



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

# IJRSET

International Journal of Innovative Research in  
**SCIENCE | ENGINEERING | TECHNOLOGY**

# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 12, Issue 6, June 2023

**ISSN** INTERNATIONAL  
STANDARD  
SERIAL  
NUMBER  
INDIA

Impact Factor: 8.423

9940 572 462

6381 907 438

[ijirset@gmail.com](mailto:ijirset@gmail.com)

[www.ijirset.com](http://www.ijirset.com)

# Optimization of Process Parameter for Friction Stir Welding Process

Milan Rajyaguru<sup>1</sup>, Mr. Bimal Patel<sup>2</sup>

P.G. Student, Department of Mechanical Engineering, Swaminarayan College of Engineering & Technology, Saij, Kalol, India<sup>1</sup>

Assistant Professor, Department of Mechanical Engineering Swaminarayan College of Engineering & Technology, Saij, Kalol, India<sup>2</sup>

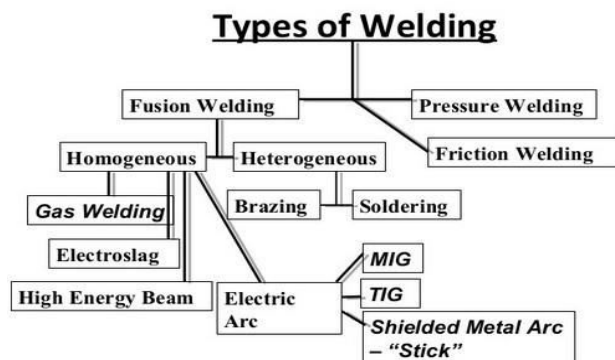
**ABSTRACT:** Image Friction stir welding process is a novel solid-state joining process that is environmental friendly and versatile in its applications. Counted as one of the most significant developments in this age, friction stir welding process is used to joining of high strength alloys which present difficulties with the conventional fusion techniques. As one of the most significant developments as far as metal joining is concerned, friction stir welding process requires less energy as compared to conventional welding methods; no flux or gas is required hence making the friction stir welding process environmentally safe. Being an efficient method, friction stir welding process doesn't involve any filler metal hence any alloy can be joined without consideration of compatibility of composition as opposed to conventional welding methods where compatibility is an issue. This project highlights the fundamentals and optimization of process parameters of friction stir welding process and gives a review of studies that have been conducted to improve this method with a focus on similar materials

**KEYWORDS:** stir welding, friction welding, strength, clamping location, tool travel speed, rpm.

## I. INTRODUCTION

Welding is a process of joining two metal pieces as a result of significant diffusion of the atoms of the welded pieces into the joint (weld) region. Welding is carried out by heating the joined pieces to melting point and fusing them together (with or without filler material) or by applying pressure to the pieces in cold or heated state. A solid state of welding process is when taken into consideration only friction welding is used, over here weld joint is made by heating created from mechanically induced sliding motions between two surfaces. The friction welding is one of the solid state welding processes, where weld joint is made by heating is created from mechanically induced sliding motion between rubbing surface in under pressure. The heat is generated by co-efficient of friction of the material. To get a quick heat from surface area, when the rotational speed is high. This technique, which we refer to as "friction welding" provides a very simple method of joining a probe to a work piece. The Types of Friction welding is shown as below:

### TYPES OF FRICTION WELDING:



1. Linear Friction Welding:
2. Spin Welding:

3. Rotary Friction Welding:
4. Inertia Friction Welding:
5. Friction surfacing:
6. Friction Stud Welding:
7. Friction Stir Welding:

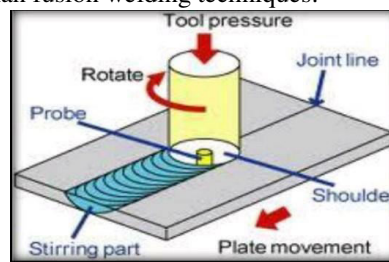
### **Friction Stud Welding**

Friction stud welding provides the capability to weld a pattern of studs to the hull of a disable submarine, to which a pad- eye can be attached for the SRC haul-down cable and life support gas can be provided by means of a hot tap process using hollow studs Combined with an ADS, the system provides rescue capabilities well beyond 300 feet (91m) Concurrent with the Navy's application for underwater friction stud welding for submarine rescue, Oceaneering pursued the application commercially for offshore platform repairs

### **Friction Stir Welding**

Friction stir welding also produces a plasticized region of material, but in a different manner. A non-consumable rotating tool is pushed into the materials to be welded and then the central pin, or probe, followed by the shoulder, is brought into contact with the two parts to be joined. The rotation of the tool heats up and plasticizes the materials it is in contact with and, as the tool moves along the joint line, material from the front of the tool is swept around this plasticized annulus to the rear, so eliminating the interface Friction stir welding (FSW) is a novel welding technique invented by The Welding Institute (TWI) in 1991. FSW is actually a solid-state joining process that is a combination of extruding and forging and is not a true welding process. FSW has several advantages over fusion welding. Some of the process advantages are given below

1. FSW is energy efficient.
2. FSW requires minimal, if any, consumables.
3. FSW produces desirable microstructures in the weld and heat-affected zones
4. FSW is environmentally "friendly" (no fumes, noise, or sparks)
5. FSW can successfully join materials that are "unweldable" by fusion welding methods.
6. FSW produces less distortion than fusion welding techniques.



**Fig 1.2.6 Friction stir welding**

### **INTRODUCTION OF FRICTION STIR WELDING**

The process, uses a rotating, non-consumable tool, consisting of a bigger circular area, the shoulder, with a smaller diameter pin sticking out, the probe. The process is typically described in four steps: The plunge operation: the rotating probe is slowly pressed down until the shoulder make Contact with the material. The dwelling period: the tool maintains its position, generating frictional heat until the desired temperature is reached. The actual welding operation: the rotating tool is moved along a joint line with a certain contact pressure between the tool and the material and a predefined traverse speed. This creates a solid state joint, i.e. without melting the material. The heat generation is mainly due to the frictional heat, generated between tool and material, and also by material deformation, similar to a

hot-working process. The probe on the tool stirs the plasticized material, creating a very fine micro-structure. To create more pressure and preventing void formation behind the probe, the tool is often tilted towards the trailing edge of the tool. This “tilt-angle” is typically between 1 and 3. Finally when the joint is created, the tool is pulled up, leaving a small “key-hole” in the end. Friction-stir welding (FSW) is a solid-state joining process (meaning the metal is not melted) and is used for applications where the original metal characteristics must remain unchanged as much as possible. It works by mechanically intermixing the two pieces of metal at the place of the join, transforming them into a softened state that allows the metal to be fused using mechanical pressure, much like joining clay, dough, or plasticise. This process is primarily used on aluminium, and most often on large pieces which cannot be easily heat treated post weld to recover temper characteristics.

Friction Stir Welding was invented at The Welding Institute in Cambridge, UK, in 1991 and the first patent for FSW in butt joint configuration was filed in 1991 by Wayne Thomas (Thomas et al., 1991). The FSW process is one of the latest innovations in the area of welding. It has several advantages compared to traditional fusion welding techniques and is mainly used for lightweight alloys such as aluminium and magnesium. Friction stir welding (FSW) is a solid-state welding process developed by The Welding Institute (UK) in 1991, and now being used increasingly for joining aluminum alloys, for which fusion welding is often difficult. FSW uses a rotating tool with a probe travelling along the weld path, and plastically deforms the surrounding material to form the weld.

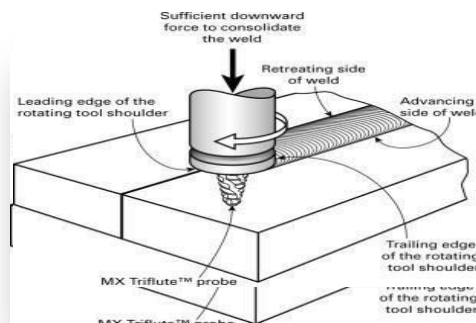


Fig 1.3.2 Friction stir welding with tool

The material subjected to FSW does not melt and recast, the resultant weld offers advantages over conventional fusion welds, such as less distortion lower residual stresses and fewer Defects. When developing such a technology, one of the most important factors is the possibility to join different aluminum alloys. The development of sound joints between dissimilar materials is a very important consideration for many emerging applications, including ship building, aerospace, transportation, power generation, as well as the chemical, nuclear, and electronics industries.

**WHY FSW?**

MIG welding is a flexible and productive method and is therefore widely used for welding of aluminum alloys in shipbuilding. However, two disadvantages with MIG welding are deformation of the base material and a decrease in strength within the heat affected zone. Other fusion welding techniques like TIG and plasma welding are also widely used. However, these methods have the same weakness as MIG welding. FSW presented an alternative welding/joining technique to existing fusion welding methods. The solid-state nature of FSW leads to several advantages over fusion welding methods as problems associated with cooling from the liquid phase are avoided. Issues such as [porosity](#), [solute redistribution](#), [solidification cracking](#) and [liquation cracking](#) do not arise during FSW. In general, FSW has been found to produce a low concentration of defects and is very tolerant of variations in parameters and materials.

FSW steel involves taking the process into a considerably higher operation temp required than it normally used for aluminum alloy. Major advantage is that decrease heat input relative to arc weld this leads to improve mechanical properties as well as decrease distortion and residual stress. So friction stir welding are very use in the aerospace marine and railway industries. FSW steel involves taking the process into a considerably higher operation temp required than it normally used for aluminum alloy Major advantage is that decrease heat input relative to arc weld this leads to improve mechanical properties as well as decrease distortion and residual stress. As tool passes the weld cools

there by joining of two plates together. since max. Temp created by FSW process usually less than 80% of the melting temp of the therefore FSW can avoid welding defect cause by traditional fusion welding.

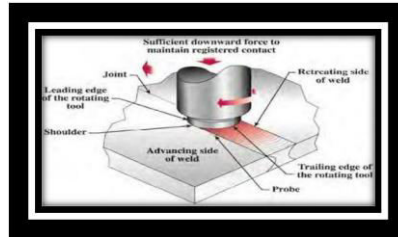


Fig 1.3.3 Fsw with joint penetration

**PRINCIPLE OF OPERATION**

The nib is slightly shorter than the weld depth required, with the tool shoulder riding a top the work surface. A constantly rotated cylindrical-shouldered tool with a profiled nib is reversely fed at a constant rate into a butt joint between two clamped pieces of butted material. the mechanical mixing process and the adiabatic heat within the material is generate the heat, produce the stirred materials to soften without melting. when the pin is move in down word direction and come in tocontact with work piece Frictional heat is generated between the wear-resistant welding components and the work pieces

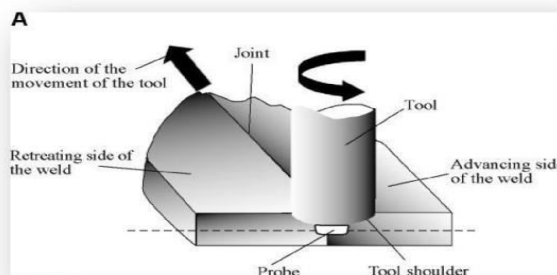


Fig 1.4.1 Operational principle of Fsw process

As shown in the fig tool travel along the weld line result in hard state is deform and dynamic recrystallization of the material base should be done.

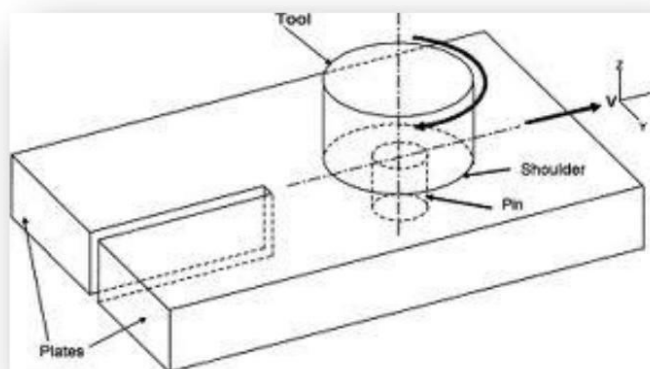


Fig 1.4.2 3-D view of Fsw process

**II. METHODOLOGY**

Effect of some important parameter such as rotational speed & transverse speed on weld properties is major topics for researchers. In order to study the effect of FSW process parameter, mostly follow the traditional experimentally techniques, Though research work applying DOE method have been reported in literature. It appears that the optimization of process parameter of different material combination using DOE method has not been reported yet.



Considering the above fact, the DOE method is adopted to analyze the effect of each processing parameter for optimal tensile strength for friction stir welding joint of different material.

We had studied different parameter which is most essential for FSW process out of them we had taken following input parameter for our project work.

- 1. Tool rpm
  - 2. Welding speed.
  - 3. Clamping position
- (b) Basic of parameter
- 1. Tool rpm: 45 - 2000 r.p.m
  - 2. Welding speed: 16-800 mm/min
  - 3. Clamping position (At some distance from one side)

By the DOE(Design of experiment) method of comparison was done and tensile strength of weld workpiece was found. DOE method In common use DOE or experimented design is the design of any source by which information-gathering practice where variation is present, this can be either full control of experiment or not. In statistical display this terms are usually used for controlled experiments. General planning of experimentation is used to evaluate physical objects, chemical composition, structure, component, and the material used in it. The related other study are discussed the article and opinion votes and surveying it statistically, natural experiments etc. For query study the experiments and differences between this types of study. The person performing the experiment is usually interested in seeing its effect on the same process or treatment on some object which maybe people, parts of people, groups of people or anything. Thus the process of carrying the design of experiments has very huge application over engineering. A method of DOE is designed by Ronald Fisher in the books written by him. "The arrangement of Field Experiment" and "Design of Experiments. Conclusion of the optimum parameter combination for obtaining good tensile strength.

### III. EXPERIMENTAL PROCEDURE

Three different parameters were used while this experiment was held. Those parameters were tool rpm, welding speed, and the clamping (holding location) etc. It was to the mark this 3 parameters has an effect of friction stir well. AA 6061 Aluminum Alloy plates were chosen for the present project work. Friction stir welding is done by a special designed tool which is made up of stainless tool. Besides all this a recyclable stainless steel tool is used for welding of 1100 AI alloy tool having description of dia. 10mm and the tool containing pin along with it. Tool used in this has a sharpened pin with circular flat. Pin dia. is 4mm to which the dia. of tool is 8mm also the length is 4mm. On a vertical milling machine the FSW is carried out.



Fig 4.1 Vertical milling machine.

AA1100 sample pieces are mounted and plates are placed in the fixtures. Now fabrication of FSW joints are done by using mechanical clamps so that plate doesn't gets separated. during welding. In these experiment there are three parameters is tool rpm, welding speed & clamping position is used for friction stir welding of the AA6061 aluminium alloy.



Suitable fixture was mounted on the workpiece.. with the help of the collet an tool was mounted on the vertical arbour. the movement of the horizontal bed is along X & Y Axis the vertical tool head can be moved along vertical guide ways Z-axis. On a backup plate an two Aluminum plates of size 60X30mm were perfectly clamped in a milling machine bed.



**Fig 4.2 Fixture for clamping.**

Into the tool holder Specially designed welding tool is inserted. In clockwise direction tool is plunged into the joint in the downward direction with feed rate of 5 mm/min. along the X-axis by feed rate of 10mm/min the tool welded the joint. It is important for good weld joint more intense stirring and mixing of the materials and which is done only by higher tool rotation rates generates higher temperature and generation of heat. For achieving sound weld joint the plunging the tool pin into the work piece.

Thus the rotating shoulder cannot move the stirred material efficiently from the front to the back of the tool pin, resulting in generation of welds with inner channel or surface groove. When the insertion depth is too deep, the shoulder of tool plunges into the work piece creating.



**Fig 4.3 welded part.**

The experiment are carried out with different level of tool rpm, weld speed & clamping location Experimental data are taken for different combination and different level of parameter.

**Table 4.1 experimental data**

Sr No	Tool rpm	Welding speed(mm/min)	Clamping location
1	1200	18	35
2	1200	24	25
3	1200	30	30
4	1400	18	25



5	1400	24	30
6	1400	30	35
7	1600	18	30
8	1600	24	35
9	1600	30	25

**IV. RESULT & DISCUSSION**

This chapter describes results obtained by analysis and TAGUCHI METHOD. After performing analysis of different part of welding joint with various parameters such as tool rpm, welding speed and clamping location, universal testing machine is used to examine the tensile strength.

**Taguchi Model with MINITAB16:**

For understanding the results Minitab gives many analytical and graphing tools. Factorial, response surface, mixture, and Taguchi (robust) these four types of designed experiments are basic methods of Minitab 16 with the Taguchi model. After conducting the analysis and entering the results into Minitab to create, analyze, and graph an experimental design are similar for all design types.

**Table 6.1: Experimental Results Table**

Sr No	Tool rpm	Welding speed(mm/min)	Clamping location	Tensile Strength(mph)
1	1200	18	35	25.24
2	1200	24	25	24.03
3	1200	30	30	23.63
4	1400	18	25	26.52
5	1400	24	30	25.80
6	1400	30	35	25.47
7	1600	18	30	28.12
8	1600	24	35	27.68
9	1600	30	25	26.36

**Experimental Result Analysis:**

After surveying the result first Minitab version 16 was used for the investigation of result. The S/N ratio for tensile strength higher-is-better characteristic, which can be calculated as logarithmic transformation of the loss function as shown below.

Larger is the better characteristic:

$$n = -10 \text{ Log}_{10} [\text{mean of sum of squares of measured data}]$$



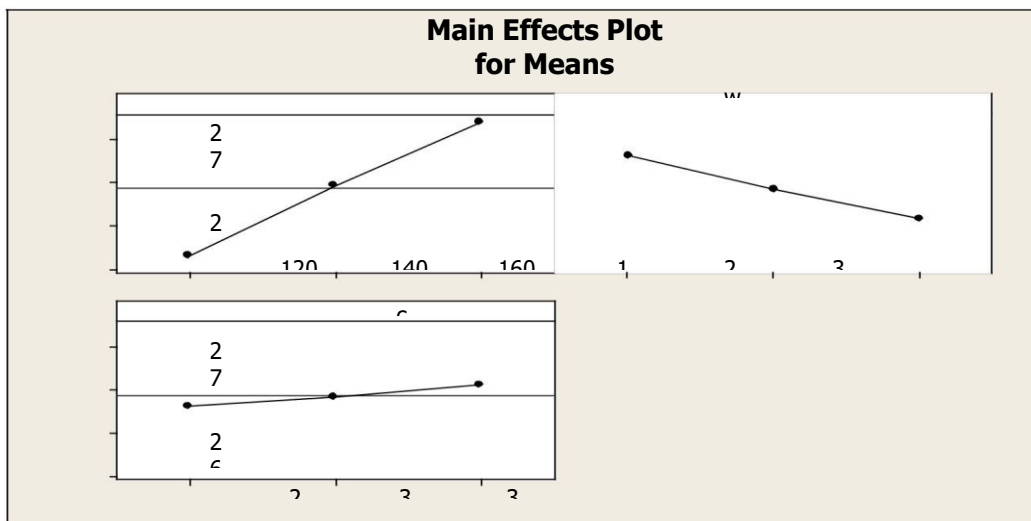


Table 6.2: Experiment result in Minitab

↓	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
	rpm	ws	cl	ts	SNRA1	MEAN1		PSNRA1	PMEAN1	PSTDE1	PLSTD1	
1	1200	18	35	25.24	28.0418	25.24		29.0929	28.3978			
2	1200	24	25	24.03	27.6151	24.03						
3	1200	30	30	23.63	27.4693	23.63						
4	1400	18	25	26.52	28.4715	26.52						
5	1400	24	30	25.80	28.2324	25.80						
6	1400	30	35	25.47	28.1206	25.47						
7	1600	18	30	28.12	28.9803	28.12						
8	1600	24	35	27.68	28.8433	27.68						
9	1600	30	25	26.35	28.4156	26.35						
10												
11												

(S/N) ratio is apply after the result is perform and this experimental result is than forward to signal to noise (S/N) ratio.tensile test was formulated with the help of signal to noise ratio(S/N) are as follow the table. Examine and investigating the better combination of parameter levels is justify a high level oftensile strength.The means & signal to noise (S/N) ratio of the various process parameter when they slightly changed. It is clear that a larger S/N ratio corresponds to better quality characteristics in terms oftensile

Fig 6.1Main Effects Plot for Means of tensile strength





**Table 6.3 Response table for Means of tensile strength**

Level	Tool rpm	Weld speed (mm/min)	Clamp location (mm away)
1	24.30	26.63	25.63
2	25.93	25.84	25.85
3	27.38	25.15	26.13
Delta	3.08	1.48	0.50
Rank	1	2	3

Tool rpm is most affected parameter as compare to of clamping location, and welding speed and we can understand it from values of tool rpm, welding speed and clamping location. With the help of experimental study we see that the tool rpm is most affected parameter as compare to of clamping location, and welding speed when we compare this three process parameters.

**Regression Analysis:**

Tensile test of the welded joint of fs was predicted by simple linear regression model and regression model was developed for all aluminium alloy. **Tensile strength vs rpm, ws, cl** The regression equation is

$$\text{Tensile strength} = 16.5 + 0.00771 \text{ rpm} - 0.123 \text{ ws} + 0.0497 \text{ cl}$$

goodness of fit is indicated by Coefficient of determination (R<sup>2</sup>) by model in this case R<sup>2</sup> (0.9970) indicates only <1% total variation are not explained by the model.

**V. CONCLUSION**

Special importance on finding optimal welding parameter for tensile strength. This presented in this thesis has focused on optimization of process parameter of a fs process. For good tensile strength of the welding joint which parameters is most effective is find out is main aim of this research. Three input parameters rotational speed, welding speed & clamping location of the different combination is use for finding out tensile strength of weld joint and also which combination of parameter is most effective is basic research of this research. In this experiment that are the among the nine joint produced in this investigation. this joints was produced with different combination of parameter as per doe method. after that tensile test of each joint. Ultrasonic testing machine is use for tensile test of each joint.

The rotational speed of the tool has got significant effect on tensile strength followed by the welding speed and clamping location we conclude after finishing of the experimental work and the determination of tensile strength. When rotational speed of the tool are increase increasing the tensile strength of weld joint. Tensile strength is higher with lower welding speed & the clamping location of the work piece is center (35 mm away). this indicates the higher range of tool rpm, lower range of welding speed & clamping location of the work piece is center is suitable for achieving the maximum tensile strength. So that the tool rotational speed has been found dominant parameter for tensile strength, followed by welding speed & clamping location shows minimal effect on tensile strength of the weld joint. After that the response surface methodology was adopted to develop the regression analysis which were check for their adequacy

using annova test.

Tensile strength is 27.80 mpa is find out after performing the experiment by below set of parameter. Tool rotational speed 1600rpm ,welding speed 18mm/min, clamping location are 35 mm away

#### REFERENCES

- [1] Malde, M. (2009). Thermomechanical modeling and optimization of friction stir welding. Louisiana State University and Agricultural & Mechanical College.
- [2] Nielsen, S. (2010). Top management team diversity: A review of theories and methodologies. *International Journal of Management Reviews*, 12(3), 301-316.
- [3] Buffa, G., Fratini, L., & Pasta, S. (2008, August). Residual stresses in friction stir welding: numerical simulation and experimental verification. In *International Centre for Diffraction Data. Proceedings of the ICRS-8 8th International Conference on Residual Stresses* (pp. 444-453).
- [4] Ganesh, P., & Kumar, V. S. (2011). Finite element simulation in superplastic forming of friction stir welded aluminium alloy 6061-T6. *International Journal of Integrated Engineering*, 3(1), 9-16.
- [5] Oliphant, A. H. (2004). Numerical modeling of friction stir welding: a comparison of alegra and forge3. Brigham Young University.
- [6] Prasanna, P., Rao, B. S., & Rao, G. K. M. (2010). Finite element modeling for maximum temperature in friction stir welding and its validation. *The International Journal of Advanced Manufacturing Technology*, 51(9-12), 925-933.
- [7] Zna, N. A. T. E. Z. N. E., Pomi, I. T., & Zvarov, N. (2011). The tensile behavior of friction-stir-welded dissimilar aluminum alloys. *Materiali in tehnologije*, 45(6), 623-626.
- [8] Mohanty, H. K., Venkateswarlu, D., Mahapatra, M. M., Kumar, P., & Mandal, N. R. (2012). Modeling the effects of tool probe geometries and process parameters on friction stirred aluminium welds. *J. Mech. Eng. Autom*, 2(4), 74-79.
- [9] Jayaraman, M., Sivasubramanian, R., Balasubramanian, V., & Lakshminarayanan, A. K. (2009). Optimization of process parameters for friction stir welding of cast aluminium alloy A319 by Taguchi method.



SJIF Scientific Journal Impact Factor

Impact Factor: 8.423



# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

 9940 572 462  6381 907 438  [ijirset@gmail.com](mailto:ijirset@gmail.com)



[www.ijirset.com](http://www.ijirset.com)

Scan to save the contact details