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Cost Estimation of Pipe Friction Stirs Welding

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ABSTRACT

Friction stir welding was a promising welding technology from the same moment of its existence because of its easy use, being ecologically friendly processed and with no need for filler metal. The present paper discusses the cost analysis of pipe friction stir welding spicily aluminum 6061.cost estimation were performed on pipe with different thickness 2 to 4 mm. rotational speeds 485 to 1800 RPM and a travel speed 4 to 10 mm/min. The each cost component of joining Al 6061 aluminum pipe welding was each component cost (Labor cost, Power cost, Machine cost and Tooling cost) has been closely analyzed and major cost components have been included in the cost model. We used these cost models to predict the cost of friction stir welded pipe joints. Initial results show that the rotational speed, material thickness and travel speed increased due to increase the total cost.

Keywords: *Friction Stir Welding; Aluminum Pipe; Cost Analysis.*

1.0 Introduction

Aluminum can't successfully be arc welded in an air environment, due to the affinity for oxygen. If fusion welded in normal atmosphere oxidization readily happens and this outcome in both slag inclusion and porosity in the weld, greatly reducing its mechanical properties. In modern years, there has been a potent demand for lightweight transport equipment.

The use of aluminum alloys to substitution ferrous alloys in transport equipment is most effective in reducing the weight of automobiles and aerospace vehicles. Considerable tonnages of aluminum alloys are used in the transport manufacture. In that esteem, the strength to weight ratios of aluminum alloys has thus been a predominant design consideration. Several strengthening mechanisms have been used in the else 30 years to incubate new aluminum alloys with high strength to weight ratios. Stampede hardening, precipitation hardening, and improvement of grain structure provide active strengthening mechanisms [1-2].

Fusion welding of mercantile aluminum alloys is mostly hard and not bespoke for some aluminum alloy groups. The existence of protective tenacious oxide film on aluminum alloys is accountable for such difficulties. Extensive surface planning to take off the oxide film are needful before welding of some aluminum alloys.

Fusion welding of Al-alloys, whilst, faces some other problems, such as, generation of welding defects such as blowholes, cracks, welding distortion, and angular distortion, which reduced the mechanical properties of weldments. Fusion welding of high strength Al-alloys caused significant changes in the microstructure of cold worked and age hardened alloys, which drastically decrease the mechanical properties of welded alloys.[3-4].

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In this work study effective material thickness and addition Aluminium Oxide powder on mechanical properties by friction stir welding pipes. The advantage of hydro forming of FSW tubes is the tailoring of the starting materials that can vary in thickness and/or composition to optimize weight or performance. This tailoring is typically carried out in stamping by welding sheets of different thickness together. The blank is then stretch formed and drawn, resulting in a part with optimized weight (Davies et al., 2005; Ambrogio et al., 2006; Grant et al., 2006; and Buffa et al., 2007).

Recently more, attempts have been made to weld dissimilar aluminium alloys, which ultimately could provide flexibility in design as well as optimize strength, weight, and corrosion resistance (Kou and Le, 1984; Lammlein et al., 2010; Longhurst et al., 2010a and 2010b; and Schneider, 2011). To date, no work has been reported on the welding of tailor welded tubes for hydroforming. The study shows the preliminary results on Friction Stir Welding (FSW) of 2024-T3 aluminium alloy tubes and the impact of the welding process on weld quality. Welding was performed on tubes with similar thickness.

The mechanical properties of the welds were assessed by hardness and tensile measurements on as-welded and heat treated tubes (Zeng et al., 2006).So in recent years has spread the use of friction stir welding alloys, aluminium has been used successfully in welding plate In 2013 appeared to use this method in the pipe welding aluminium has been successfully stunning and we began to develop and improve the mechanical properties of the pipes, welded by the addition Aluminium Oxide (Al_2O_3) powder during the welding process[4].

A large number of research papers are available in the literature on various aspects of FS welded aluminium alloy such material flow, development of microstructure and mechanical properties in friction stir welding for plates and sheets, but the research papers that done in pipe parts by using friction stir technique are quite rare and also there is no research in the field of determining the cost of friction stir welding It was alleged that we are one of the first researchers worked in this field in order to implement the Code cost estimation of friction stir welding. The present paper discusses the cost analysis of pipe friction stir welding spicily aluminium 6061.cost estimation were performed on pipe with different thickness 2 to 4 mm. rotational speeds 485 to1800 RPM and a travel speed 4 to 10 mm/min. The each cost component of joining Al 6061 aluminium pipe Welding was Each component cost (Labor cost, Power cost, Machine cost and Tooling cost) has been closely analyzed and major cost components have been included in the cost model. We used these cost suggestion models to predict the cost of friction stir welded pipe joints. Initial results show that the rotational speed, material thickness and travel speed increased due to increase the total cost.

2.0 Experimental work

The cost estimate of friction stirs welding for aluminium pipes 6061 is calculated using special software. The pipe sections, 30mm, and relatively thin walled 2to 4 mm. Wire welded at similar alloy joints using (FSW) process. All process parameters are taken from theoretical study in this work [7-15].

3.0 Cost analysis of aluminium 6061 pipes welded joint

Welding costs may be divided into two categories; the fixed costs and variable cost. The choice of a particular joining process is usually based on cost issues. Therefore, it is necessary to develop a model for cost estimation. Various cost components are available for cost estimation. The commonly occurring components are discussed below. Other cost components critical for special products and processes must be included during cost estimation on a case-specific basis. The typical components of a cost estimate are as follows [16-17]:

1. Labor cost (weld preparation time + actual weld time)
2. Power cost
3. Machine cost
4. Tool cost

3.1 Weld time

The weld time equation for calculating is given in table 1.

$$\text{Weld time } (W_T) = \frac{L}{F} + \frac{d}{F_d} + T_d$$

Table 1: The Weld Time Values

Weld time			
Travels speed mm/min	Material thickness		
	2	3	4
4	30.25	30.38	30.45
8	15.325	15.38	15.45
10	12.325	12.38	12.45

3.1.1 Labor cost

This is one of the most expensive elements contributing to the total weld cost. It should be accounted for properly because careful attention could suggest ways and means to increase productivity by any change that permits a reduction of the total workforce for the job. Because this process is applied semi automatically and automatically, the operator factor can vary widely. Operator factors for semiautomatic welding usually range from 25% to as high as 60%. The cost of labour estimation is based on weld preparation time, number of weld runs and lengths of welds. The rate of production determines the number of working hours and the product of the hourly labour rate and the number of labour hours determines the cost of labour. The model also includes the break time for which the labourers are paid. The labour cost estimation equation for calculating is given below [16-17].

3.2 Machine cost

Machine cost includes the cost of welding equipment, weld preparation equipment, and special handling equipment. The hourly cost of the equipment is calculated from the costs for depreciation, interest, and maintenance, together with an estimate of the annual usage time. The machine cost estimation equation for calculating is given below [16-17].

$$\text{Machine cost} = \frac{[W_T + T_S + T_{ch}] \times C_M}{57}$$

3.3 Power cost

The cost of power includes the number of working hours of the welding machine and its power consumption. The power consumed depends on the power rating of each machine. Heavy machines usually tend to higher rates of power consumption. Hence, the power rating of each FSW machine is used to calculate the cost of power. The power cost estimation equation for calculating is given below [16-17].

$$\text{Power cost} = 0.014 \times P_R \times W_T \times C_P$$
$$\text{Power rating } P_R = 16.7 \times F_x \times w \times r_s$$

3.4 Tool cost

The design of the tool is a critical factor as a good tool can improve both the quality of the weld and the maximum possible welding speed. It is desirable that the tool material is high carbon steel, sufficiently strong, tough and hardwearing, at the welding temperature. [8]. the tool pin penetration depth was suggested to be at least about 90% of the work piece thickness. The tooling cost provides the cost incurred in using a particular tool for making a joint. It also takes into consideration the life of the tool. The tool cost estimation equation for calculating is given below.

$$\text{Tool cost} = \frac{C_T \times Q \times W_T}{T}$$

Experimental studies the total cost of Friction stir welded joint can be calculated as follows. This suggestion model considers various cost components involved in the cost estimation of a FSW joint.

Friction stir welding cost = $L_C + M_C + P_C + T_C$

4.0 Result and Discussion

Contribution of Cost Component on Total Cost Fig. 1 illustrates the cost distribution without considering material cost which includes a large portion (95%) of the total cost.

It has been found that the cost of labour is the major contributor towards the total cost of a joint and the cost of a joint depends predominantly on the length of the weld for joints considered.

Along with the length of weld, and thickness of the base pipe, the material of the joints is also depends.

In this work, the present optimum welding parameters are spindle speed 485 to 1800 RPM, travel speed 4 to 10 mm/min and material thickness 2 to 4 mm.

5.0 Effect of Welding Parameters

Based on the above results, the total cost of FSW of 6061 Aluminium pipe, alloy is discussed for optimum process parameters of rotational speed, travels speed and material thickness and the effect of that parameter on the total.

The effect of rotation speed at the total cost of friction stirs welded 6061 aluminium pipes was shown in fig. 2 to fig.10 it concludes that, the total cost of weld joint was less at lower rotation speeds (485 RPM).

As the rotation speed is increased from (1800 RPM), there was a significant increase in the total cost also.

The total cost increased up to a maximum rotation speed of 1800 RPM and material thickness 4 mm.

If the travel speed is beyond 10 mm/min, it was observed that the total cost of the weld joint is decreasing at material thickness 2mm and travel speed 4mm/min.

Fig 1: Shows the Cost Distribution for Weld Joint Fabricated Using FSW Process.

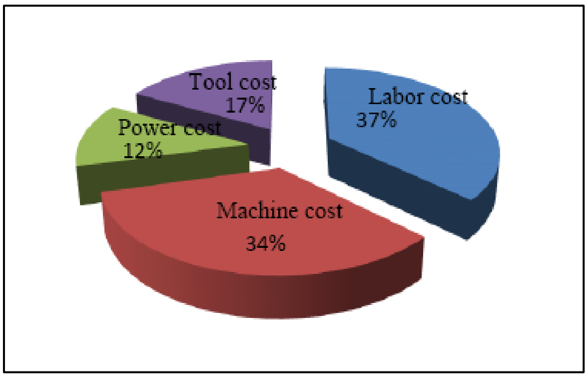


Fig 2: Relation Between Rotation Speed and Total Cost (At Travel Speed 4 mm/min and Material Thickness 2mm)

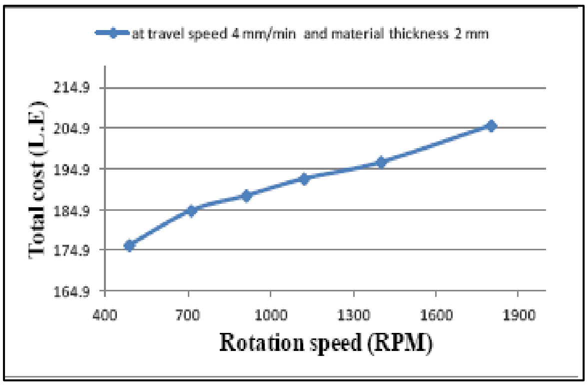


Fig 3: Relation Between Rotation Speed and Total Cost (At Travel Speed 8 mm/min and Material Thickness 2mm)

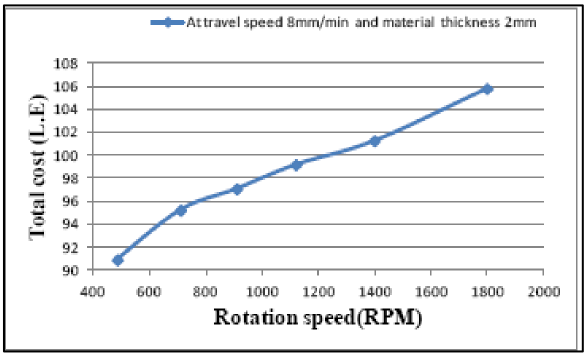


Fig 4: Relation Between Rotation Speed and Total Cost (At Travel Speed 10 mm/min and Material Thickness 2mm)

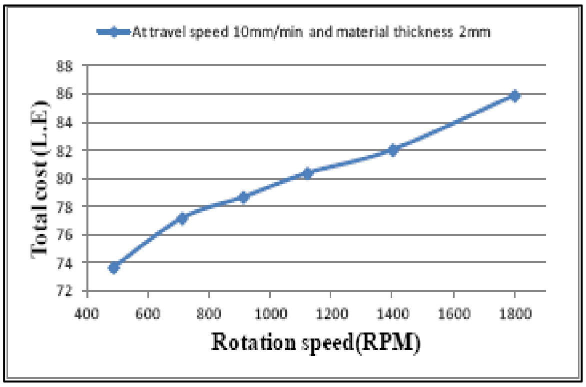


Fig 5: Relation Between Rotation Speed and Total Cost (At Travel Speed 4 mm/min and Material Thickness 3mm)

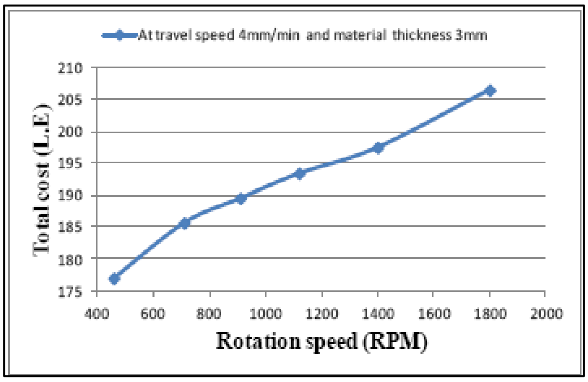


Fig 6: Relation Between Rotation Speed and Total Cost (At Travel Speed 8 mm/min and Material Thickness 3mm)

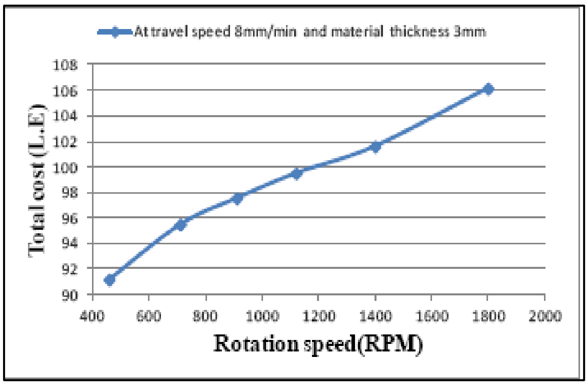


Fig 7: Relation Between Rotation Speed and Total Cost (At Travel Speed 10 mm/min and Material Thickness 3mm)

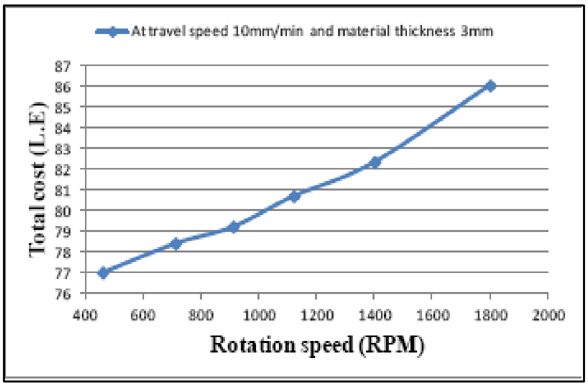


Fig 8: Relation Between Rotation Speed and Total Cost (At Material at Travel Speed 4 mm/min and Thickness 4mm)

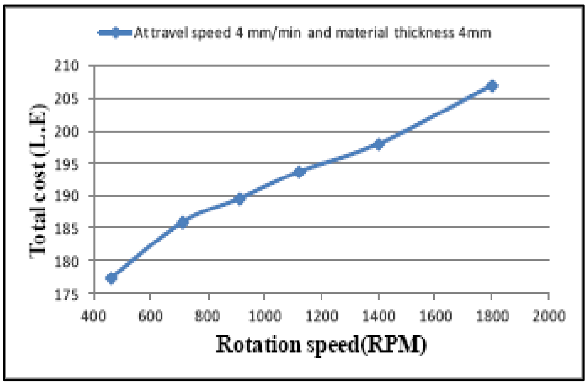


Fig 9: Relation Between Rotation Speed and Total Cost (At at Travel Speed 8 mm/min and Material Thickness 4mm)

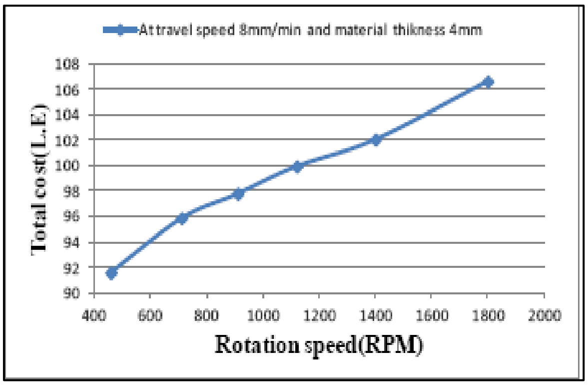


Fig 10: Relation Between Rotation Speed and Total Cost (At at Travel Speed 10 mm/min and Material Thickness 4mm)

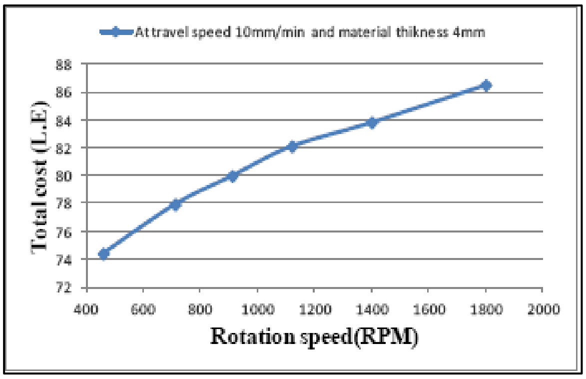


Fig 11: Relation Between Rotation Speed and Tool Life

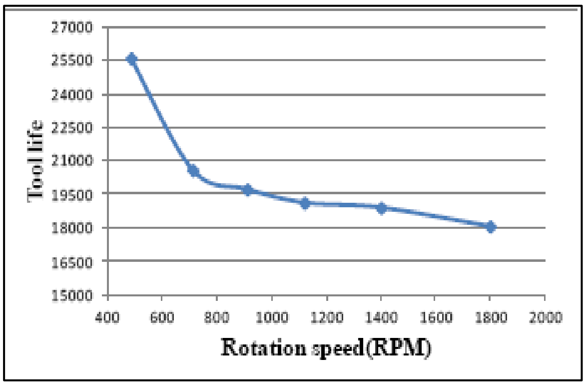


Fig 12: Relation Between Experimental Total Cost and Predicted Total Cost

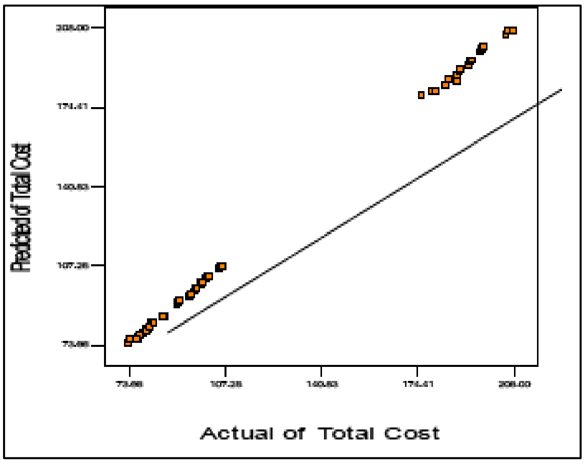


Fig 13: Bar graph Showing the Maximum Desirability of 0.665 for the Combined Objective

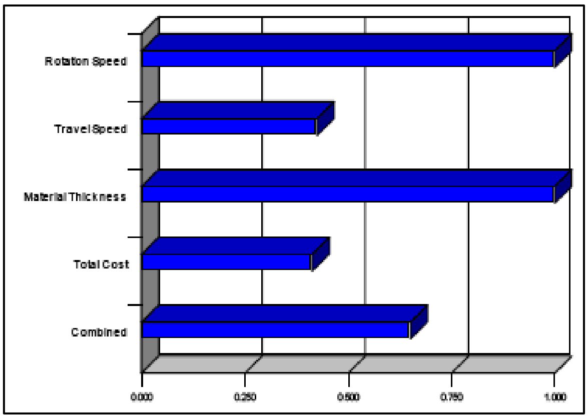


Fig 14: shows the maximum desirability of 0. 665 for the combined objective

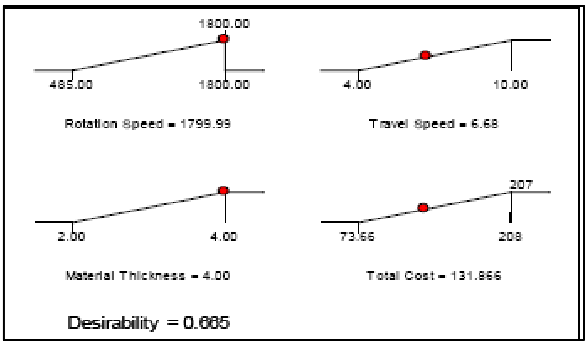


Fig 15: Main Affects Plot for Total Cost Values

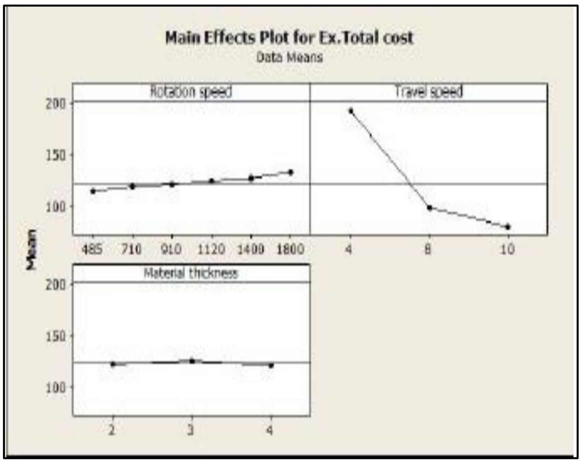
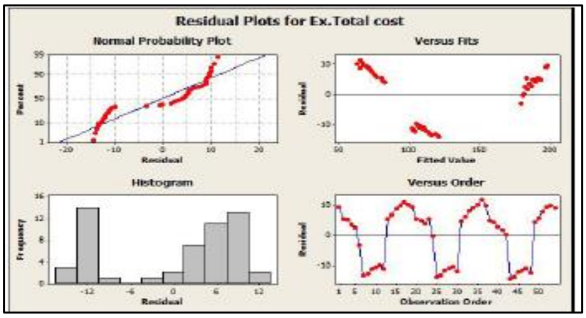


Fig 16: Residual Plot for Total Cost



Residual is the fitting the total cost error it is the difference between the actual total cost value and the predicted of the total cost estimate. Standardized residual for total cost is defined as the residual of the total cost divided by the standard deviation of residuals total cost. Normal Probability Plot: The normal plot of the residuals displays the residuals versus their expected values when the distribution is normal.

Use the normal probability plot of residuals to verify the assumption that the residuals are normally distributed. The normal probability plot of the residuals should approximately follow a straight line. Residuals versus Fits: The residuals versus fits graph plots the residuals on the y-axis and the fitted values on the x-axis. Use the residuals versus order plot to verify the assumption that the residuals are independent of other seen from fig. 16.

6.0 Checking for Adequacy of Model

The total cost value and total cost predicted value of the responses from regression equations are approaching in it seen from figure 12which detects that there is a perfect correlation between the total cost value and predicted total cost value of the responses. Which it has been introduced considerations signalize a very good sufficiency of the suggestion regression models. It can be seen from figure 12 relation between total cost and predicated total cost .All the coefficients were evaluated and tested by applying 'F-test' using Design-Expert software for their significance at a 90% confidence level. After locating the significant coefficients, the final suggestion model was developed to total cost of FSW joints of 6061 aluminum pipes as given below.

7.0 Optimization of parameters of FSW on responses

One of the most substantial objectives of this realization was to maximize the total cost of friction stir welded joints pipes of Al 6061 and also, find the optimum process parameters from the suggestion model developed. We feel that numerical optimization such describes multiple response methods called desirability this method used to solve multiple response optimization problems, combines multiple responses into a dimensionless measure of performance called the overall desirability function. The desirability ranges between 0 and1.The suggestion model predicted optimal results from above technique are a total cost that can be obtained is 208. The acquired desirability value of 0.477 shows fig. 13and fig.14.

8.0 Graphical Results for Total Cost

8.1 Rotational Speed

The Rotational speed is directly proportional to the total cost of the weld. The frictional heat input increases with increase in the rotational rate of the tool. Thus the increase in the Rotational speed enhances the heat input of the process which in turn results in better material flow and increases the material to be displaced in a unit time. The maximum total cost of the weld is also seen when the process parameter rotational speed set at a higher level in the process window show figure 15.

8.2 Travel speed

As travel speed is one of the important process parameters, the considered level doesn't affect the responses as the variation in the level average is not appreciable.

This implies within the selected range of process window the levels can be fixed at any level to have the desired output show figure 15.

8.3 Material thickness

Total cost of the welded joints depends on the material thickness. The material thickness with flat surfaces is associated with eccentricity, which allows the material to flow around the pin. The tapered pin profile produces the pulsating action as the ratio between the static volumes to the dynamic volume is more than one show fig. 15. Residual is the fitting the total cost error it is the difference between the actual total cost value and the predicted of the total cost estimate. Standardized residual for total cost is defined as the residual of the total cost divided by the standard deviation of residuals total cost. Normal Probability Plot: The normal plot of the residuals displays the residuals versus their expected values when the distribution is normal show fig. 16. Use the normal probability plot of residuals to verify the assumption that the residuals are normally distributed. The normal probability plot of the residuals should approximately follow a straight line. Residuals Versus Fits :The residuals versus fits graph plots the residuals on the y-axis and the fitted values on the x-axis. Use the residuals versus order plot to verify the assumption that the residuals are independent from other.

Fig 17: Multi-Vari Chart for Total Cost by Rotation Speed, Material Thickness and Travels Speed

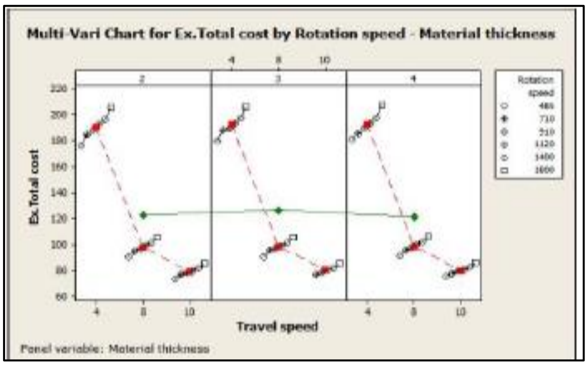
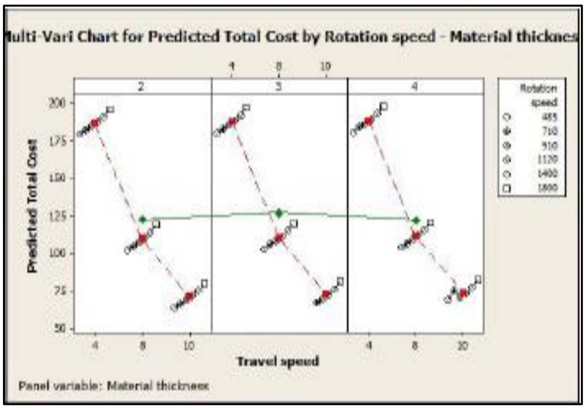


Fig 18: Multi-Vari chart for Predicted Total Cost by Rotation Speed, Material Thickness and Travels Speed



It is shown in Fig. 17 and Fig.18, Multi-Vari chart for total cost and predicted total cost by rotation speed, material thickness and travels speed shown in Fig. 17 and Fig.18 that the decrease metal thickness welded whenever the overall low total cost of friction stir welding and increase the rotational speed and travels speed increases the total cost of friction stir welding and appear as line red which is the average rotation speed at travels speeds and green the amount of the deviation between the travels speed and rotational speed

9.0 Conclusions

The FSW cost suggestion model in this paper includes certainties in the assumptions due to the novelty in the process. The model is expected to provide decision-makers with a set of decision-making models of the friction stir welding process, including the determination of material aluminium pipes 6061 cost, under various evaluation cost.

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Nomenclature

CL	Unit labor cost (L.E/HR)
CM	Unit machine cost (L.E /HR)
CP	Unit cost of power (L.E /kWh)
CT	Unit cost of tool (L.E /tool)
Cpc	Variable power cost per joint (L.E)
Clc	Labor cost per joint (L.E)
Cmc	Machine cost per joint (L.E)
Ct	Tool cost per joint (L.E)
Ctotal	Total cost of the joint (L.E)
F	Tool feed rate (mm/min)
Fp	Tool plunge feed rate (mm/min)
L	Length of the weld (mm)
n	Number of weld passes
S	Travel speed (mm/min)
TCh	Tool change-over time (min)
Td	Dwell time (min)
TS	Setup time (min)
TW	Weld preparation time (min)
Z	Thickness of the base material (mm)