iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 7 **Issue:** IV **Month of publication:** April 2019

DOI: https://doi.org/10.22214/ijraset.2019.4046

Study of Influence of Temperature Variation in Hot Sink Underwater Friction Stir Welding Of 4 mm Thick AA6061 Plate and Corrosion Study

Yagnik Patel[1], Kaushal Bhavsar[2], Hardik Chavda[3]
[1,3]*PG Student, Mechanical Department, Kadi sarva Viswavidyalaya University, Gandhinagar.*
[2]*Assistant Professor, Mechanical Department, Kadi sarva Viswavidyalaya University, Gandhinagar.*

Abstract: AA6061 aluminum alloy has a gathered wide acceptance in the fabrication of light weight structures requiring high strength to weight ratio and good corrosion resistance. Friction stir welding (FSW) is an emerging solid state joining process in which the material that is being weld does not melt and recast. This process uses a non consumable tool to generate frictional heat in the abutting surfaces. The present investigation is aimed to study the tensile strength, microstructures and corrosion behavior of underwater friction stir welding (UFSW) welded joints of AA6061 at variable temperature of water and compare that result with normal friction stir welding process with same parameter. 4 mm thickness has been used as the base material for preparing single pass butt welded joints.

Keywords: Underwater Friction stir welding, microstructure, Tensile strength, corrosion behaviour, variable temperature of water.

I. INTRODUCTION

In recent years, more and more metal structures have been used in ship building and marine construction. Hence, a wide spread interest has been taken by researches to fulfill some important requirements for underwater joint technology. The heat treatable wrought aluminium-silicon-magnesium alloys AA6061 have moderate strength and possess excellent welding characteristics compared to high strength aluminum alloys. Hence, this class of alloys is mostly used in marine frames, pipelines, storage tanks and aircrafts application. Friction stir welding is a solid state joining process in which weld is produced by using a rotating, non consumable welding tool to locally soften a workpiece, through heat produced by friction and plastic work, thereby allowing the tool to stir the joint surfaces. Although the heat input in the FSW process is relatively low and the time at process temperature is short compared with fusion welding, various grain structures and grains recrystalization phenomena dynamically occurring during the FSW process, in 6xxx series of stir welded Al alloy, have different corrosion susceptibilities in each area of the joined zone. In FSW process, generally, in the weld nugget zone (WNZ), and heat affected zone (HAZ), the time at peak temperature is short, and cooling is relatively rapid.

II. LITERATURE REVIEW

F. Heirani et. al.[1] focused on the effect of processing parameters on microstructure and mechanical behavior of underwater friction stir welding of Al5083 alloy and compared that result with the normal friction stir welding for same processing parameters

S. Sinhmar et. al.[2] investigated on the microstructure corrosion behavior and mechanical properties of the friction stir welded joint of AA2014 in natural cooled and water cooled condition. 3.5% NaCl solution was used for the corrosion test. The result found that the corrosion resistance of water cooled joint was found higher than natural cooled FSW joints

H .J. Zhang et.al.[3] discussed about the UFSW of 2219-T6 aluminium alloy at a fixed welding speed and various rotation speed in order to influence of rotation speed on the performance of underwater joints. The result showed the when the rotation speed is too low or too high, the hardness is relatively low because of inadequate tool stirring or excess heat input.

P. Baille et. al.[4] studied about the comparison of the mechanical and microstructural properties produced during friction stir welding of S275 structural steel in air and water. . It is concluded that there was no significant difference in the strength, hardness or fatigue life of the air and underwater specimen. Only charpy impact toughness was decreased for underwater specimen due to less angular grain structure.

F. Gharavi et. al.[5] focused on the corrosion behavior of friction stir lap welded AA6061-T6 aluminium alloy in sodium chloride + hydrogen peroxide solution. The result suggested that the corrosion resistance in different weld region for the friction stir lap welding sample is poorer than that for the parent alloy.

S. Rajkumar et. al.[6] discuss about the predicting tensile strength, hardness and corrosion rate of friction stir welded AA6061-T6 aluminium alloy joints at different parameter and optimum welding condition was found to maximize the tensile strength and minimize the corrosion rate. The corrosion rate can be reduced by minimum with acceptable mechanical properties if the optimal welding conditions are used.

S. Shanavas et. al.[7] studied the feasibility of underwater friction stir welding of AA5052 H32 aluminium alloy to improve the joint performance than normal friction stir welding. The result showed that the ultimate tensile strength obtained by UFSW about 2 % greater than that of normal FSW process.

H. Zhang et. al.[8] conducted underwater friction stir welding of 2219-T6 aluminium alloy to obtain the optimum welding condition and mathematical model was developed to optimize the welding parameters for maximum tensile strength The result indicated that a maximum tensile strength of 360 MPa can be achieved through UFSW, higher than the maximum tensile strength obtained by normal condition. This Value is 6% higher than the maximum tensile strength obtained in normal FSW.

V. Balasubramanian et. al.[9] aimed to study the effect of welding processes such as GTAW, GMAW and FSW on mechanical properties of AA6061 aluminium alloy. From this investigation, they found that FSW joints of AA6061 showed superior mechanical properties compared with GTAW and GMAW joints due to formation of very fine, equiaxed microstructure in the weld zone.

L.Dumpala et. al.[10] focused on the study of mechanical properties of aluminium alloys on the normal friction stir welding and underwater friction stir welding for structural application. The experimentation temperature results are validated by utilizing deform-3D.

A. Heidarzadeh et. al.[11] focused on the tensile behavior of friction stir welded AA6061-T4 aluminium alloy joints. In this investigation, three welding parameters, five levels and 20 runs are used to develop for predicting the tensile properties.

III.EXPERIMENT WORK

.

Fig. 1 Vertical milling machine

All the Machine specification datasheet is mention below.

TABLE I
MACHINE SPECIFICATION TABLE

Technical Data	Vertical Milling Machine UF1 Model
Overall Size (L ✖W) (mm)	1.175 ✖230
Clamping area (mm^2)	1000 ✖230
T-slot/ Width/ CD	3/ 14/ 45
Speed range (rpm)	45 - 2000 rpm
Nos. of feed	18
Longitudinal feed range (mm/min)	16 – 800
Transverse feed range (mm/min)	16 – 800

AA6061 is used in this study and was supplied in the form of plates measuring 60×50 (length ×width). The thickness of the plate is 4 mm. The prepared samples were clamped in a small container, and then water is poured into the container to immerse. Hot water is required for this study. The main welding parameters for this experiment are tool rotation speed, welding speed and water temperature. The parameters were selected as a trade off between rotation and welding speed so that no defect was produced. The tensile specimens were cut perpendicular to the welding direction from the joints. The tensile test was performed on universal testing machine. From the previous researches, it has been found that the feasible range of the tool rotation speed for the best outcomes is between 600 rpm to 1400 rpm so the speed selected for this experiments are 710, 1000 and 1400 rpm. Welding speed along the joint are 25 mm/min and 50 mm/min. Most important variable for this experiment is temperature of water. The underwater friction stir welding process will be carried out at different temperature of water so the temperature value selected for the experiment is 50 ^{0}C and 80 ^{0}C.

Fig. 2 Experimental Setup

The rolled plates of 4 mm thickness, medium strength AA6061 aluminium alloy was used as a base metal. Chemical composition and mechanical properties of the base metal are as shown in table. The plate was cut to the required size (60 mm ✕ 50 mm) by grinder machine followed by milling. The initial joint configuration was obtained by securing the plates in position using mechanical clamps. The direction of welding was normal to the rolling direction. Single pass welding procedure was followed to fabricate the joints. Non-consumable tools made of high carbon steel were used to fabricate the joints.

A. FSW Tool

Fig. 3 FSW Tool

H13 hot work tool steel material was selected. To produce FSW joint among plates FSW butt joint among plates FSW tool with "Taper cylindrical" pin profile has designed. Tool material has selected AISI hot work H13 tool steel. Hot work tool steel is used to weld aluminum alloy. This alloy is one of the hot work, chromium type tool steel. This alloy is weldable. H13 finds application for hot die work, die casting and extrusion dies. Machinability of the H13 is medium to good.

The chemical composition (in weight %)of H13 Tool steel are as below:

TABLE III
CHEMICAL COMPOSITION TOOL

Carbon	Chromium	Molybdenum	Copper	Phosphorous	Silicon	Sulphur
0.32-0.45	4.75-5.5	0.2-0.5	1.1-1.75	0.03 max	0.8-1.2	0.03 max

Mechanical and Physical properties of H13 Tool steel are as below:

TABLE IIIII
MECHANICAL AND PHYSICAL PROPERTIES OF TOOL

Modulus of Elasticity	210 GPa
Ultimate/ Tensile strength	1990 MPa
Density	7750 Kg/m^3
Thermal conductivity	24.4 W/m-K
Hardness	49 HRC

B. Base Plate Material

The base plate material used for experiment is aluminium alloy 6061(AA 6061). More ever choosing this particular grade is being given more attention due to its lightness, lower cost and good workability. The most important reason for selecting material is that this is used in marine application.

The Chemical Composition of AA 6061 are as below:

TABLE IVV
CHEMICAL COMPOSITION OF AA6061 PLATE

Elements	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
Weight%	0.6	0.35	0.25	0.10	0.9	0.21	0.13	0.11	97.35

TABLE VV MECHANICAL AND PHYSICAL PROPERTIES OF AA6061

UTS (MPa)	Tensile yield strength (MPa)	Elongation %	Hardness (Brinell Number)	Melting Temperature (^{0}C)	Modulus of Elasticity (GPa)	Thermal conductivity (W/m-K)	Density (gm/cm^3)
310	276	12 - 25	95	585	68.9	151-202	2.70

C. Corrosion Rate Measurement Method

The friction stir welded specimens were cut to the dimensions of 60 mm ✕100 mm✕ 4 mm to evaluate the corrosion rate by immersion test method. The specimens were ground with 500#, 800#, 1200#, 1500# grit SiC paper washed with distilled water and dried by warm flowing air. The corrosion rates of the AA6061 alloy were estimated through the weight loss measurement. The original weight (W_0) of the specimen were recorded and then immersed in the solution of 3.5% NaCl solution for 24 h. Finally, the corrosion products were removed by immersing the specimens for one minute in the solution prepared by using 50 g chromium trioxide (CrO_3), 2.5 g silver nitrate ($AgNO_3$) and 5 g barium nitrate ($Ba(NO_3)_2$) for 250 ml distilled water. The final weight (wt) of the specimen was measured and the net weight loss was calculated using the following equation

Corrosion rate = (87.6 × W)/ (A × D × T)

Where,

W = weight loss in mg

A = Surface area of specimen in cm^2

D = density of the material g/cm^3

T = corrosion time in hr.

IV. RESULT AND DISCUSSION

Aluminium alloy 6061 is used in this experiment and was supplied in the form of plates whose dimension measuring 60 × 50 × 4 (length × width × thickness). The samples were clamped in a small container. Hot water is poured into the container. Temperature of the water for the experiments are 50 ^{0}C and 80 ^{0}C. Welding parameters like tool rotation speed, welding speeds are selected 710 rpm, 1000 rpm, 1400 rpm and 25, 50 mm/min respectively.

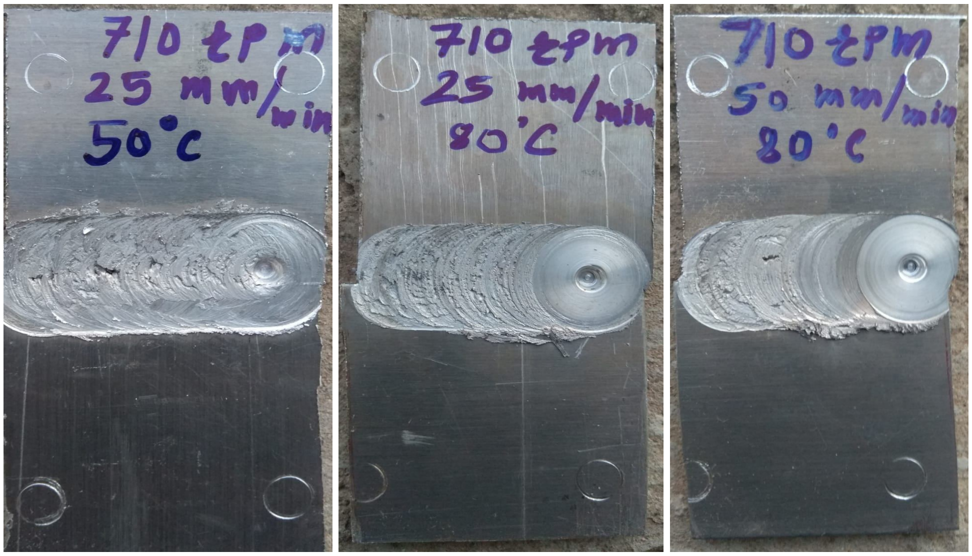


Fig. 4 Welded Plates of 710 rpm

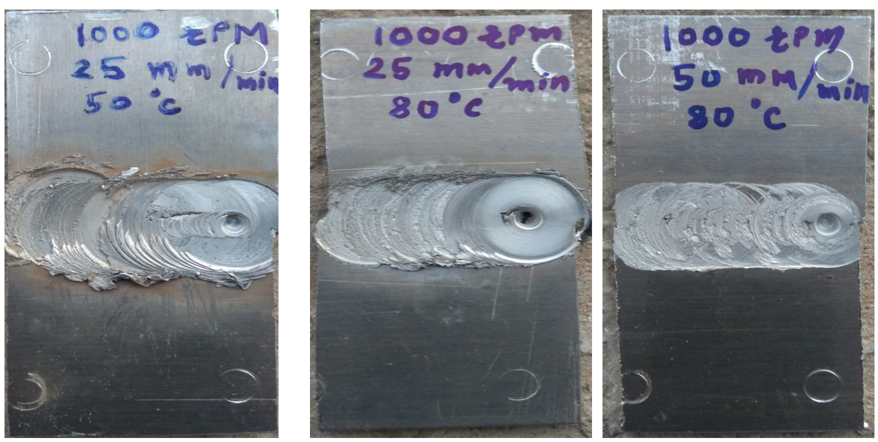


Fig. 5 Welded Plates of 1000 rpm

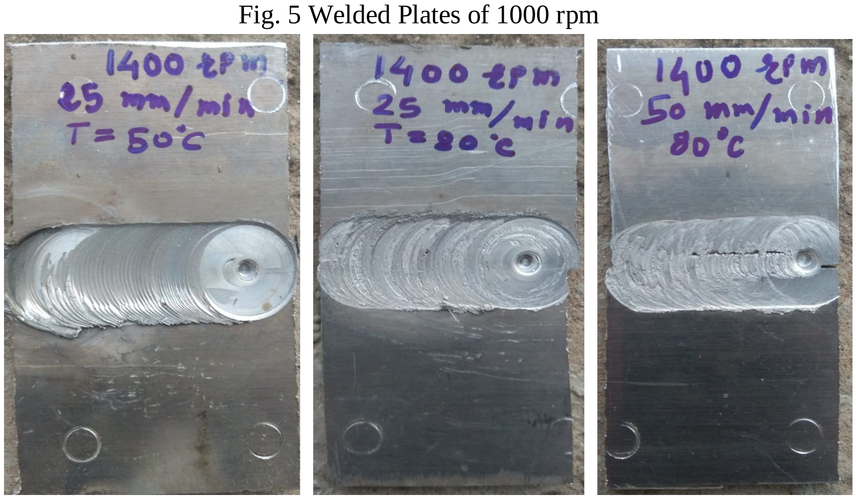


Fig. 6 Welded Plates of 1400 rpm

A. Load Carrying Capability of UFSW Samples

TABLE V
LOAD CARRYING CAPABILITY FOR UFSW SAMPLES

No.	Rotation Speed (rpm)	Welding speed (m/min)	Water Temperature (^{0}C)	Load (kN)
1	710	25	50	0.000
2	710	25	80	5.220
3	710	50	80	1.520
4	1000	25	50	1.200
5	1000	25	80	1.260
6	1000	50	80	2.560
7	1400	25	50	1.580
8	1400	25	80	1.980
9	1400	50	80	2.200

TABLE VI
LOAD CARRYING CAPABILITY OF GENERAL FRICTION STIR WELDING SAMPLES

No.	Rotation speed (rpm)	Welding speed (mm/min)	Load (kN)
1	1400	25	3.580

B. Corrosion Rate Evaluation

TABLE VII
CORROSION RATE TABLE

No.	Sample	Weight loss (mg)	Surface area (cm^2)	Corrosion rate ($\times 10^{-4}$ mm/hr)	Load carrying capability
1	710/25/50	43	84	34.6	0
2	710/25/80	8	59	9.1651	5.220
3	710/50/80	16	78	13.8651	1.520
4	1000/25/50	17	78	14.73	1.200
5	1000/25/80	8	66	13.313	1.260
6	1000/50/80	6	58	7	2.560
7	1400/25/50	23	94	16.538	1.580
8	1400/25/80	16	76	14.23	1.980
9	1400/50/80	13	74	11.874	2.200

Although aluminium forms a protective aluminium oxide layer on the surface, this thin layer can be breached in aggressive environments leading to corrosion. In particular, NaCl containing environments lead to the formation of aluminium chlorides which in turn reduce the effectiveness of the oxide layer in preventing corrosion. For that reason, the effect of friction stir welding input parameters on corrosion behavior of the welds was investigated. It can be noticed that the corrosion rate is minimum as the rotational speed in centre level, whereas at lower or higher tool rotational speeds, the corrosion rate is maximum. Similarly, the joint fabricated at the welding speed of 50 mm/min, rotation speed 1000 rpm and 80 ^{0}C Water temperature yielded the lower corrosion rate. The results demonstrated that the lowest corrosion rate could be obtained when all the FSW input parameters were at their middle level. The results indicate that as the tensile strength increases, the corrosion rate decreases.

C. Chemical Testing of Water

While conducting the underwater friction stir welding of AA6061 alloy, aluminium oxide vapour is produced which is precipitate in water and formed into the small particles. Chemical testing of water is required to know the quantity of aluminium oxide produced. Container size is 180 mm✕ 100 mm in which the water quantity is 80 ml.

FIG. 7 CHEMICAL TESTING OF WATER

1) Clear colorless liquid with presence of Al_2O_3
2) Quantity of water = 80 ml
3) Quantity of Al_2O_3 = 0.49 %
4) pH = 8.85

pH obtained for this water is 8.85 so it can be said that this is near to the neutral water. It will not harmful for the water. From this, it can be said that this underwater friction stir welding process is environment friendly process.

V. CONCLUSION

In this work, Underwater friction stir welding of AA6061 alloy with various welding parameters were carried out successfully and compares with an air-cooled weld. The following conclusions are drawn.

A. As the temperature of water is increased, Load carrying capacity is increased so tensile strength is increased
B. Tool rotation speed 710 rpm, welding speed 25 mm/min and 80 ^{0}C Water temperature sample has a maximum tensile strength.
C. In comparison with air cooled specimen, the increase in tensile strength of water cooled samples can be due to increase of hardness in stir zone resulted by an ultra fine grain structure. Tensile strength of UFSW sample is increased by 45.81 % compared to the air cooled specimen.
D. A corrosion rate is minimum at 1000 rpm tool rotation speed, 50 mm/min welding speed and ^{0}C Water temperature.

V. ACKNOWLEDGMENT

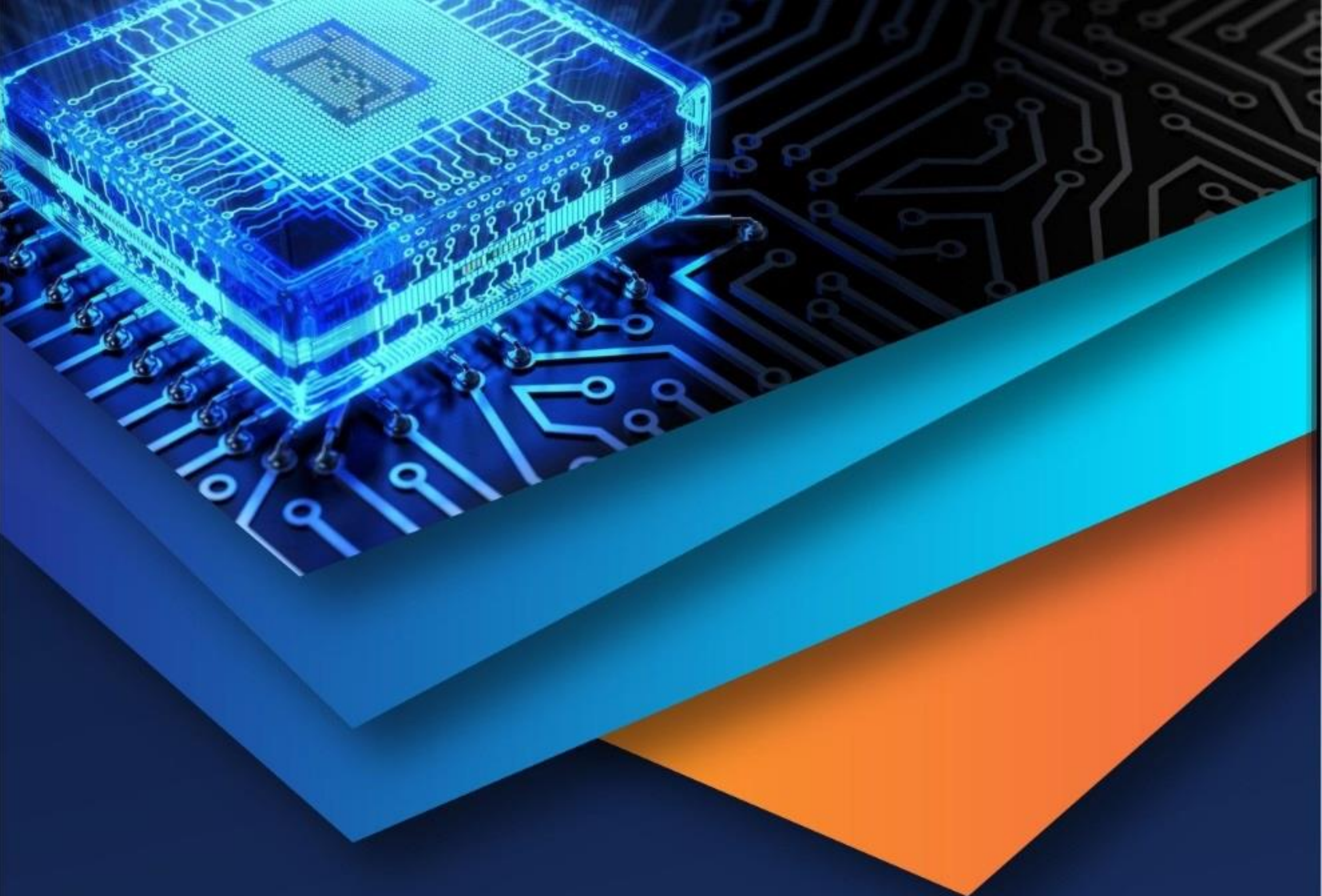
I am humbly expressing thanks to my respected guide Prof. Kaushal H. Bhavsar for his valuable time and constant help given to me. He provided me this opportunity to work in this inspiring project. With his enthusiasm, inspiration, and great efforts to explain things clearly and simply, he helped to make this work fun. Throughout my dissertation period, he provided encouragement, sound advice, good teaching, good company, and lots of good ideas.

Finally, I am thankful to all the faculty members of Mechanical Engineering Department and my parents, all my friends who have directly or indirectly helped me during this experiment work.

REFERENCES

[1] Farzad Heirani, Alireza Abbasi , Mohammad Ardestani "Effects of processing parameters on microstructure and mechanical behaviors of underwater friction stir welding of Al5083 alloy" Journal of Manufacturing Processes 25 (2017) 77–84
[2] S. Sinhmar, D.K. Dwivedi "Enhancement of mechanical properties and corrosion resistance of friction stir welded joints of AA2014 using water cooling" Materials Science & Engineering A 684 (2017) 413–422
[3] H.J. Zhang, H.J. Liu , L. Yu, "Microstructure and mechanical properties as a function of rotation speed in underwater friction stir welded aluminium alloy joints" Materials and Design 32 (2011) 4402–4407
[4] P. Baillie, S. W. Campbell, A. M. Galloway, S. R. Cater, N. A. McPherson , "Friction stir welding of 6 mm thick carbon steel underwater and in air" Science and Technology of welding and joining , volume 20, 2015-issue 7
[5] Farhad Gharavi, Khamirul A. Matori, Robiah Yunus, Norinsan K. Othman, Firouz Fadaeifard, " Corrosion evaluation of friction stir welded lap joints of AA6061-T6 aluminum alloy " Transactions of Nonferrous Metals Society of China,Volume 26, Issue 3, March 2016, Pages 684-696

[6] S. Rajakumar , C. Muralidharan, V. Balasubramanian, " Predicting tensile strength, hardness and corrosion rate of friction stir welded AA6061-T6 aluminium alloy joints. " Materials and Design 32 (2011) 2878–2890
[7] S. Shanavas, J. Edwin Raja Dhas & N. Murugan, "Weldability of marine grade AA 5052 aluminum alloy by underwaterfriction stir welding" The International Journal of Advanced Manufacturing Technology.
[8] Huijie Zhang , Huijie Liu, "Mathematical model and optimization for underwater friction stir welding of a heat-treatable aluminum alloy" Materials & Design,Volume 45, March 2013, Pages 206-211.
[9] A. K. Lakshminarayanan & V. Balasubramanian & K. Elangovan, "Effect of welding processes on tensile properties of AA6061 aluminium alloy joints" The International Journal of Advanced Manufacturing Technology January 2009, Volume 40, Issue 3–4, pp 286–296.
[10] Lingaraju Dumpala, Laxmi Mohan Kumar Chintada, Devadas Deepu, Pravin Kumar Yadav, "Study of Mechanical Properties of Aluminium Alloys on Normal Friction Stir Welding and Underwater Friction Stir Welding for Structural Applications." International Journal of Mechanical and Mechatronics Engineering Vol:11, No:7, 2017
[11] A. Heidarzadeh , H. Khodaverdizadeh , A. Mahmoudi , E. Nazari , "Tensile behavior of friction stir welded AA 6061-T4 aluminum alloy joints." Materials & Design,Volume 37, May 2012, Pages 166-173.
[12] Friction stir welding from basics to application by Daniela Lohwasser and Zhan Chen
[13] https://en.wikipedia.org/wiki/6061_aluminium_alloy



10.22214/IJRASET

INDEX COPERNICUS 45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY