# Abstract

Friction stir welding (FSW) is a relatively newer technique in the domain of solid state joining but has found multiple utility in various industries across the world. By employing FSW, several issues that conventional fusion welding poses viz. distortion, low efficiency, etc. can be avoided. FSW has been highly suitable for welding metals viz. aluminum and magnesium which were highly challenging to be welded by conventional welding techniques. For this reason, FSW has been embraced by aerospace and marine industries which require welding of large aluminum panels. Joining of dissimilar metals is one of the interesting aspects that FSW is found to handle quite easily as joining occurs much below the actual melting temperature of the metals. Research is also underway for welding metals having high melting points (steel and titanium based alloys) using FSW in an efficient manner.

Efficient welding of pipelines is a vital need for industries like power plants, marine, food and chemical industries. Pipe welding is frequently required in various applications involving transfer of fluids. In fact, the weldment becomes a point of higher concern when the temperature of the flowing fluid is high especially in power plant based applications. Due to the inherent challenges associated with circular pipe welding viz. weld configuration, curved geometry at the weld zone, ovality issues, etc. the optimal combination of weld parameters for linear welding may not be one to one mapped in case of pipe welding even though keeping the material to be welded the same as that of pipes.

In the present work, FSW is conducted individually on industrial grade pipes made of AISI-316L and P91steel. Both these pipes are employed in various power plant based applications and efficient joining of them is a vital concern to the industry. Initially, welding is carried out in position control mode of AISI-316L steel pipes by varying parameters viz. spindle speed (RPM), transverse speed/feed rate (mm/min) and tool depth (mm) to get an

idea about the welding process and to assess the effect of these parameters on the mechanical properties of the weldment. Based on the weld quality and the data recorded during the welding process, the optimum vertical force is determined. This sets the stage for carrying out the welding in force control (FC) mode of the machine which seems to be the logical option considering some degree of variation noticed in the pipe geometry. Under FC mode, the effect of two parameters i.e. spindle speed (rpm) and welding speed (mm/min) on the weld characteristics of the two steel pipes have been investigated. Microhardness and tensile tests have been conducted to assess the mechanical strength of the joints. Microstructure evaluation by optical microscopy (OM) and field emission scanning electron microscopy (FE-SEM) is done in order to comprehend the mechanical performance of the weldments. Both the steel pipes displayed beyond 100% joint efficiency at optimal combination of parameters. AISI-316L steel exhibited better joint strength at low welding speed whereas P91 steel showed the same at higher welding speed. Stir zone of both the welded samples revealed higher hardness values than respective base metals (BM). However, this increase is significant in case of P91 steel. The optimal parameter combination produced defect free weld. Thermo-mechanically effected zone (TMAZ) in case of P91 is wider compared to AISI-316L as revealed by optical microscopy (OM) and field emission scanning electron microscopy (FE-SEM). The results indicate that FSW is able to produce high quality joints in both AISI-316L and P91 steel pipes which may be useful for industrial based applications.

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