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# Optimization of Friction Stir Welding Parameters of Aluminium Alloy Using Taguchi Method

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***Abstract:***

Friction Stir Welding is the most effective welding technique that welds dissimilar metal with accurate mechanical and metallurgical properties. In this research investigation, Aluminium 6061 and Aluminium 7075 grade is used as a base material. The input parameters such as Spindle speed (rpm), Welding speed (mm/min) and Welding time (sec) are used when the output parameters is Tensile strength in terms of N/mm2. Taguchi L9 orthogonal array is used to identify the ranking process and Analysis of variance is used to identify the most significant parameters and contribution of process parameters. By using experimental results, the optimized parameters are analyzed and confirmed.

***Keywords:*** *Aluminium 6061, Aluminium 7075.*

## I. INTRODUCTION

Friction Stir welding (FSW) is identified as the most influencing welding technique and it play a vital role in industrial applications. According to Cavaliere and its team, the major influence of distribution of heat on the base metals, structures, metal flow and strength depends on the tool geometry and edge preparation [1]. Nansaarng and Chaivanich investigates FSW is the tool which has no flaws in mechanical and metallurgical properties [2]. Taguchi and ANOVA are the most powerful technique in identifying optimum input parameters and results. Most of the research conclude that the most convincing parameter of FSW is Tool rotational Speed, and it depends on choosing the parameters [3]. Jayaraman investigates few things in Aluminium Alloys by choosing Tool rotational speed; welding speed and vertical force, he states that tool rotational speed is the most influencing parameter whereas, welding speed and vertical force support to achieve maximum tensile strength of 143 MPa. Here, he discussed the same work using Artificial Neural Network (ANN). The same statement is evaluated by Lakshminarayanan in 2008 and the author reveals that the most convincing parameter is tool rotational speed [4]. Daniel Das and his team investigates the modified technique from FSW in the year 2015, and they reveal that Tool rotational speed is the most convincing parameter. But in this research work, we decide to have an experimental research work by choosing two different input parameters along with spindle speed [6-10]. In this research work, we got different opinion from the previous author illustration. In general, the Aluminium 7075 cannot be welded using fusion welding technique. Hence, we decide to weld the base metal Al 7075 using friction stir welding. In this research work, the effects of parameters such as spindle speed, welding speed and welding time are investigated using FSW welded base metal AA 7075 and the effectiveness are measured by analyzing tensile strength, results are determined [5].

## II. EXPERIMENTAL INVESTIGATION

In this research work, AA 6061 and AA 7075 in the form of plate of dimensions 70 mm X 140 mm X 5 mm thick. The material composition of the base metals is shown in Table 1 and Table 2 respectively.

**Table 1. Al 6061 material composition.**

| Alloy | Mg | Si | Fe | Cu | Cr | Zn | Ti | Mn | Al |
|---|---|---|---|---|---|---|---|---|---|
| Wt % | 0.9 | 0.7 | 0.6 | 0.3 | 0.25 | 0.2 | 0.1 | 0.05 | Balance |

**Table 2. Al 7075 material composition.**

| Alloy | Fe | Si | Cu | Mn | Mg | Cr | Zn | Ti | Al |
|---|---|---|---|---|---|---|---|---|---|
| Wt % | 0.5 | 0.4 | 1.6 | 0.1 | 2.5 | 0.15 | 5.5 | 0.4 | Balance |

Taguchi L9 orthogonal array has been proposed in this research work. The parameters used in this research work are spindle speed (rpm), welding speed (mm/min) and welding time (sec).

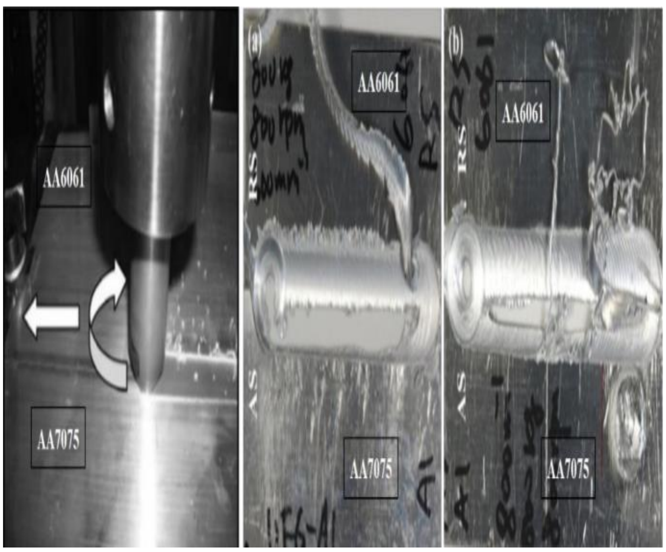


**Fig 1. Sample welded by FSW**

The quality of the process parameters is identified using Taguchi ranking process that was framed by Genichi Taguchi. Analysis of Variance has used to identified the most influencing parameter and contribution of process parameter. The dimension of the tool pin 18mm diameter in shoulder and 5mm diameter in pin. The tensile test has been carried out using MTS – 317 universal tensile testing machine with the strain rate of 1/1000 1/s. Table 3 shows the factors and levels of $L_9$ orthogonal array. Fig 1 shows the sample that welded by FSW.

**Table. 3** $L_9$ orthogonal array factors and levels

| FACTOR | LEVELS | | |
|---|---|---|---|
| | **1** | **2** | **3** |
| **Spindle Speed (rpm)** | 900 | 1200 | 1500 |
| **Welding Speed (mm/min)** | 3 | 6 | 9 |
| **Welding time (sec)** | 90 | 100 | 110 |

In this research investigation, the factors are spindle speed, welding speed and welding time. There are three levels used in this research work for each and every factors. 900 rpm, 1200 rpm and 1500 rpm are the three levels for the factor spindle speed. 3 mm/min, 6 mm/min and 9 mm/min are the three levels for the factor welding speed are 90 sec, 100 sec and 110 sec respectively.

## III. RESULTS AND DISCUSSIONS

### 1. Signal to Noise Ratio

The signal to noise ratio helps in reducing fluctuations in the output parameter tensile strength. In this research work, the tensile strength is the most significant output parameter, that evaluates the quality of joints. The optimum parameters has been optimized by using “Larger is better” criteria. The following equation helps in identifying SN ratio.

$S/N = -10*\log(\Sigma(1/Y2)/n)$

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**Table. 4** $L_9$Orthogonal Array

| EXPERIMENT NUMBER | INPUT PARAMETERS | | | OUTPUT PARAMETERS |
|---|---|---|---|---|
| | SPINDLE SPEED (rpm) | WELDING SPEED (mm/min) | WELDING TIME (mm) | TENSILE STRENGTH (N/mm$^2$) |
| 1 | 900 | 3 | 90 | 152.24 |
| 2 | 900 | 6 | 100 | 149.17 |
| 3 | 900 | 9 | 110 | 146.10 |
| 4 | 1200 | 3 | 100 | 159.10 |
| 5 | 1200 | 6 | 110 | 156.03 |
| 6 | 1200 | 9 | 90 | 134.97 |
| **7** | **1500** | **3** | **110** | **165.95** |
| 8 | 1500 | 6 | 90 | 144.89 |
| 9 | 1500 | 9 | 100 | 141.82 |

According to Table 4, the nine experimental values along with the input and output parameters have been tabulated. From Table 4, the optimum tensile strength has been identified by input parameters 1500 rpm spindle speed, 3 mm/min welding speed and 110 sec welding time is 165.95 N/mm$^2$. Table 5 and Table 6 provides response table of S/N Ratio and means and Fig 2 and Fig 3 provides graph plot of Main effects plot for S/N Ratio and means. By the rank process depth of cut is the most significant parameters for optimal joint strength.

**Table 5. Response table for SN Ratio**

| Level | Spindle Speed (rpm) | Welding Speed (mm/min) | Welding time (sec) |
|---|---|---|---|
| **1** | 43.47 | 44.03 | 43.16 |
| **2** | 43.50 | 43.52 | 43.51 |
| **3** | 43.55 | 42.98 | 43.85 |
| **Delta** | 0.08 | 1.05 | 0.69 |
| **Rank** | **3** | **1** | **2** |

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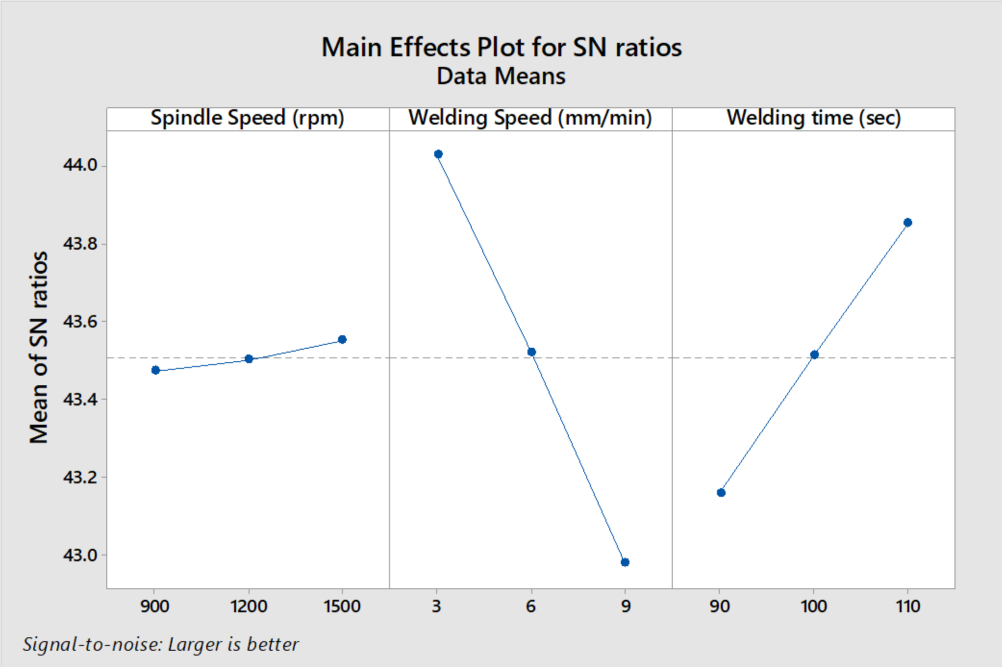


**Fig 2. Main Effects plot for S/N ratios.**

**Table 6. Response table for data means**

| Level | Current (A) | Speed (mm/min) | Arc Gap (mm) |
|---|---|---|---|
| **1** | 149.2 | 159.1 | 144.0 |
| **2** | 150.0 | 150.0 | 150.0 |
| **3** | 150.9 | 141.0 | 156.0 |
| **Delta** | 1.7 | 18.1 | 12.0 |
| **Rank** | **3** | **1** | **2** |

From Table 5, the welding speed of FSW is the most convincing parameter followed by the welding time in terms of seconds. These two parameters contribute more in joining quality joints. From Fig 2, the graph plot for SN shows that 44.03 mm/min welding speed contributes more compared with the other two parameters. The delta value has been recorded as 18.1. This SN ratio records high optimized value and it solved using Larger is better criteria.[12]

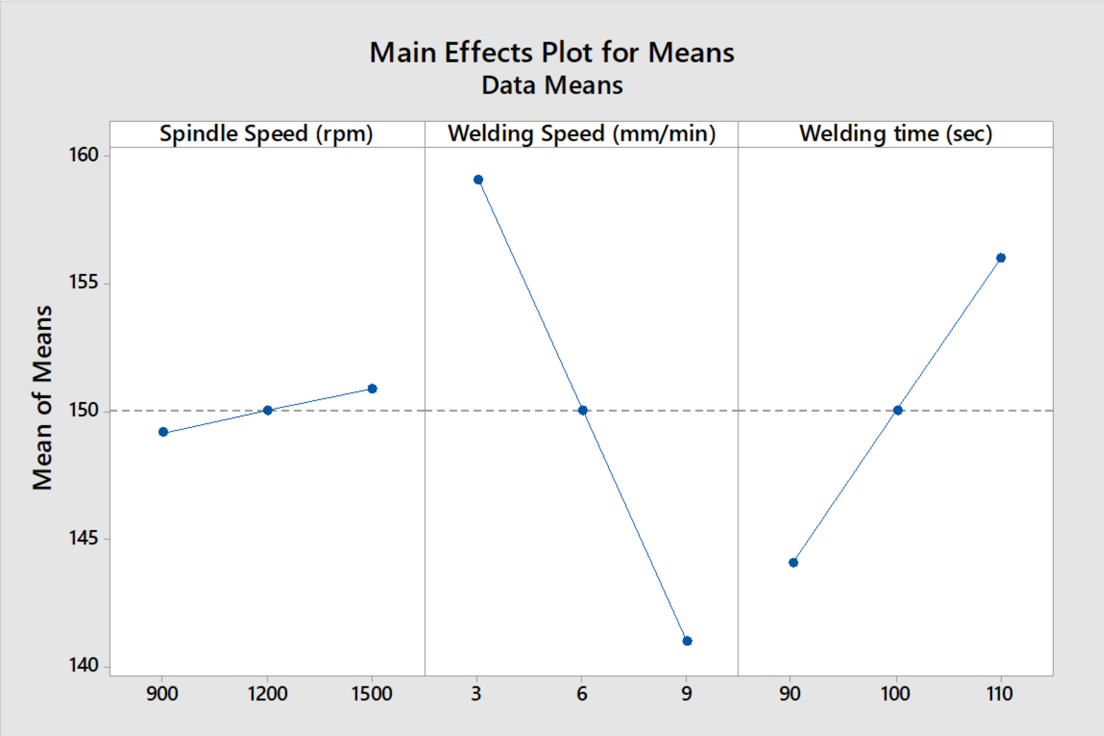


**Fig 3. Main Effects plot for means.**

**Table 7. Model summary of R-Sq, Adj and Prediction**

| S | R-sq | R-sq(adj) | R-sq(pred) |
|---|---|---|---|
| 0 | 100% | 100% | 100% |

Table 7 shows that the model summary of R-Square value and its adjacent value. The values are recorded as 100%, which means the errors are minimum.Table 8 shows that the contribution of process parameters where as the spindle speed contributes 9.61%, Welding speed contributes 63.13% and welding time contribution is 30.25%. From table 7, the welding speed is the highest contributing parameters followed by welding time (30.25%). Fig 4 shows the pictorial representation of process parameters. Fig 5 shows the interaction plot of the process parameters.[13-17]

**Table 8. Percentage of contribution by ANOVA**

| Source | DF | Adj SS | Adj MS | F-Value | P-Value | Percentage of Contribution |
|---|---|---|---|---|---|---|
| **Spindle Speed (rpm)** | 2 | 4.417 | 2.208 | - | - | 9.61 |
| **Welding Speed (mm/min)** | 2 | 493.154 | 246.577 | - | - | 63.13 |
| **Welding time (sec)** | 2 | 215.784 | 107.892 | - | - | 30.25 |
| **Error** | 2 | 0.000 | 0.000 | - | - | 0 |
| **Total** | 8 | 713.355 | - | - | - | 100% |

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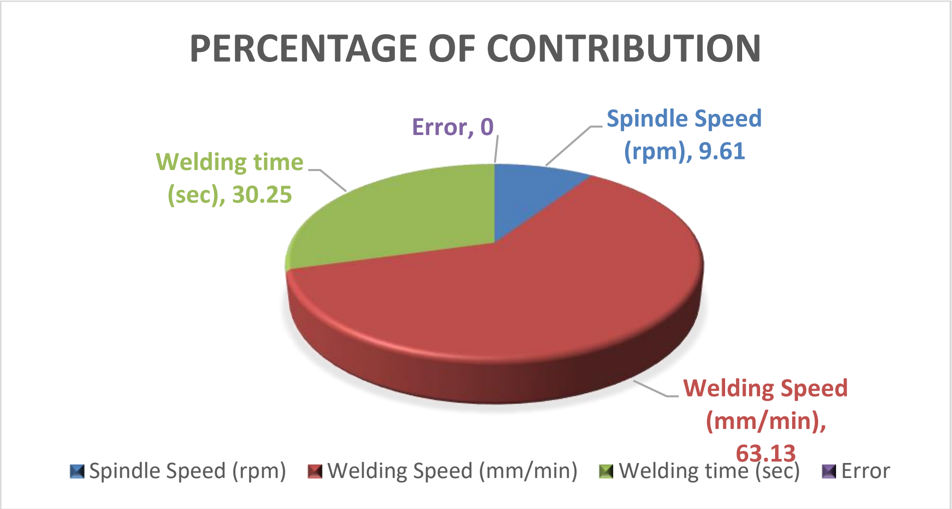


**Fig 4. Percentage of contribution of process parameters**

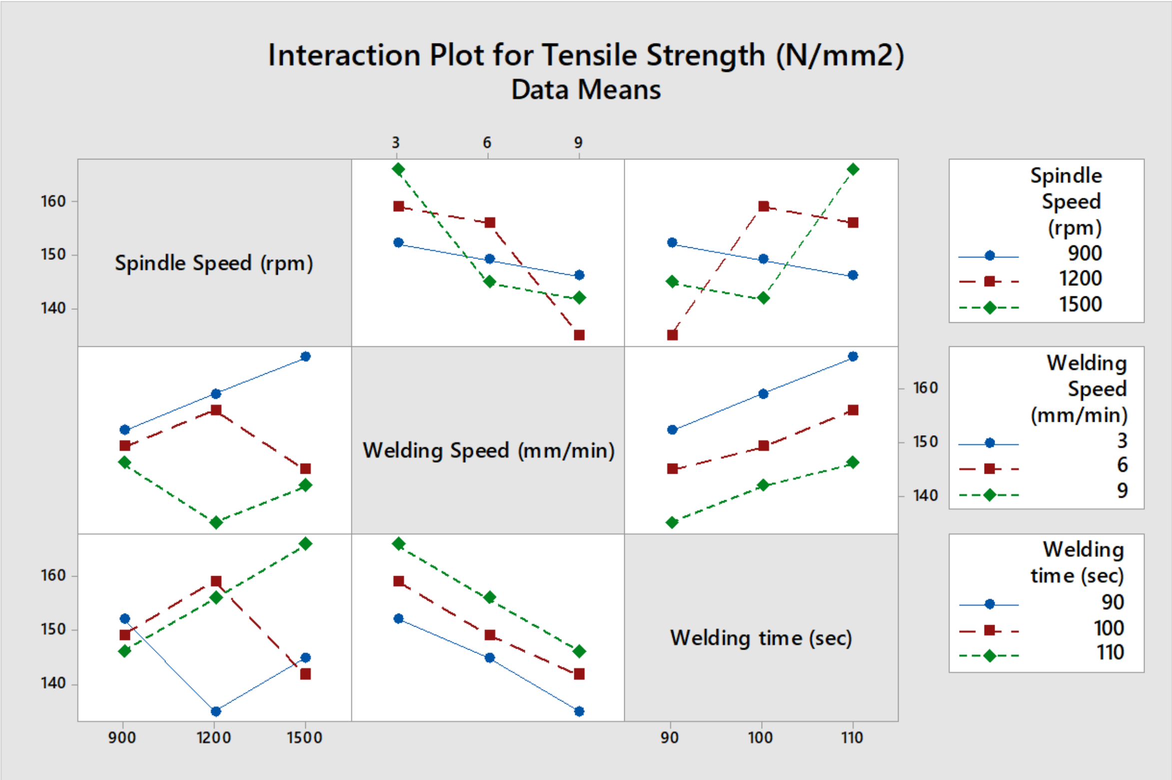


**Fig 5. Interaction plot of process parameters**

Table 9 is the comparison table between the process parameters of experimental and Taguchi method. From the table, it clearly shows that there will be slight deviation between the optimum tensile strength of Experimental and Software predicted method. Equation 1 shows that regression equation that produces optimum tensile strength values.

**Table 9. Theoretical and experimental values – a comparison**

| Method | Input parameters | | | Output Parameter |
|---|---|---|---|---|
| | Spindle Speed (rpm) | Welding Speed (mm/min) | Welding Time (sec) | Tensile strength ($N/mm^2$) |
| **Taguchi** | 1500 | 3 | 110 | 165.95 |
| **Experimental** | 1500 | 3 | 110 | 161.30 |

Tensile Strength = 104.8 + 0.002860 * Spindle Speed - 3.022 * Welding Speed + 0.5997 * Welding time (1)

## IV. CONCLUSION

In this research investigation, Al 6061 and Al7075 are welded using Friction Stir Welding process. The input parameters are Spindle speed (rpm), Welding speed (mm/min) and Welding time (sec). From the above investigation, conclusions are listed

Radiography test concludes that there was no speck at the weld interface

By Taguchi analysis, the optimum strength has been achieved by using 1500 rpm spindle speed, 3 mm/min welding speed and 110 sec.

By Analysis of variance, the optimum joint has been achieved by contribution of welding speed (63.13%), followed by the welding time (30.25%) and spindle speed (9.61%).

By comparing the experimental and software predicted value, there was a slight deviation of tensile strength values.

## REFERENCES

[1]. Cavaliere, P., G. Campanile, F. Panella, and A. Squillace. "Effect of welding parameters on mechanical and microstructural properties of AA6056 joints produced by friction stir welding." Journal of Materials Processing Technology 180, no. 1-3 (2006): 263-270.

[2]. Yadhav, V. D., and S. G. Bhatwadekar. "Friction stir welding of dissimilar aluminium alloys AA1100 to AA6101-T6." Int J Res Aeronaut Mech Eng 3, no. 1 (2015): 1-6.

[3]. Bayazid, S. M., H. Farhangi, and A. Ghahramani. "Investigation of friction stir welding parameters of 6063-7075 aluminum alloys by Taguchi method." Procedia Materials Science 11 (2015): 6-11.

[4]. Balasubramanian, V., and A. K. Lakshminarayanan. "The mechanical properties of the GMAW, GTAW and FSW joints of the RDE-40 aluminium alloy." International Journal of Microstructure and Materials Properties 3, no. 6 (2008): 837-853.

[5]. Paramaguru, Dhanis, SrinivasaRaoPedapati, MokhtarAwang, and HamedMohebbi. "Mathematical Model to Predict Tensile Strength of Underwater Friction Stir Welded (UFSW) on 5052 Aluminium Alloys." In ASME 2018 International Mechanical Engineering Congress and Exposition. American Society of Mechanical Engineers Digital Collection, 2018.

[6]. Jayaraman, N., Paul S. Prevéy, and Murray Mahoney. "Fatigue Life Improvement of an Aluminum Alloy FSW with Low Plasticity Burnishing." In Proceedings 132nd TMS Annual Meeting, San Diego, CA. 2003.

[7]. Das, A. Daniel, and S. Senthil Kumaran. "FWTPET Investigation on SA213 Tube to SA387 Tube Plate." In Applied Mechanics and Materials, vol. 852, pp. 355-361. Trans Tech Publications Ltd, 2016.

[8]. Kumaran, S. Senthil, and A. Daniel Das. "An investigation of Boiler Grade Tube and Tube Plate without block by using friction welding process." Materials Today: Proceedings 5, no. 2 (2018): 8567-8576.

[9]. Kumaran, S. Senthil, and A. Daniel Das. "An Examination of Seamless Ferritic tube and Austenitic alloy tube plate joining by Friction Welding process." Materials Today: Proceedings 5, no. 2 (2018): 8539-8546.

[10]. Das, A. Daniel, and S. Senthil Kumaran. "FWTPET Investigation on SA213 Tube to SA387 Tube Plate." In Applied Mechanics and

Materials, vol. 852, pp. 355-361. Trans Tech Publications Ltd, 2016.
[11]. MINITAB 17, Minitab Inc.,
[12]. Sellappa, S., Prathyumnan, S., Keyan, K. S., Joseph, S., Vasudevan, B. S. G., &Sasikala, K. (2010). Evaluation of DNA damage induction and repair inhibition in welders exposed to hexavalent chromium. Asian Pac J Cancer Prev, 11(1), 95-100.
[13]. Sudha, S., Kripa, S. K., Shibily, P., Joseph, S., &Balachandar, V. (2011). Biomonitoring of genotoxic effects among shielded manual metal arc welders. Asian Pac J Cancer Prev, 12(4), 1041-4.
[14]. Karthik, R., Chen, S. M., Elangovan, A., Muthukrishnan, P., Shanmugam, R., & Lou, B. S. (2016). Phyto mediated biogenic synthesis of gold nanoparticles using Cerasusserrulata and its utility in detecting hydrazine, microbial activity and DFT studies. Journal of colloid and interface science, 468, 163-175.
[15]. Balakrishnan, M., Dinaharan, I., Palanivel, R., &Sivaprakasam, R. (2015). Synthesize of AZ31/TiC magnesium matrix composites using friction stir processing. Journal of Magnesium and Alloys, 3(1), 76-78.
[16]. Selvan, M. C. P., Raju, N. M. S., &Sachidananda, H. K. (2012). Effects of process parameters on surface roughness in abrasive waterjet cutting of aluminium. Frontiers of Mechanical Engineering, 7(4), 439-444.
[17]. Shanmughasundaram, P., Subramanian, R., &Prabhu, G. (2011). Some studies on aluminium–fly ash composites fabricated by two step stir casting method. European journal of scientific research, 63(2), 204-218.