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Effect of rotational speed on temperature in Friction stir spot welding of high density polyethylene sheets

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Abstract:

Friction stir spot welding situations have an impact on the welding integrity of thermoplastics like high density polyethylene (HDPE) sheets. These materials could connected viafriction stir welding (FSW), though typical tools do not provide great results. FSSW is a new weld technology utilizedforpolymer materials weldingwhich are difficult for weldingbycustomary welding procedures. The goal of this experiment is to fuse comparable HDPE materials utilizing friction stir spot welding (FSSW) procedure. In present research, welding parameters investigated were tool rotating speed, tool plunge depth, and dwell duration in three stages. Peak temperature in the joining zone was used to assess the performance of welded samples. Temperature measurements were taken forestablishinga maximum temperature of joining zone as function of tool rotating speed. The findings revealed a correlationamongst peak temperature and rotating speed. After eliminating the weld root problem, the final findings show that FSSW of HDPE sheets may be the viable alternative to traditional joining procedures.

Keywords: Friction stir welding (FSW), High density polyethylene (HDPE), Friction stir spot welding (FSSW), Thermal history.

1. Introduction:

Worldwideleanings in CO_2 emissions and gas prices has compelled automobile and aeronautical manufacturers forcreatingsafer, lighter, and environmentally friendly automobiles [1]-[2]. The use and improvement of lightweight materials (such as polymers, magnesium, and aluminium,) may drastically reduce vehicle weight. The present hybrid constructions in which materials (polymers or metals) are included often necessitates connection of the components. Lightweight metals (i.e. aluminum) have qualities such as higher strength, electrical conductivity and great heat conductivity. High density polyethylene (HDPE) sheets have acceptable corrosion resistance, strength-to-weight ratios, and insulating qualities [3]-[5]. As a consequence, dissimilar material junctions amongmetal and polymer may combine diverse characteristics, resulting in a hybrid material with structural performance.

Spot welding is a popular connecting method in the automobile industry [6]. Because of its benefits in compatibility for automation and weld effectiveness, this welding method is frequently utilised in the union of sheet metal components [7]. International trends compel a car production to produce safer, lighter, eco-friendly, and eventually less expensive automobiles [8]. Automobilesload may be reduced by substituting traditional cast irons and steels with modern lightweight materials like reinforced polymer composites magnesium, and aluminium [9]-[10]. However, the weldability of these novel automobile materials is restricted, necessitating improvements in both traditional welding methods and innovative welding techniques [11].

Plastic welding procedures are classified into two types: those that use mechanical association to generation of heat (friction,vibration and ultrasonic welding) and those that use exterior heating (resistive and implant welding, hot gas and plate welding) [12]-[13]. Friction stir welding (FSW) is ainnovative joining method that have potential to contend with traditional plastic weld procedures [14]. FSW welds by utilising a non consumable spinning tool having specifically designed shoulder for temporarily workpiecesoftening via plastic dissipation and friction, enabling a tool to agitate acombined area. The lowered weld temperature in the method makes conceivable considerably lower residual stresses and distortion, novel building approaches, permitting superior fatigue performance, and feasible welding of thick and extremely thin metels [15].

From the time wheninnovation in 1991, FSW has emerged like technology of choice into ordinary joining of aluminium; uses in joining problematic metals although at slower rate [16]. This is presently utilized to broad range of materials, together with copper [17], titanium and its alloys [18], magnesium alloys [19], metal matrix composites [20], steel [21], and differentalloy and metal [22-23]. Presently, several forms of FSW tool have been employed for connecting and treat thermoplastic [22]-[28]. As illustrated in Fig. 1, friction stir spot welding process (FSSW) engagesin three phases: retracting, stirring, and plunging [29].

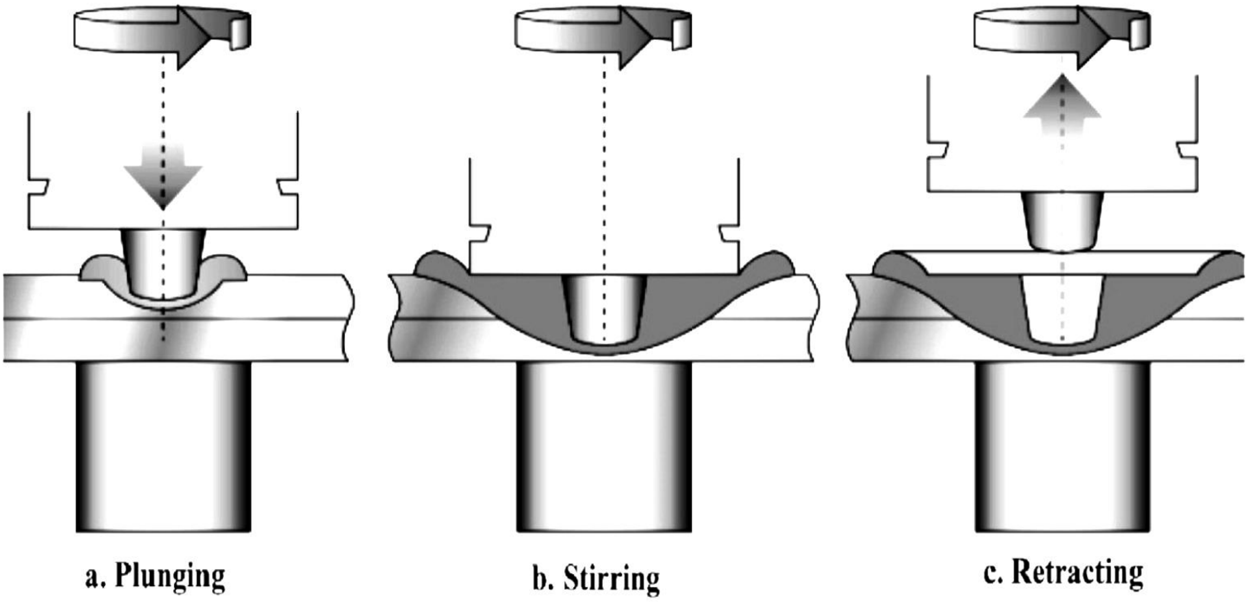


Fig. 1. Various phases of FSSW.

FSW is done with thenon-consumable spinning tool which contains two important parts: pin, and shoulder as seen in Fig. 2.

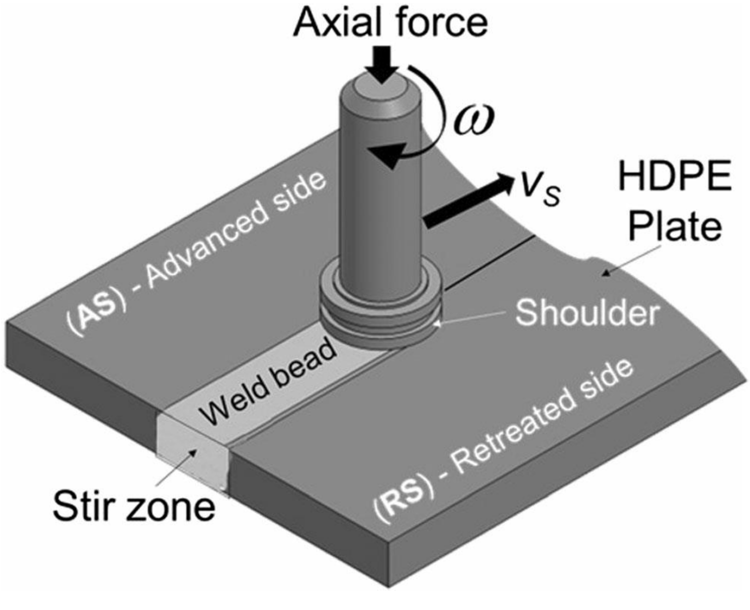


Fig. 2 Diagram of FSW displaying parameters and parts

Polyethylene (PE) is a most utilised polyolefin thermoplastics because of its toughness, flexibility, and durability. According to Vijayan et al. [30], thermoplastics are typically welded by processes that include succeeding conditions: heat conduction (hot gas welding, socket, and heated wedge), mechanical friction and heat radiation. FSW is a member of the final group (mechanical friction). PE offers great features such as high chemical and corrosion resistance, strong environmental stress fracture resistance, light weight, high stiffness, and inexpensive maintenance and fabrication costs, according to Peacock [31]. On one side, Lai et al. [32], who examined on the weldability of PE utilising electron butt fusion and beam irradiation welding, demonstrated that even in acceptable circumstances, flaws are present. Furthermore, Leskovics et al. [33] showed a ductility loss of FSW joints, indicating that a presence of defects combined with ductility loss results in a major impairment in mechanical qualities.

Significant changes in crystal orientation and crystallinity % are also predicted, as stated by Li et al. [34], and a decrease in lifespan expectancy, as seen by Kiss and Czigany [35], who evaluated welding impactand rotational speed upon FSW joints.The authors used tensile tests and differential scanning calorimetry to assess the applicability of FSW in polymers (DSC). They discovered that non-homogenization causesembrittlement at welded joints, which is connected to a decrease in crystallinity inside the welded areas. Grewell and colleagues [36] Therefore, major efforts have been lately made to study the impacts of utmost critical reasons on mechanical characteristics of FSW joints.

Hoseinlaghab et al. [37] inspected the creep qualities of FSW joints in PE using tilt angle, tool geometry, and rotating and welding speed. They discovered thecomparativefreedomamongpin shape and process parameters, with cylindrical pins producing the greatest weld quality and creep qualities. Nateghi and Hosseinzadeh [38] investigated the impact of an aided cooling nugget on PE FSW. The findings revealed that utilising aided cooling improves angular distortion, tensile strength, and residual stress of FSW joints. Bozkurt [39] came to the conclusion that rotational speed is critical most parameter influencing the mechanical characteristics [40].

Vijendraet al., [41] explored FSW into PE utilising novel tool design of pin heated by induction although its hardness reduced. In addition, DSC revealed a significant amount of crystallisationin the stir zone. Banjare et al. [42] improved surface smoothness and reduced chip formation and material loss in FSW for numerous thermoplastics. Simes and Rodrigues [43] evaluated polymer thermo mechanical conditions and material flow in FSW. The researchers discovered that discrepancies in shoulder and pin determined flow might enlighten the creation of significant weld ability and discontinuities issues. Nonrotational shoulder tools provide the benefits of lowering heat transfer to the welded joint, increasing tensile power, and minimising a major issue known as "root defect" in thermoplastic FSW [44].

There seem to be few papers on polymer FSW uses. There are few publications on the function of FSW process parameters based on M.S. straight cylindrical tool with concavity. Given the above, the goal of theworkis look into effect of tool rotating speed upon peak temperature in joining zone of HDPE FSW joints for obtain maximum strength. In this work, HDPE sheets were welded using a mild steel tool.

2. Experimental procedures

High density polyethylene sheets 6 mm thick were employed in this study. A lap-shear specimen is shown in Figure 3, and it is used to assess FSSW when subjected to shear stress conditions. The specimens were welded with employing specific experimental set-up.

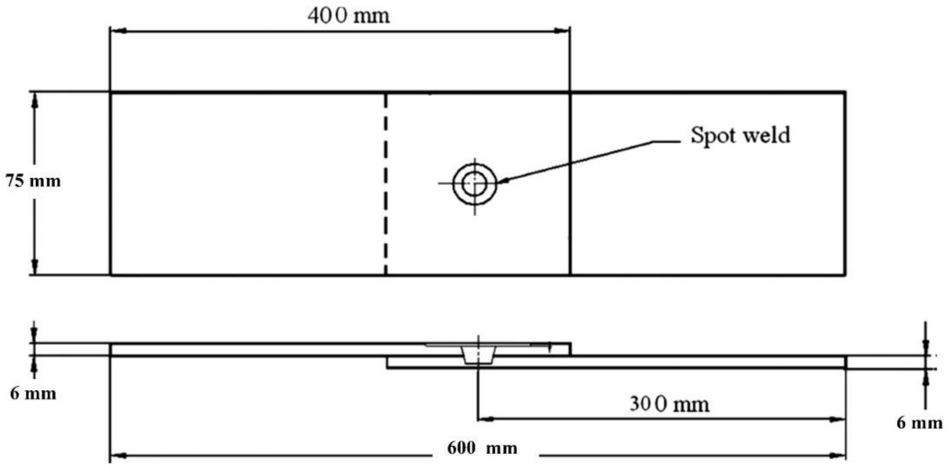


Fig. 3. Lap-shear test specimen configuration.

Figure 4 depicts the friction stir welding experimental setup, including the fixture. In acentre of a specimen, a spot weld joint was obtained. A correctly built clamping device was used to secure the specimens forproducing the FSSW experiments.Every step of the welding process was carried out at ambient temperature. The shoulderand pin of a tool were at room temperature before each welding operation. An infrared thermometer was used to determine the weld joint's temperature. As soon as the dwell period ended, the tool was withdrawn, and this is when the maximum temperature was reached.

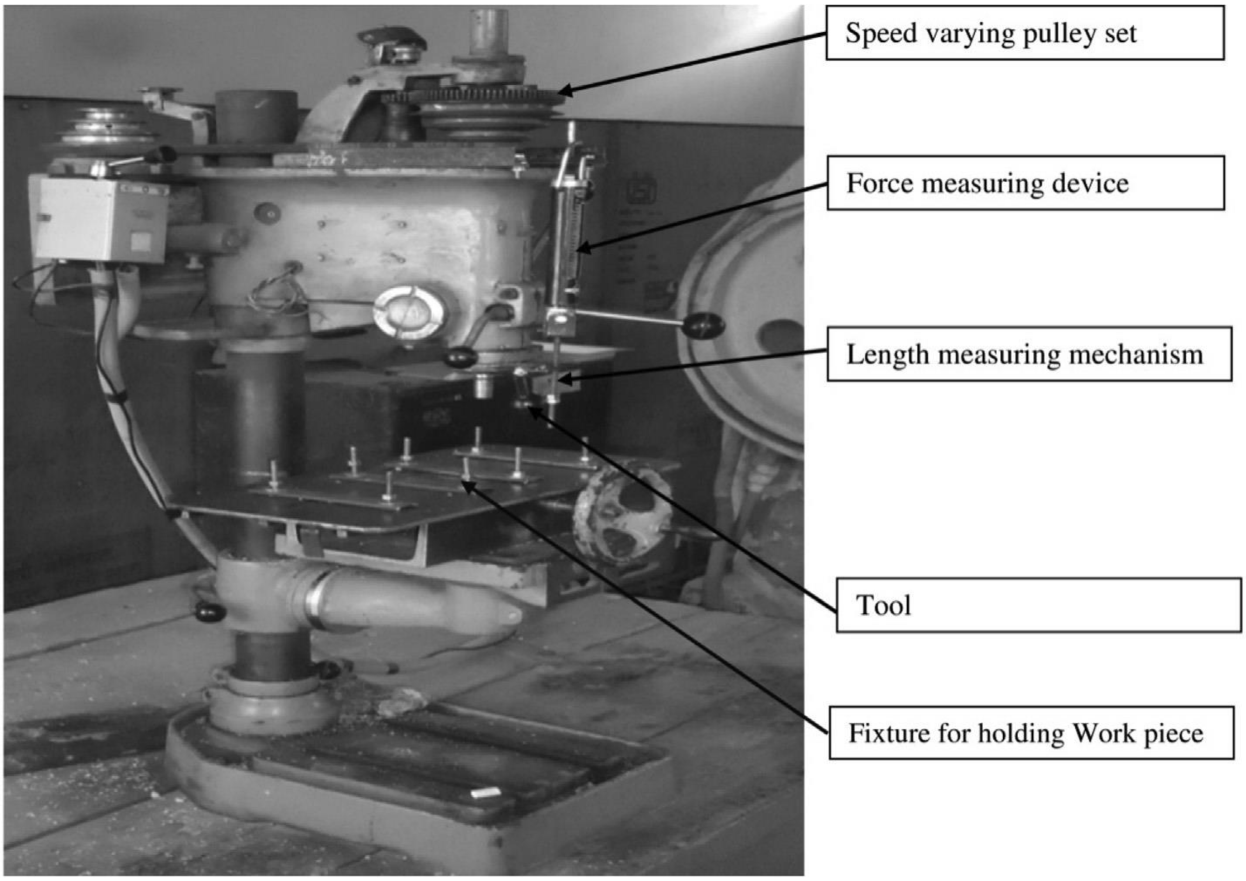


Fig. 4. Friction stirs welding in an experimental setup.

Table 1 shows various tool diameters as well as a magnified cross sectional image of the tool (M.S. straight cylindrical tool with concavity).

Table 1. Tool Geometry and Specifications of Tools for 6 mm sheet HDPE Sheet.

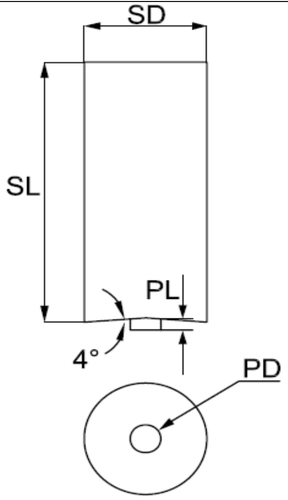
Tool Geometry	Tool Material & Type	Shoulder Diameter (SD)	Shoulder Length (SL)	Pin Size (PD)	Pin Length (PL)	Shoulder Concavity Angle (SCA)
	M.S. straight cylindrical tool with concavity	30 mm	70 mm	7.5 mm	9 mm	4°

Table 2 shows a welding parameters and ranges utilized in this investigation. Revolving tool sank into the work components at a constant pace down to the appropriate depth with a precision of 0.02 mm.

Table 2. Selected parameters and their ranges.

Parameters	Level 1	Level 2	Level 3
Tool Rotational Speed (rpm)	560	900	1400
Tool Plunge Depth (mm)	10.4	10.6	10.8
Dwell Time(sec)	30	45	60

Specimens having dimensions of 400 mm x 75 mm were created during the experiment. The fixture is made out of a clamping plate that ensures even pressure distribution on sheets. The overlap area of the lap joint is 200mm x 75mm, and the sheet thickness is 6 mm. As a result, a tool with a 9 mm pin length was used forpiercing the overlapping region of sheets. Taguchi method of design of experiments is very reliable method. Several authors have used this method in Lapping operation [45]-[46].ofThe L18 OA design of Taguchi method was used for the experimentations. The trials were carried out with speed variations of 560, 900, and 1400 rpm; tool plunge depth variations of 10.4, 10.6, and 10.8 mm; and dwell duration variations of 30–60 sec.

3. Results and Discussions:

3.1. Tool rotational speed effectupon peak temperature in the joining zone

Fig. 7. showsresult of rotational speed of tool at 560 rpm on a peak temperature in a joining zone. It shows that rotational speed of tool at 560 rpm, peak temperature in joining zone varies from the 95 to 98 degree Celsius.

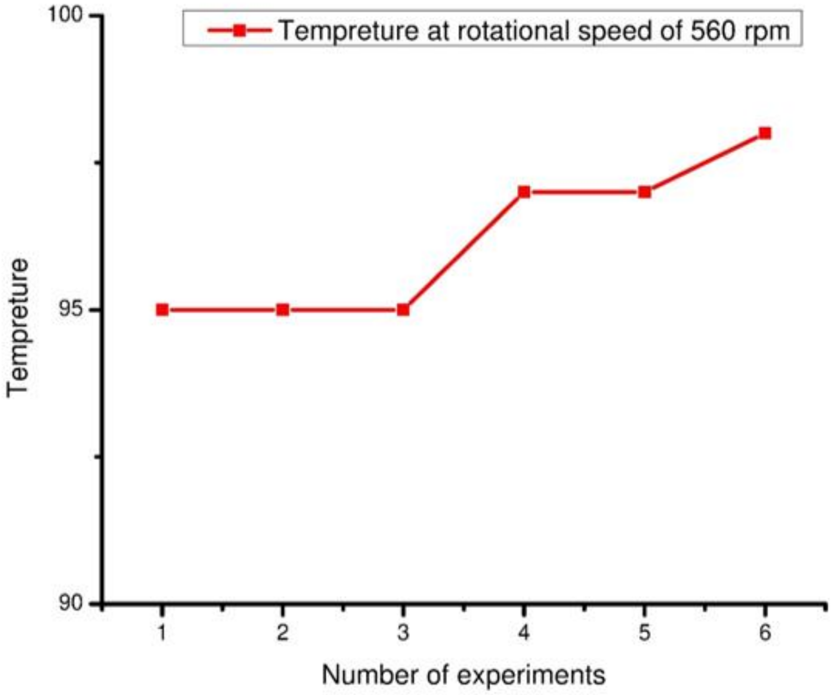


Fig. 7. Influence of rotational speed of tool at 560 rpmupon peak temperature

Fig. 8. shows the result of rotational speed of toolat900 rpm upon peak temperature in joining zone. It clearly shows that rotational speed of tool at 900 rpm, peak temperature in joining zone varies from the 108 to 115 degree Celsius

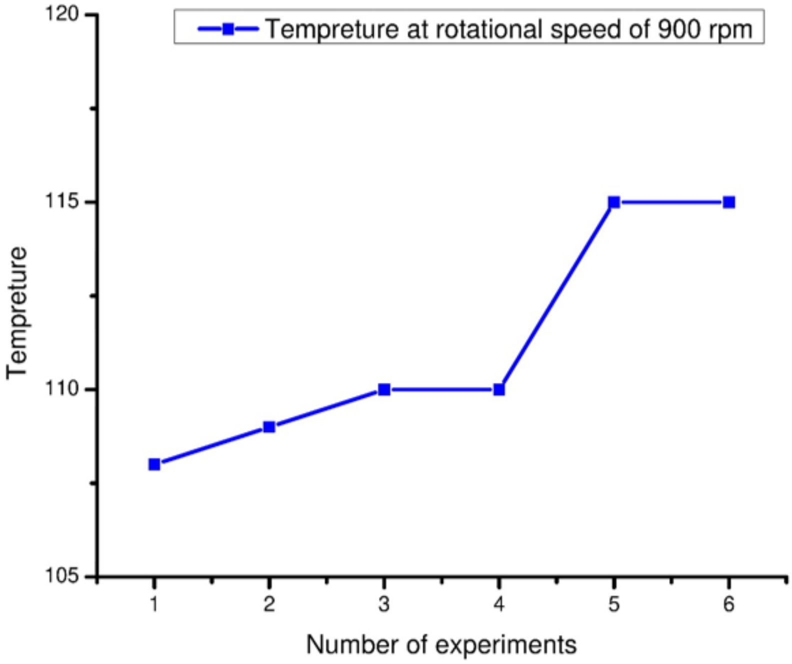


Fig. 8. Influence of rotational speed of tool at 900 rpm upon peak temperature

Fig. 9. showsinfluence of rotational speed of tool at 1400 rpm on the peak temperature in the joining zone. It clearly shows that rotational speed of tool at 1400 rpm, peak temperature in joining zone varies from the 119 to 130 degree Celsius.

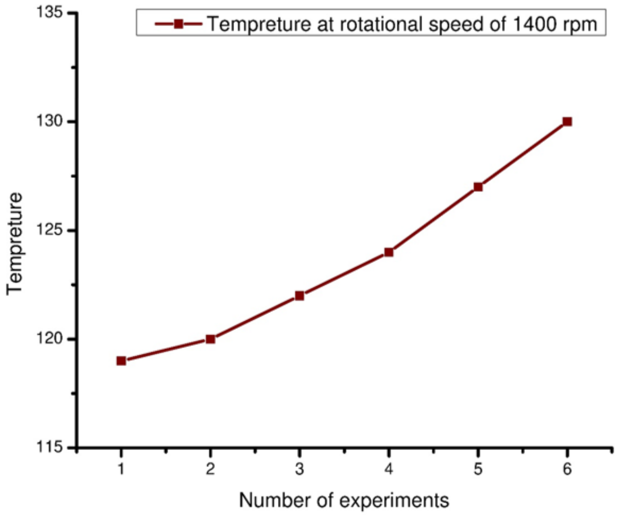


Fig. 9. Effect of tool rotational speed of 1400 rpm on the peak temperature

Fig. 10. shows the combined effect of tool rotational speed of 560, 900 and 1400 rpm on the peak temperature in the joining zone. From fig. 10, it can be seen that for tool rotational speed of 560, 900 and 1400 rpm peak temperature in the joining zone varies from the 95 to 98 degree Celsius, 108 to 115 degree Celsius, and 119 to 130 degree Celsius respectively. Maximum peak temperature of 130 degree Celsius was observed at a rotational speed of 1400 rpm whereas the lowest peak temperature of 95 degree Celsius was observed at a rotational speed of 560 rpm. This trend shows that the peak temperature in the joining zone is directly proportional to the rotational speed of the tool.

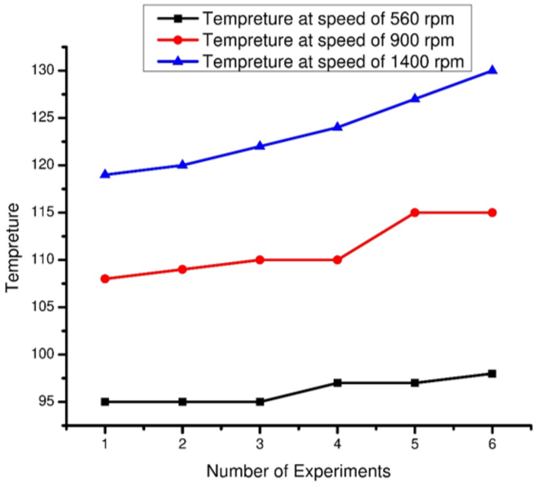


Fig. 10. Combined effect of tool rotational speed of 560, 900 and 1400 rpm

With increased traverse speed, i.e., quicker tool movement, the production of frictional heat decreases and becomes inadequate to distort the material plastically. Therefore, greater rotating speed is required to compensate for the inadequate heat production. The increased rotating speed increased the friction between the shoulder and the polyethylene sheet, resulting in additional heat production.

4. Conclusions

High density polyethylene sheets are weldedutilisingFSSW in this study. Impacts of tool rotational speed are explored and connected to the joining zone's peak temperature. The following are the primary findings that can be derived from this study:

(1) It is possible to generate good weld connections with HDPE utilisingFSSW technology.

(2) The tool rotating speed influences the production of FSSW nuggets and the joint strength.

(3) The increased rotating speed increased the friction between the shoulder and the polyethylene sheet, resulting in additional heat production.

(4) If optimal welding settings are applied, FSW of HDPE may be a viable alternative to traditional joining procedures.

(5) Future study should focus on evaluating tool performance by altering tool material, shoulder diameter (SD), shoulder length (SL), pin size (PD), pin length (PL), shoulder concavity angle (SCA), and pin angle (PA).

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