

Friction stir welding (FSW) of pure aluminium is highly sensitive to the backing condition because the backing plate not only supports the workpiece against downward forging but also governs heat extraction from the weld zone. This study optimized the FSW parameters for 6-mm pure aluminium under three backing conditions: aluminium, mild steel, and an insulating fly-ash bed, and evaluated their effects on tensile strength, joint efficiency, hardness, fracture morphology, and phase stability. Butt joints were produced on a vertical milling machine using a low-cost dedicated fixture. A Taguchi L9 orthogonal array was employed to examine tool rotational speed, welding speed, and tool geometry (straight cylindrical, triangular, and straight square), followed by ANOVA and regression-based optimisation. The base metal showed 180.793 MPa ultimate tensile strength, 34.3% elongation, and 75.2 HRB hardness. The aluminium backing condition yielded 93.20-113.41 MPa and 51.55-62.72% joint efficiency, while mild steel gave 72.43-139.10 MPa and 40.06-76.93%. The fly-ash bed produced the best performance, achieving 107.10-165.78 MPa and 59.23-91.69% joint efficiency, with a maximum tensile strength of 165.78 MPa. Hardness was highest under aluminium backing and remained closer to the base metal under fly ash. Fractography showed tunnel defects, voids, and coarse dimples in the aluminium condition, fewer severe features in mild steel, and abundant fine dimples indicative of ductile fracture in the fly-ash condition. XRD showed no additional peaks, confirming the absence of foreign material transfer into the nugget. These findings show that backing condition is a key optimisation variable and that fly ash is an effective low-cost insulating backing medium for improving weld performance in pure aluminium FSW.