Vidya Jyothi Institute of Technology
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(Aziz Nagar, C.B.Post, Hyderabad -500075)

Department of Mechanical Engineering

Circular

MED/Major Projects/01

Dt: 02.12.2019

All the final year mechanical engineering students are informed that a project work has to be undertaken as a partial fulfillment for the award of degree. In this connection you are required to form into groups with three to four members. Grouping is done voluntarily by yourself considering the domain of interest in mechanical engineering. Hence you are required to submit the group along with the domain/project topic so that faculty member can be allocated as supervisor/guide. Also you can speak to the faculty member in choosing them as supervisors for the project work undertaken. The submission of the group to **Mr.Prasad Kumar**, Asst.Professor, who is project coordinator on or before **19.12.2019.**

HoD

(Dr.G.Sreeram Reddy)

VIDYA JYOTHI INSTITUTE OF TECHNOLOGY
DEPARTMENT OF MECHANICAL ENGINEERING
IV -Year, II - Sem Section –A - Major Project Batch Allocation- 2019-20

S.No	Batch No	Roll No	Name of the Students	Name of the Project Guide	Project Title	Place of Work	Related PO/PSO
1	I	16911A0332	M.SAI KUMAR	Dr.M.Naveen Kumar	Prototype model building of automobile component by reverse engineering	VJIT	PO1, PO2, PO3, PO4, PO5, PO9, PO12, PSO1, PSO2
2		16915A0304	B. SAI NIHAR				
3		17915A0305	A.KARAN				
4		17915A0313	B.RAVI TEJA				
5	II	16911A0349	S.RAMANUJAN	Mr.T.Pavan Kumar	Evaluation of mechanical properties of and thermal behaviour of novel composite material	VJIT	PO1, PO2, PO3, PO4, PO5, PO9, PO12, PSO1, PSO2
6		17915A0307	B.JAYACHNDRA				
7		17915A0311	B.SAIHARIHARAN				
8		17915A0312	B.DEEKSHITH				
9	III	16911A0301	A.SANJAY	Dr.M.Naveen Kumar	Design and fabrication of automatic gear shifting mechanism in automobile	VJIT	PO1, PO2, PO3, PO4, PO9, PO12, PSO2
10		16911A0304	A.RAVINDRA				
11		16911A0312	CH.SAI SRINIVAS				
12		16911A0335	M.RAHUL				
13	IV	16911A0314	CH.LIKITHA	Mr.S.Prasad Kumar	Investigation on friction stir weldingof disimilar aluminium alloys (AA6061 & AA6351) using various micro powders	VJIT	PO1, PO2, PO3, PO4, PO5, PO9, PO12, PSO1
14		16911A0319	E.VISHNU				
15		16911A0328	K.SRIKANTH				
16		17915A0309	B.PAVANI				
17	V	16911A0308	B.SHIVANI	Mr.C.Naveen Raj	Development of composite materials usingvarious fibers & epoxy resin	VJIT	PO1, PO2, PO3, PO4, PO5, PO9, PO12, PSO1
18		16911A0325	J.SWAPNA				
19		16911A0336	M.VINEELA				
20		16911A0355	UVS CHANDAN				
21	VI	169110305	A.BALAKRISHNA	Mr.S.Ramakrishna	Optimal design of Basalt-Kenaf and E glass kenaf composite	VJIT	PO1, PO2, PO3, PO4, PO5, PO9, PO12, PSO1, PSO2
22		169110326	KA MALLESH YADAV				
23		16911A0357	V.VISHNU				
24		17915A0308	B.SHESHI KUMAR				
25	VII	16911A0323	G.AJAY REDDY	Dr.B.V.Reddi	Synthesis of TiO2 Nano structure with different morphologis	VJIT	PO1, PO2, PO3, PO4, PO5, PO9, PO12, PSO1, PSO2
26		16911A0330	K.DURGA PRASAD				
27		16911A0331	K.RUCHITHA				
28		16911A0346	P.DIVIJ				
29	VIII	16911A0337	MD.ADIL	Dr.Phanindra Bogu	Impact of notch topology on the fatigue life of UNS S32760 super duplex stainless steel	VJIT	PO1, PO2, PO3, PO4, PO5, PO9, PO12, PSO2
30		16911A0338	MD.IMAAZ				
31		16911A0360	ZUBAIR AHMED				
32		16911A0345	P.SOURAB				

RUBRICS FOR EVALUATION OF PROJECTS

Criterion for Evaluation/ Rubric	Poor (1)	Satisfactory (2)	Good (3)	Very Good (4)	Excellent (5)
Requirements	Project does not adhere to its requirements.	Project minimally adheres to its requirements.	Project mostly adheres to its requirements	Project completely adheres to its requirements	Project completely adheres to its requirements and suits current day's industry needs.
Creativity	Project is significantly incomplete and lacking creativity.	Project is somewhat incomplete and slightly creative.	Project is complete and creative.	Project is complete, creative and novel.	Project is highly creative and visibly appealing.
Model Building	Contains no involvement of mechanical engineering concepts.	Contains minimal involvement of mechanical engineering concepts.	Contains involvement of mechanical engineering concepts in study-oriented approach.	Contains involvement of mechanical engineering concepts like design, fabrication, analysis etc. without any live model or simulation.	Contains involvement of mechanical engineering concepts like design, fabrication, analysis etc and working model/ simulation as well.
Quality of the work	Project is of poor quality work.	Project appears hastily created or is of poor quality work.	Project construction could benefit from more than a minimal amount of effort.	Project construction could be improved somewhat in select areas.	Project is of excellent, durable construction.

VIDYA JYOTHI INSTITUTE OF TECHNOLOGY (AUTONOMOUS)

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Department of Mechanical Engineering

IV YEAR PROJECT REVIEW MARKS

I	Understanding background and topic (3M)
II	Specific Project goals (2M)
III	Literature Survey (2M)
IV	Project Planning (4M)
V	Presentation skills (4M)

S.No	H.T.NO	NAME OF THE STUDENT	PROJECT TITLE	Review I (15)	Review II (15)	Review III (20)	Total (50)
1	16911A0301	ALURI SANJAY SREENIVAS	Design And Fabrication Of Automatic Gear Shifting Mechanism In Automobile	12	14	16	42
2	16911A0303	APNAGARI NAVEEN KUMAR	Ergonomic And Budget Mini Chopper Bike	11	14	14	39
3	16911A0304	ATHELLI RAVINDRA	Design And Fabrication Of Automatic Gear Shifting Mechanism In Automobile	12	13	16	41
4	16911A0305	AVULA BALAKRISHNA	Optimal Design Of BASALT-KENAF & EGLASS- KENAF Composite	10	12	15	37
5	16911A0306	BALLARY SURYAKANTH	Experimental Investigation Of Mechanical Properties Of Mild Steel AISI 1040 Using Mig Welding Process	12	14	14	40
6	16911A0307	BANDA VIKAS YADAV	Experimental Investigation Of Mechanical Properties Of Stainless Steel 304 Using Tig Welding Process	11	12	15	38
7	16911A0308	BANDREDDI SHIVANI	Development Of Composite Materials Using Various Fibers & Epoxy Resin	12	12	14	38
8	16911A0310	BHUKYA NAGA	Comparative Elevation Of Mild Steel Welded Joints Employed By Different Process	11	12	14	37
9	16911A0312	CHELAKALA SAI SRINIVAS	Design And Fabrication Of Automatic Gear Shifting Mechanism In Automobile	10	14	15	39
10	16911A0313	CHINTHA ARUN	Experimental Investigation Of Mechanical Properties Of Stainless Steel 304 Using Tig Welding Process	11	12	15	38
11	16911A0314	CHIRUMALLA LIKITHA	Investigation On Friction Stir Welding Of Dissimilar Aluminium Alloys (Aa6061 & Aa 6351) Using Various Micro Powders	11	13	14	38
12	16911A0315	D MANI RATNAM	Experimental Investigation Of Mechanical Properties Of Stainless Steel 304 Using Tig Welding Process	12	11	16	39
13	16911A0317	DEVARA NAVEEN	Thermal Evaluation Of Pulsating Heat Pipe For Different Fluids	12	12	15	39
14	16911A0318	EEDULA BHARGAV REDDY	Thermal Evaluation Of Pulsating Heat Pipe For Different Fluids	12	13	15	40
15	16911A0319	ETTADI VISHNU	Investigation On Friction Stir Welding Of Dissimilar Aluminium Alloys (Aa6061 & Aa 6351) Using Various Micro Powders	10	13	13	36
16	16911A0321	GANDEEDU VIJAYALAXMI	Effects Of Annealing Cycle On The Mechanical Properties And Micro Structure Of The Cold Rolled Steel Coils	11	13	15	39
17	16911A0322	GUNDABIONA SESHANTH	Design Of Lattice Structure And Slipper Sole Using Additive Manufacturing	11	12	14	37
18	16911A0323	GUNREDDY AJAY KUMAR REDDY	SYNTHESIS OF TITANIA (Tio2) NANO STRUCTURES WITH DIFFERENT MORPHOLOGIES	11	11	14	36
19	16911A0325	JAITHARAM SWAPNA	Development Of Composite Materials Using Various Fibers & Epoxy Resin	10	12	12	34
20	16911A0326	K A MALLESH YADAV	Optimal Design Of BASALT-KENAF & EGLASS- KENAF Composite	11	12	15	38
21	16911A0328	KATUKOJWALA SRIKANTH	Investigation On Friction Stir Welding Of Dissimilar Aluminium Alloys (Aa6061 & Aa 6351) Using Various Micro Powders	11	13	13	37
22	16911A0330	KOPPINEEDI DURGA PRASAD	SYNTHESIS OF TITANIA (Tio2) NANO STRUCTURES WITH DIFFERENT MORPHOLOGIES	11	12	16	39
23	16911A0331	KOTHAPALLY RUCHITHA	SYNTHESIS OF TITANIA (Tio2) NANO STRUCTURES WITH DIFFERENT MORPHOLOGIES	11	12	15	38
24	16911A0332	M SAI KUMAR	Prototype Model Building Of Automobile Component By Reverse Engineering	10	11	15	36
25	16911A0333	MALGARI KRANTHI SWAROOP REDDY	Experimental Investigation Of Mechanical Properties Of Stainless Steel 304 Using Tig Welding Process.	10	11	16	37
26	16911A0334	MARGAM PREM	Experimental Investigation Of Mechanical Properties Of Mild Steel AISI 1040 Using Mig Welding Process	10	11	15	36
27	16911A0335	MEGHARAJ RAHUL	Design And Fabrication Of Automatic Gear Shifting Mechanism In Automobile	11	11	15	37
28	16911A0336	MENNENI VEENILA	Development Of Composite Materials Using Various Fibers & Epoxy Resin	12	14	14	40
29	16911A0337	MOHAMMED ADIL	IMPACT OF NOTCH TOPOLOGY ON THE FATIGUE LIFE Of UNS S32760 SUPER DUPLEX STAINLESS STEEL	11	14	13	38
30	16911A0338	MOHAMMED IMAZUDDIN	IMPACT OF NOTCH TOPOLOGY ON THE FATIGUE LIFE Of UNS S32760 SUPER DUPLEX STAINLESS STEEL	12	14	16	42
31	16911A0339	MOHAMMED ISHAQ	Ergonomic And Budget Mini Chopper Bike	12	14	15	41
32	16911A0341	MOTAM RAJKUMAR	Comparative Elevation Of Mild Steel Welded Joints Employed By Different Process.	12	11	16	39
33	16911A0342	MUNGI ARAVIND REDDY	Experimental Investigation Of Mechanical Properties Of Mild Steel AISI 1040 Using Mig Welding Process	11	13	16	40
34	16911A0343	NOMULA SHRUTHI	Thermal Evaluation Of Pulsating Heat Pipe For Different Fluids	12	12	15	39
35	16911A0345	PAMBA SOURAB KUMAR	IMPACT OF NOTCH TOPOLOGY ON THE FATIGUE LIFE Of UNS S32760 SUPER DUPLEX STAINLESS STEEL	11	13	15	39
36	16911A0346	PATLOLLA DIVIJ REDDY	SYNTHESIS OF TITANIA (Tio2) NANO STRUCTURES WITH DIFFERENT MORPHOLOGIES	11	12	12	35
37	16911A0348	RONDI NAVEEN	Design Of Lattice Structure And Slipper Sole Using Additive Manufacturing	11	13	15	39
38	16911A0349	S RAMANUJAM	Evolution Of Mechanical Properties Of A Novel Composite Material	11	14	13	38
39	16911A0351	SANDAPALLY VAMSHI	Experimental Investigation Of Mechanical Properties Of Mild Steel AISI 1040 Using Mig Welding Process	11	12	16	39
40	16911A0352	SAPAVATH SUNIL	Comparative Elevation Of Mild Steel Welded Joints Employed By Different Process.	12	12	13	37
41	16911A0354	TEJAVATH SANDEEP	Comparative Elevation Of Mild Steel Welded Joints Employed By Different Process.	12	13	16	41
42	16911A0355	ULLANGUNTA VENKATA SAI CHANDAN	Development Of Composite Materials Using Various Fibers & Epoxy Resin	12	14	13	39
43	16911A0357	VELUALA VISHNU	Optimal Design Of BASALT-KENAF & EGLASS- KENAF Composite	12	13	15	40
44	16911A0358	VELLAMPALLI PURNA PAVAN SUDHAKAR	Design Of Lattice Structure And Slipper Sole Using Additive Manufacturing	9	15	15	39
45	16911A0359	YERRABAPANI LAXMI PRASANNA	Design Of Lattice Structure And Slipper Sole Using Additive Manufacturing	11	11	14	36
46	16911A0360	ZUBAIR AHMED	IMPACT OF NOTCH TOPOLOGY ON THE FATIGUE LIFE Of UNS S32760 SUPER DUPLEX STAINLESS STEEL	9	12	14	35
47	17915A0301	A VIJAY KUMAR	Effects Of Annealing Cycle On The Mechanical Properties And Micro Structure Of The Cold Rolled Steel Coils	11	10	14	35
48	17915A0303	ALLI VINAY KUMAR	Ergonomic And Budget Mini Chopper Bike	11	11	15	37
49	17915A0304	ALWALA SAI KIRAN	Effects Of Annealing Cycle On The Mechanical Properties And Micro Structure Of The Cold Rolled Steel Coils	10	10	13	33
50	17915A0305	AREKATIKE KARAN	Prototype Model Building Of Automobile Component By Reverse Engineering	11	13	14	38
51	17915A0306	AWSHALA SAGAR	Effects Of Annealing Cycle On The Mechanical Properties And Micro Structure Of The Cold Rolled Steel Coils	9	13	15	37
52	17915A0307	B JAYACHANDRA	Evolution Of Mechanical Properties Of A Novel Composite Material	11	12	16	39
53	17915A0308	BARDHA SHASHI KUMAR REDDY	Optimal Design Of BASALT-KENAF & EGLASS- KENAF Composite	12	11	16	39
54	17915A0309	BASWA PAVANI	Investigation On Friction Stir Welding Of Dissimilar Aluminium Alloys (Aa6061 & Aa 6351) Using Various Micro Powders	10	12	15	37
55	17915A0310	BATHULA RAJASHEKHAR REDDY	Thermal Evaluation Of Pulsating Heat Pipe For Different Fluids	12	12	15	39
56	17915A0311	BAVIRISETTI SAI HARI HARAN	Evolution Of Mechanical Properties Of A Novel Composite Material	10	12	15	37
57	17915A0312	BOJJA DIKSHITH	Evolution Of Mechanical Properties Of A Novel Composite Material	12	11	12	35
58	17915A0313	BOMPALLY RAVITEJA	Prototype Model Building Of Automobile Component By Reverse Engineering	9	12	14	35
59	16915A0304	B SAI NIHAR (Re-Admn 30/06/2017)	Prototype Model Building Of Automobile Component By Reverse Engineering	11	11	15	37
60	16911A0361	A HITESH KUMAR	Rocker Bogie Suspension System	11	13	15	39
61	16911A0362	AJAY BIRADAR	Design And CFD Analysis Of A Car Rear Aerofoil	11	12	15	38

HOD Mech

VIDYA JYOTHI INSTITUTE OF TECHNOLOGY

DEPARTMENT OF MECHANICAL ENGINEERING

Date: 06.10.2020

CIRCULAR

As an initiative by the department of mechanical engineering in the identification of best projects, a selection committee has been constituted to review and scrutinize all the projects for the academic year 2019-2020, based on following factors.

1. Creativity
2. Type of Materials used
3. Manufacturing Methods Employed
4. Experimentation results through design of experiments
5. Analysis of results
6. Conclusion

The prospective projects selected are taken for award to be conferred on graduation day.

The committee members are:

1. Dr.V.V.Satyanarayana
2. Dr.B.V.Reddy
3. Mr.J.Jagadesh Kumar

HoD MECH

VIDYA JYOTHI INSTITUTE OF TECHNOLOGY

DEPARTMENT OF MECHANICAL ENGINEERING

Date: 15.10.2020

CIRCULAR

After thorough reviewing of all the projects by considering following factors, the committee members has selected the best projects for which award is to be conferred on 12.10.2020.

1. Creativity
2. Type of Materials used
3. Manufacturing Methods Employed
4. Experimentation results through design of experiments
5. Analysis of results
6. Conclusion

The Best Projects are:

S.NO	H.T.No.	NAME OF THE STUDENT	PROJECT TITLE	GUIDE
I	16911A0314	CH.LIKITHA	Investigation On Friction Stir Welding Of Dissimilar Aluminium Alloys (Aa6061) Using Various Micro Powders	Mr.S.Prasad Kumar
	16911A0319	E.VISHNU		
	16911A0328	K.SRIKANTH		
	17915A0309	B.PAVANI		
II	16911A03K9	MAHESH	Investigation on the properties of magnetic nano particles using arc discharge method	Mr. Hasan
	16911A03H9	ANIL		
	16911A03L7	RANJITH		
	16911A03H4	NITHISH		
III	16911A0395	MD.ZOHAIB	Experimental investigation of dual fuel diesel engine with alternate fuels	Mr.K.Ravi Kumar
	16911A0394	MD.ARBAZ		
	16911A03B0	SHAMIN BASHEER		
	16911A03A2	P.SRIKANTH		

HoD/MECH

Vidya Jyothi Institute of Technology

DEPARTMENT OF MECHANICAL ENGINEERING

MAIN PROJECT BATCHES WITH TITLE AND GUIDES 2019-2020

SECTION-A

Batch	Roll No	Name of the Student	Marks/Grade	Name of the Project Guide	Project Title
I	16911A0332	M.SAI KUMAR	A	Dr.M.Naveen Kumar	Prototype model of automobile component by reverse engineering
	16915A0304	B. SAI NIHAR	A		
	17915A0305	A.KARAN	A		
	17915A0313	B.RAVI TEJA	A		
II	16911A0349	S.RAMANUJAN	B	Mr.T.Pavan Kumar	Evaluation of mechanical properties of and thermal behaviour of novel composite
	17915A0307	B.JAYACHNDRA	B		
	17915A0311	B.SAIHARIHARAN	B		
	17915A0312	B.DEEKSHITH	B		
III	16911A0301	A.SANJAY	A	Dr.M.Naveen Kumar	Design of automatic gear shifting
	16911A0304	A.RAVINDRA	A		
	16911A0312	CH.SAI SRINIVAS	A		
	16911A0335	M.RAHUL	A		
IV	16911A0314	CH.LIKITHA	O	Mr.S.Prasad Kumar	Investigation On Friction Stir Welding Of Dissimilar Aluminium Alloys (Aa6061 & Aa 6351) Using Various Micro Powders
	16911A0319	E.VISHNU	O		
	16911A0328	K.SRIKANTH	O		
	17915A0309	B.PAVANI	O		
V	16911A0308	B.SHIVANI	B	Mr.C.Naveen Raj	Development of composite Materials using various fibres And epoxy resin
	16911A0325	J.SWAPNA	B		
	16911A0336	M.VINEELA	B		
	16911A0355	UVS CHANDAN	B		
VI	169110305	A.BALAKRISHNA	B	Mr.S.Ramakrishna	Optimal Design Of Basalt-Kenaf And E Glass –Kenaf Composite
	169110326	KA MALLESH YADAV	B		
	16911A0357	V.VISHNU	B		
	17915A0308	B.SHESHI KUMAR	B		
VII	16911A0323	G.AJAY REDDY	A	Dr.B.V.Reddi	Synthesis of TiO2 Nano structure with different morphologis
	16911A0330	K.DURGA PRASAD	A		
	16911A0331	K.RUCHITHA	A		
	16911A0346	P.DIVIJ	A		
VIII	16911A0337	MD.ADIL	A	Dr.Phanindra Bogu	Fatigue analysis UNS S32760
	16911A0338	MD.IMAAZ	A		
	16911A0360	ZUBAIR AHMED	A		
	16911A0345	P.SOURAB	A		

A Proposed Project Report on

INVESTIGATION ON FRICTION STIR WELDING OF DISSIMILAR ALUMINIUM ALLOYS (AA6061 & AA 6351) USING VARIOUS MICRO POWDERS

Submitted in partial fulfillment of the requirement for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

MECHANICAL ENGINEERING

BY

CH LIKITHA	**16911A0314**
E VISHNU	**16911A0319**
K SRIKANTH	**16911A0328**
B PAVANI	**17915A0309**

Under the guidance of

Mr. S PRASAD KUMAR

(Assistant Professor)

Submitted to

DEPARTMENT OF MECHANICAL ENGINEERING

VIDYA JYOTHI INSTITUTE OF TECHNOLOGY

(Autonomous)

(Affiliated To Jawaharlal Nehru Technology University, Hyderabad)

Aziz nagar gate, CB Post, Hyderabad – 500075

(2016-20)

VIDYA JYOTHI INSTITUTE OF TECHNOLOGY DEPARTMENT OF MECHANICAL ENGINEERING

BONAFIDE CERTIFICATE

This is to certify that the project work entitled "**INVESTIGATION ON FRICTION STIR WELDING OF DISSIMILAR ALUMINIUM ALLOYS (AA6061 & AA6351) USING VARIOUS MICRO POWERS"** is bonafide project work submitted by a

CH LIKITHA	**16911A0314**
E VISHNU	**16911A0319**
K SRIKANTH	**16911A0328**
B PAVANI	**17915A0309**

In the department of MECHANICAL ENGINEERING in partial fulfilment of requirements for the award of degree of bachelor of technology in "Mechanical Engineering" for the academic year 2017-18. This work has been carried under my guidance and has not been submitted the same for any university/institution for award of any degree/diploma.

PROJECT GUIDE

Mr. S. PRASAD KUMAR

HEAD OF DEPARTMENT

Mr. G.SREERAM REDDY

Internal Examiner:

External Examiner:

DECLARATION

We hereby declare that the whole work done in completing this project is our own effort and we have not copied it from anywhere. During our project, our project guide **Mr. S. PRASAD KUMAR** guided us to complete our project taking his valuable time. We are very thankful to "**VIDYA JYOTHI INSTITUTE OF TECHNOLOGY**" for giving us opportunity to do our project in this esteemed organization. For the award of the degree of **BACHELOR OF TECHNOLOGY** in mechanical engineering.

Project associates:

CH LIKITHA	**16911A0314**
E VISHNU	**16911A0319**
K SRIKANTH	**16911A0328**
B PAVANI	**17915A0309**

ACKNOWLEDGMENT

The project entitled "**INVESTIGATION ON FRICTION STIR WELDING OF DISSIMILAR ALUMINIUM ALLOYS (AA 6061 & AA 6351) USING VARIOUS MICRO POWDERS"** is sum of total effort of our batch. It is our duty to bring forward each and every one who is directly and indirectly in relation with our project and without whom it would not have gained a structure. We express our deep sense of gratitude to our respected guide, assistant professor Mr. S. Prasad Kumar for his valuable help and guidance, we are thankful to him for the encouragement he has given us to complete the project. We also owe a great thanks to our institution VJIT, Moinabad and HOD Professor G. Sree Ram Reddy for his encouragement and also fine support in achieving success. Finally we thank our professors, our parents, workshop technicians for their fine motivation and inspiration.

CH LIKITHA	**16911A0314**
E VISHNU	**16911A0319**
K SRIKANTH	**16911A0328**
B PAVANI	**17915A0309**

ABSTRACT

Friction stir welding is a joining process in which two or more work parts are weld in solid state by means of frictional heating and plastic deformation typically below the melting temperature of the materials to be joined. This technique has a wide metallurgical advantages compared to fusion and resistance welding.

This research work deals with investigation of friction stir welding of dissimilar Aluminum alloys (AA 6061 and AA 6351) with and without silicon carbide, aluminium oxide, titanium nano particles. Tool required to weld will be designed using CAD software and will be fabricated. Friction stir weld will be done using fabricated tool on the dissimilar metals at various process parameters with and without silicon carbide, aluminium oxide, titanium nano particles and welded joints are investigated for hardness, tensile strength, microstructure and impact tests.

Mechanical properties obtained from different tests are analyzed and compared for friction stir welding done with and without titanium nano particles.

Keywords: Friction stir welding, frictional heating, plastic deformation

CONTENT

LIST OF FIGURES

LIST OF TABLES

CHAPTER -1

INTRODUCTION

The friction stir welding (fsw) is a new welding technique in domain of welding. it is solid state welding process and invented by the welding institute (twi) of Cambridge, England in 1991 [1]. this process is simple, environment friendly, energy efficient and becomes major attraction for an automobile, aircraft, marine and aerospace industries due to the high strength of the fsw joints as near as base metal. It allows considerable weight savings in light weight construction compared to conventional joining technologies. in contrast to conventional joining welding process, there is no liquid state for the weld pool during fsw, the welding takes place in the solid phase below the melting point of the materials to be joined. thus, all the problems related to the solidification of a fused material are avoided [2]. Materials which are difficult to fusion weld like the high strength aluminum alloys can be joined with minor loss in strength.

In friction stir welding a non-consumable rotating tool with a specially profiled threaded/unthreaded pin and shoulder is rotated at a constant speed. The tool plunges into the two pieces of sheet or plate material and through frictional heat it locally plasticized the joint region. The tool then allowed to stir the joint surface along the joining direction. During tool plunge, the rotating tool undergoes only rotational motion at only one place till the shoulder touches the surface of the work material, this is called the dwelling period of the tool. During this stage of tool plunge it produces lateral force orthogonal to welding or joining direction. The following diagram depicts the procedures of fsw/fsp.

The upper surface of the weld consists of material that is dragged by the shoulder from the retreating side of the weld, and deposited on the advancing side. After the dwell period the tool traverse along the joining direction, the forward motion of the tool produces force parallel to the direction of travel known as traverse force. After the successful weld, the tool reaches to termination phase where it is withdrawn from the work piece [4]. This is shown in fig. 1.1(d). During the welding process the parts have to be clamped rigidly onto a backing bar in a manner that prevents the abutting joint faces from being forced apart. The length of the tool pin is slightly less than the weld depth required and the tool shoulder should be in intimate contact with the work surface.

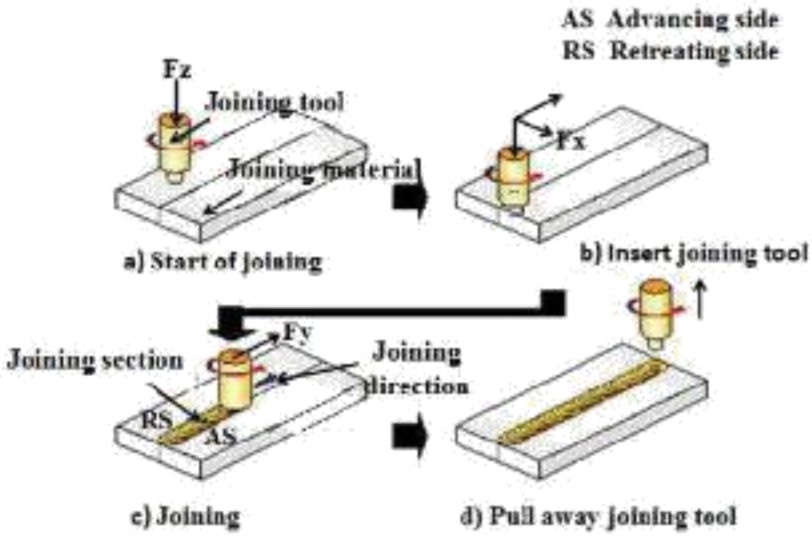


Fig. 1.1 Schematic representation of FSW [3]

Besides tight clamping of the members to be welded, the key to success is to select the optimum parameters which include rotational speed, welding speed, axial force, and tool pin as well as shoulder profile. Detailed description of FSW process is shown in Fig.1.2.

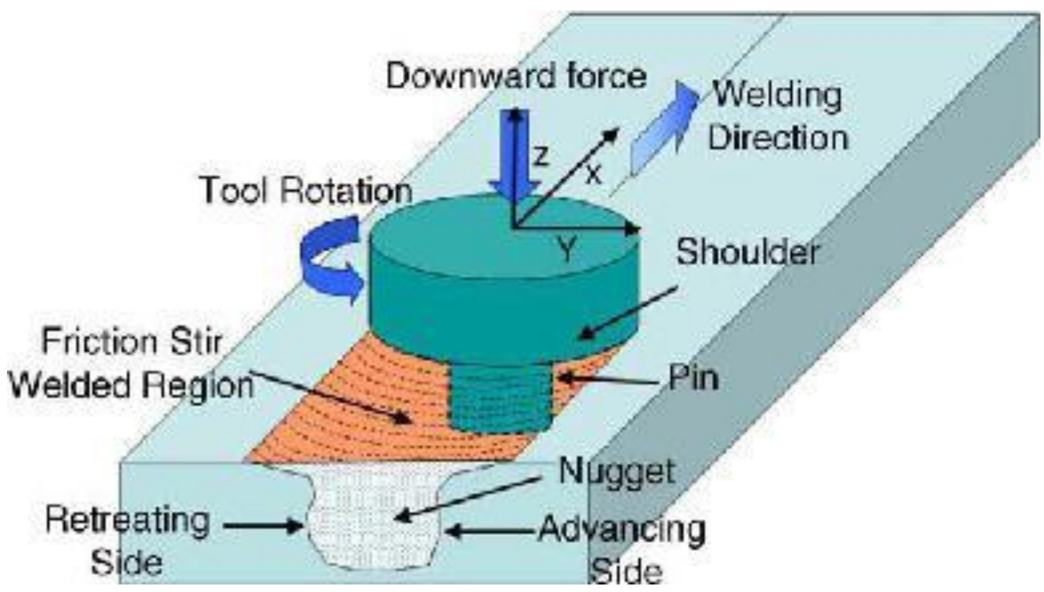


Fig. 1.2 Friction stirs welding [5]

Above diagram of friction stir welding indicates two terms advancing side and retreating side, when rotation of tool is the same as the tool traverse direction along weld line is called advancing side and when rotation of tool is opposite to the tool traverse direction is called retreating side. Non consumable tool is most important tool in friction stir welding process, it serves following function like heating of the work piece, movement of material to produce joint and containment of the hot metal beneath the tool shoulder. Friction stir welding tool consist pin and shoulder and both has individual purposes.

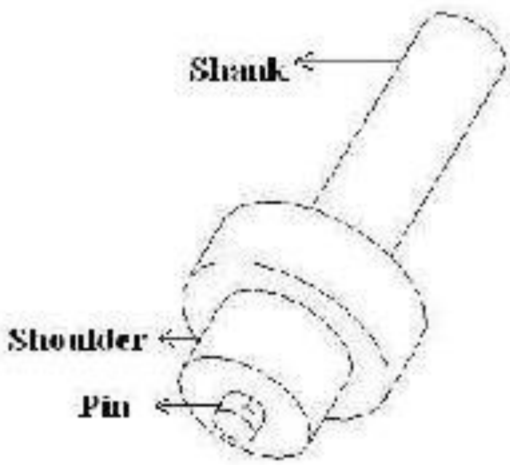


Fig.1.3 FSW Tool

In recent development, the FSW has found application into the welding of the circumference, cylinders, curvilinear, three dimensional objects and objects which require finer executing movements. FSW is considered to be the most significant development in metal joining in a decade and is a ‘‘green’’ technology due to its energy efficiency, environment friendliness, and versatility. The process has the unique characteristics, as there is no melting of parent material, the alloying elements are not lost and thus mechanical properties are preserved. Therefore, the degree of combining different materials is high and hence increases the possibility of welding materials which was difficult to weld. As compared to the conventional welding methods, FSW consumes considerably less energy. No cover gas or flux is used, thereby making the process environmentally friendly. Key benefits of FSW process are enlisted in table 1.1 [5].

Metallurgical benefits	• Solid phase process • Low distortion of work piece • Good dimensional stability and repeatability • No loss of alloying elements • Excellent metallurgical properties in the joint area • Fine microstructure • Absence of cracking • Replace multiple parts joined by fasteners

Environmental benefits	• No shielding gas required • No surface cleaning required • Eliminate grinding wastes • Eliminate solvents required for degreasing • Consumable materials saving, such as rugs, wire or any other gases
Energy benefits	• Improved materials use • Only 2.5% of the energy needed for a laser weld • Decreased fuel consumption in light weight aircraft, automotive and ship applications

Table 1.1: Key benefits of friction stir welding

CHAPTER-2

LITERATURE REVIEW

Aluminium and its alloys show unique characteristics like light weight, high strength, high toughness, extreme temperature capability, versatility of extruding, and excellent corrosion resistance. Those make it the obvious choice of material by engineers and designers for the variety of engineering applications.

Many researchers, they have given copious attention towards the parameters optimization like rotational speed (N), traverse speed (ʋ) and axial force (F) and apart from parameters optimization they have also given sufficient focus to find out the effect of tool pin profile on friction stir welding joints that yields optimum characteristics of joint. But very less work has been done on tool shoulder like effect of tool shoulder profiles and tool shoulder geometry on microstructure and mechanical properties of friction stir welded joint.

2.1 Process variables in FSW

The tool rotational speed (N), welding speed (ʋ) and the axial force (F) are the three important welding variables in FSW. The study of the effect of welding variables on the friction stir welding process is important because it directly decides the weld quality of the FSW joint. The welding process affects the joint properties primarily through heat generation and material flow. The rotation speed (N) results in stirring and mixing of material around the rotating pin and the translation of the tool moves the stirred material from the front to the back of the pin. The axial force (F) is another important parameter to avoid the frictional slippage at the tool work piece interface.

Mandal et al.[6] investigated the axial force during plunging of AA2024 aluminium alloy of thickness 12.5mm. It is observed that plunging is completed in 14 seconds, the peak load of 25 KN is observed at 5 seconds mark. At the end of the 14 sec., the load dropped to approximately 8 KN where it remains steady. During the initial stage of welding, high force values act on the material due to tool penetration, since the material temperature is still low and consequently its yield strength is high only when tool penetration is completed and the travel motion is not yet started, the softening of material induces a drop in axial force.

Kumar and Kailas[7] studied the role of axial force on weld nugget defect. They conclude that with the increase of axial load the defect size decreases. During the investigation they shows that the shoulder contact increases with the base material as the axial load increases and the transferred of material from the leading edge is confined in the weld cavity, and sufficient amount of frictional heat and hydrostatic pressure is generated to produce a defect free weld.

For FSW, two parameters are very important: tool rotation in clockwise or counter clockwise direction and tool traverse speed along the line of joint. The rotation of tool results in stirring and mixing of material around the rotating pin and the translation of tool moves the stirred material from the front to the back of the pin and finishes welding process. Higher tool rotation generates higher temperature because of higher friction heating and results in more intense stirring and mixing of material as will be discussed later. However, it should be noted that frictional coupling of tool surface with work piece is going to govern the heating. So, a monotonic increase in heating with increasing tool rotation is not expected as the coefficient of friction at interface will change with increasing tool rotation rate.

Han et al.[8] investigated the optimum condition by mechanical characteristic evaluation in friction stir welding for 5083-O Al alloy. The mechanical characteristics for friction stir welding (FSW) of 5083-O Al alloy were evaluated. The results show that in FSW at 800 r/min and 124 mm/min, a weld defect is observed at the start point. However, the button shape at the end point is good and the stir zone has a soft appearance. At 267 mm/min, a void occurs at the button. A slight weld defect and rough stir zone are seen both at the start and end points at 342 mm/min. Moreover, at the bottom, a tunnel-type void is observed from an early stage to the end point, and at 800 r/min, a weld defect can be found from an early stage to the end point. These defects are rough with imperfect joining due to excessive rotation speed and high physical force. Weld fractures relative to rotational and travel speeds are observed at the stir zone. The optimum FSW conditions are a welding speed of 124 mm/min and a rotational speed of 800 rpm.

Arora et al.[9] studied to design a tool shoulder diameter based on the principle of maximum utilization of supplied torque for traction. Optimum tool shoulder diameter computed from this principle using a numerical heat transfer and material flow model. Pin diameter was fixed ϕ6mm and shoulder diameters were varied ϕ15, 18, and 21 mm and best weld joint strength was got in shoulder diameter of ϕ18 mm.

Preheating or cooling can also be important for some specific FSW processes. For materials with high melting point such as steel and titanium or high conductivity such as copper, the heat produced by friction and stirring may be not sufficient to soften and plasticize the material around the rotating tool. Thus, it is difficult to produce continuous defect-free weld. In these cases, preheating or additional external heating source can help the material flow and increase the process window. On the other hand, materials with lower melting point such as aluminium and magnesium, cooling can be used to reduce extensive growth of recrystallized grains and dissolution of strengthening precipitates in and around the stirred zone.

2.2. Temperature distribution and Heat transfer in FSW

As discussed earlier, the welding parameters plays very significant role in deciding the temperature distribution as it directly influences the microstructure of welds, such as grain size, grain boundary character, coarsening and dissolution of the strengthening precipitates. Therefore, the study of temperature distribution and the resulting heat input within the work piece material is very important during FSW process.

Hwang and coworkers[10] experimentally explore the thermal histories and temperature distribution within butt joint welds of 6061-T6 aluminium alloy. Four thermocouples of K-type with data acquisition system connected to a personal computer were used to record the temperature histories during welding. The different types of thermocouple layout same side and equal distance, opposite side and equal distance and same side and unequal distance) are devised at different locations on the work piece to measure the temperature distribution during welding process. They concluded that the temperature inside the pin can be regarded as a uniform distribution and that the heat transfer starts from the rim of the pin to the edge of the work piece. For the successful welds temperature lies between 365 oC and 390 oC respectively.

Maeda et al.[11] studied experimental observation that the temperature distribution are not symmetrical about the joint line. The temperature at fifteen points of the top and the bottom surfaces were recorded using K-type thermocouple for the material of AA7075 and dissimilar materials of AA6061 with AA5083 aluminium alloys. They concluded that there is asymmetric temperature distribution between the advancing side and retreating side in both of the cases. For the defect free welding conditions the advancing side shows higher temperature distribution than the retreating side.

2.3. Tool Geometry

Tool geometry is the most influential aspect of process development. The tool geometry plays critical role in material flow and in turn governs the traverse rate at which FSW can be conducted. An FSW tool consists of a shoulder and a pin as shown schematically in Fig. 2.1.

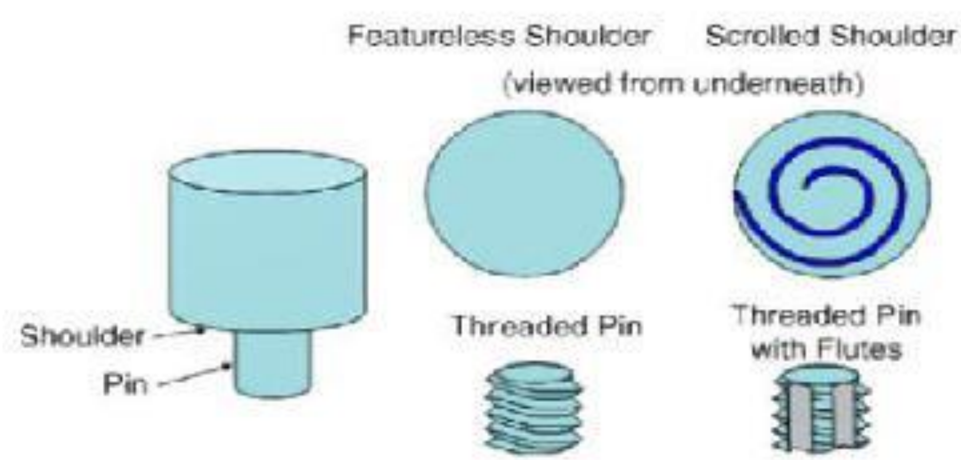


Fig.2.1 Schematic diagram of the FSW tool [5]

As mentioned earlier, the tool has two primary functions: (a) localized heating, and (b) material flow. The friction between the shoulder and work piece results in the biggest component of heating. From the heating aspect, the relative size of pin and shoulder is important. The shoulder also provides confinement for the heated volume of material. The second function of the tool is to 'stir' and 'move' the material. It is desirable that the tool material is sufficiently strong, tough and hard wearing at the welding temperature.

Tool shoulders are designed to produce heat (through friction and material deformation) to surface and subsurface regions of the work piece. The tool shoulder produces a majority of the heating in thin sheet, while the pin produces a majority of the heating in thick work pieces. Also, the shoulder produces the downward forging action necessary for weld consolidation. Tool pin is designed to disrupt the faying, or contacting, surface of the work piece, shear material in front of the tool, and move material behind the tool.

In recent years several new features have been introduced in the design of tools. Several tools designed at TWI are shown in table 2.1. The Whorl and MX-Triflute have smaller pin volumes than the tools with cylindrical pins. The tapered threads in the whorl design induce a vertical component of velocity that facilitates plastic flow. The flute in the MX-Triflute also increases the interfacial area between tool and the work piece, leading to increased heat generation rates, softening and flow of material. Consequently, more intense stirring reduces both the traversing force for the forward tool motion and the welding torque. Although cylindrical, Whorl and Triflute designs are suitable for butt welding; they are not useful for lap welding, where excessive thinning of the upper plate can occur together with the trapping of adherent oxide between the overlapping surfaces. Flared-Triflute and A-skew tools were developed to ensure fragmentation of the interfacial oxide layer and a wider weld than is usual for butt welding. The Flared-Triflute tool is similar to MX-Triflute with an expanded flute, while A-skewTM tool is a threaded tapered tool with its axis inclined to that of the machine spindle. Both of these tools increase the swept volume relative to that of the pin, thus expanding the stir region and resulting in a wider weld and successful lap joints. Motion due to rotation and translation of the tool induces asymmetry in the material flow and heating across the tool pin. To overcome this problem, TWI devised a new tool, Re-stir, which applies periodic reversal of tool rotation. This reversal of rotation eliminates most problems associated with inherent asymmetry of conventional FSW. With the exception of FSW with Re-stir tool, material flow is essentially asymmetric about joint interface. Understanding the asymmetry in material flow is important for optimal tool design [5].

Tool	Cylindrical	Whorl™	MX triflute™	Flared triflute™	A-skew™	Re-stir™
Schematics						
Tool pin shape	Cylindrical with threads	Tapered with threads	Threaded, tapered with three flutes	Tri-flute with flute ends flared out	Inclined cylindrical with threads	Tapered with threads
Ratio of pin volume to cylindrical pin volume	1	0.4	0.3	0.3	1	0.4
Swept volume to pin volume ratio	1.1	1.8	2.6	2.6	Depends on pin angle	1.8
Rotary reversal	No	No	No	No	No	Yes
Application	Butt welding; fails in lap welding	Butt welding with lower welding torque	Butt welding with further lower welding torque	Lap welding with lower thinning of upper plate	Lap welding with lower thinning of upper plate	When minimum asymmetry in weld property is desired

Table 2.1 Selection of tools designed at TWI [5]

Elangovana et al.[12] studied the influences of tool pin profile and welding speed on the formation of friction stir processing zone in AA2219 aluminium alloy. AA2219 aluminium alloy has gathered wide acceptance in the fabrication of light weight structures requiring a high strength to weight ratio. Compared to the fusion welding processes that are routinely used for joining structural aluminium alloys, friction stir welding (FSW) process is an emerging solid state joining process in which the material that is being welded does not melt and recast. This process uses a non-consumable tool to generate frictional heat in the abutting surfaces. The welding parameters and tool pin profile play major roles in deciding the weld quality. In this investigation, an attempt has been made to understand the effect of welding speed and tool pin profile on FSP zone formation in AA2219 aluminium alloy. Five different tool pin profiles (straight cylindrical, tapered cylindrical, threaded cylindrical, triangular and square) have been used to fabricate the joints at three different welding speeds. The formation of FSP zone has been analyzed macroscopically. Tensile properties of the joints have been evaluated and correlated with the FSP zone formation. From this investigation it is found that the square pin profiled tool produces mechanically sound and metallurgically defect free welds compared to other tool pin profiles.

Fujii et al.[13] investigated the effect of tool shape on mechanical properties and microstructure of friction stir welded aluminium alloys. Prospecting the optimal tool design for welding steels, the effect of the tool shape on the mechanical properties and microstructures of 5mm thick welded aluminium plates was investigated. The simplest shape (column without threads), the ordinary shape (column with threads) and the triangular prism shape probes were used to weld three types of aluminium alloys. For 1050-H24 whose deformation resistance is very low, a columnar tool without threads produces weld with the best mechanical properties, for 6061-T6 whose deformation resistance is relatively low, the tool shape does not significantly affect the microstructures and mechanical properties. For 5083-O, whose deformation resistance is relatively high, the weldablity is significantly affected by the rotation speed. For a low rotation speed (600 rpm), the tool shape does not significantly affect the microstructures and mechanical properties of the joints.

Apart from tool pin design there is significant impact of tool shoulder profile and tool shoulder geometries on weld quality. Various tool shoulder geometries have been designed by TWI. These geometries increase the amount of material deformation produced by the shoulder, resulting in increased work piece mixing and higher-quality friction stir welds. Following figure consists of scrolls, ridge or knurling, grooves, and concentric circles and can be machined on any tool shoulder profile.

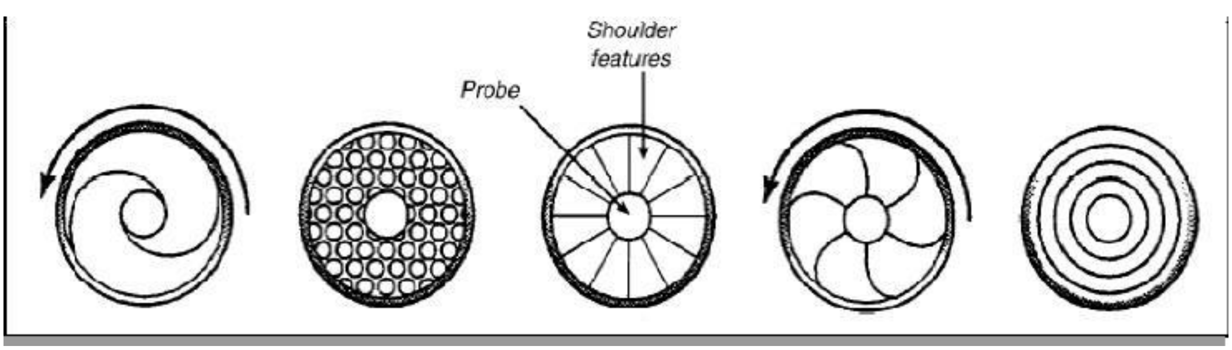


Fig.2.2 Tool shoulder geometries, viewed from underneath the shoulder [5]

Scialpi et al.[14] studied the effect of tool shoulder geometries on microstructure and mechanical properties of 6082 aluminium alloy joint welded by friction stir welding. In this study, we used three different tool shoulder geometry (fillet, fillet+scrolled, and fillet+cavity shoulder geometry tool) with 1810rpm rotational speed and 460 mm/min welding speed. Welding surface appearance and flash formation observed visually and observed that tool shoulder with fillet+scrolled produces less flash formation and rough surface finishing and tool shoulder with fillet and fillet+cavity produces little flash and good surface finishing. In the transverse tensile test the three joints showed good strength and non-considerable differences were observed, while great differences were observed in the longitudinal tensile tests of the stirred zone**,** because tool shoulder with fillet+cavity and fillet+scrolled showed an higher and higher strength and elongation with respect to fillet tool. Tool shoulder with fillet+cavity considered the best tool because that increases traverse and longitudinal strength, elongation and good surface appearance.

Galvao et al.[15] studied the influence of tool shoulder geometry on properties of friction stir welds in thin copper plate. The welds were produced using three different shoulder geometries like flat shoulder, conical shoulder and scrolled shoulder with varying the rotational and welding speed of tool. After experiment we observed that scrolled tool provides the best flow of material that yield defect free welding and scrolled tool also provides greater grain refinement that gives better weld strength and hardness with respect to flat and conical tool.

Zhang et al.[16] investigation has been carried out by rotational tool without pin but different geometry over bottom surface of tool shoulder. The experiments of FSW are carried out by using inner-concave-flute shoulder, concentric-circles-flute and threespiral- flute shoulder with welding speed of 20mm/min and 50mm/min and constant rotational speed of 1800rpm. In case of three-spiral-flute shoulder tensile strength of joint increases with decreasing of welding speed while the value of tensile strength attended by the welding speed of 20mm/min and rotational speed of 1800mm/min is about 398Mpa, which is more than parent material strength. This verify that tool with three-spiral-flute shoulder can be used to join the thin plate of aluminium alloy.

Leal at el.[17] studied to see the influence of tool geometry on material flow in heterogeneous friction stir welding of 1 mm thin plate of AA5812-H111 and AA-6016- T4 aluminum alloys. Two types of tool shoulders were used: a shoulder with conical cavity and scrolled shoulder. Pin driven flow was predominant in welds produced with the conical cavity shoulder, which are characterized by an onion ring structure. The interaction between pin-driver and shoulder-driver flow is restricted to the crown other weld, at the trailing side of the tool, and extends throughout the weld thickness, at the leading side. Although no onion ring structure was formed in welds done with scrolled shoulder, extensive mixing of the base material occurred in a plasticized layer flowing through the thickness around the rotating pin. Shoulder-driven flow is intense and continuous around the tool.

2.4. Material flow in FSW

The FSW process can be modeled as a metalworking process in terms of five conventional metal working zones: (a) preheat, (b) initial deformation, (c) extrusion, (d) forging, and (e) post heat/cool down. Typical zones obtained during the process are shown in Fig 2.3. In the preheat zone ahead of the pin, temperature rises due to the frictional heating of the rotating tool and adiabatic heating because of the deformation of material. The thermal properties of material and the traverse speed of the tool govern the extent and heating rate of this zone. As the tool moves forward, an initial deformation zone forms when material is heated to above a critical temperature and the magnitude of stress exceeds the critical flow stress of the material, resulting in material flow. The material in this zone is forced both upwards into the shoulder zone and downwards into the extrusion zone, as shown in Fig.2.3.

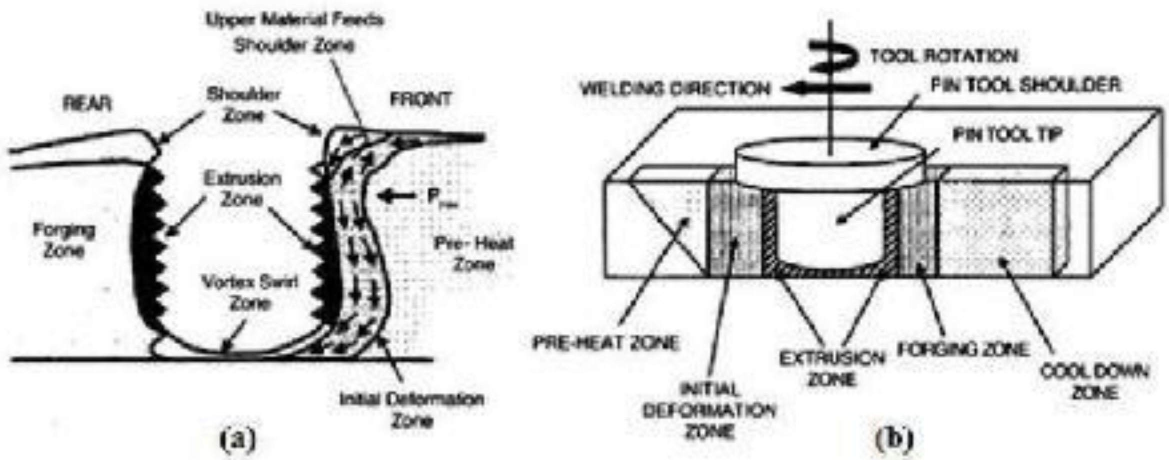


Fig.2.3 Showing (a) Metal flow pattern and (b) Metallurgical processing zones developed during friction stir welding [5]

A small amount of material is captured in the swirl zone beneath the pin tip where a vortex flow pattern exists. In the extrusion zone with a finite width, material flows around the pin from the front to the rear. A critical isotherm on each side of the tool defines the width of the extrusion zone where the magnitudes of stress and temperature are insufficient to allow metal flow. Following the extrusion zone is the forging zone where the material from the front of the tool is forced into the cavity left by the forward moving pin under hydrostatic pressure conditions. The shoulder of the tool helps to constrain material in this cavity and also applies a downward forging force. Material from shoulder zone is dragged across the joint from the retreating side toward the advancing side [18].

2.5. Microstructure zones

A typical FSW weld was produces four distinct microstructural zones: the heat affected zone (HAZ), the thermal mechanically affected zone (TMAZ), the stir zone, and the unaffected zone or base metal. A transverse section from a FSW welded joint is shown in Fig.2.4. The heat affected zone is characterized by a change in the microstructure without plastic deformation of the original grain structure. The mechanical properties are changes in this region, but there is no change in grain size or chemical properties. The TMAZ can be further divided into the non-recrystallized TMAZ and the nugget or recrystallized TMAZ. In the non-recrystallized zone, the strain and the temperature are lower and the effect of welding on the microstructure is correspondingly smaller. The detailed description about all the distinct microstructure zones is given below.

A. Unaffected material Or Parent Metal

This is material remote from the weld, which has not been deformed, and which although it may have experienced a thermal cycle from the weld is not affected by the heat in terms of microstructure or mechanical properties.

B. Heat affected Zone (HAZ)

In this region, which clearly will lie closer to the weld centre, the material has experienced a thermal cycle which has modified the microstructure and/or the mechanical properties. However, there is no plastic deformation occurring in this area. In the previous system, this was referred to as the "thermally affected zone". The term heat affected zone is now preferred, as this is a direct parallel with the heat affected zone in other thermal processes, and there is little justification for a separate name.

C. Thermo-mechanically affected zone (TMAZ)

In this region, the material has been plastically deformed by the friction stir welding tool, and the heat from the process will also have exerted some influence on the material. In the case of aluminium, it is possible to get significant plastic strain without recrystallization in this region, and there is generally a distinct boundary between the recrystallized zone and the deformed zones of the TMAZ. In the earlier classification, these two sub-zones were treated as distinct microstructural regions. However, subsequent work on other materials has shown that aluminium behaves in a different manner to most other materials, in that it can be extensively deformed at high temperature without recrystallization. In other materials, the distinct recrystallized region (the nugget) is absent, and the whole of the TMAZ appears to be recrystallized. This is certainly true of materials which have no thermally induced phase transformation which will in itself induce recrystallization without strain, for example pure titanium, β titanium alloys, austenitic stainless steels and copper. In materials such as ferritic steels and α-β titanium alloys (e.g.Ti-6Al-4V), understanding the microstructure is made more difficult by the thermally induced phase transformation, and this can also make the HAZ/TMAZ boundary difficult to identify precisely.

D. Weld nugget

The recrystallized area in the TMAZ in aluminium alloys has traditionally been called the nugget. Although this term is descriptive, it is not very scientific. However, its use has become widespread, and as there is no word which is equally simple with greater scientific merit, this term has been adopted. A schematic diagram is shown in the above Figure which clearly identifies the various regions. It has been suggested that the area immediately below the tool shoulder (which is clearly part of the TMAZ) should be given a separate category, as the grain structure is often different here. The microstructure here is determined by rubbing by the rear face of the shoulder, and the material may have cooled below its maximum. It is suggested that this area is treated as a separate sub-zone of the TMAZ.

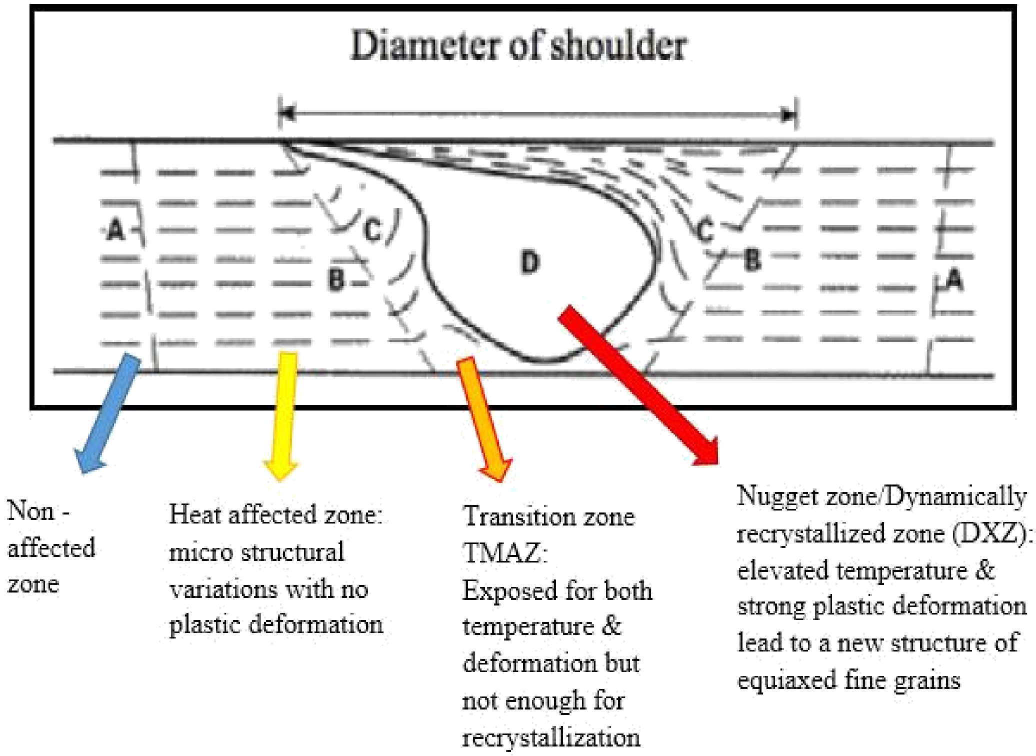


Fig 2.4: Showing the microstructure zones

2.6 Typical friction stir welding defects

Compare to fusion welding process of aluminium and its alloys, the FSW does not suffer from problems such as weld porosity, solidification cracking, and heat affected liquation cracking. This is because in FSW there is no bulk melting of the parent material. The defects in the FSW are either due to imbalance in material flow or geometrical factors associated with the position of the tool in relation to the joint. The optimal parameters settings during welding balance mass both in terms of material volume and energy. This facilitates constant volume processing while ensuring minimal impact on the pre-existing microstructure. The temperature below melting point of the parent material is the main source of plastic deformation of the material at the joint line. This facilitates microstructural change like recrystallization, coarsening and or dissolution of strengthening precipitates, grain orientation and growth. The process parameters in FSW giving rise to too hot or too cold welding condition. Too cold weld condition responsible for insufficient material flow and giving rise to defects like void formation and nonbonding. Too hot weld condition, giving rise to excessive material flow leading to material expulsion like flash formation and the collapse of the nugget within the stir zone.

2.7 Defects from too hot welds

The defects which are generated under such processing conditions are visually identified through the surface appearance of the welded joint. The improper parameter settings cause too much thermal softening. The surface of welded joint appears to contain blisters or surface galling. Furthermore, excessive heat generation can lead to thermal softening in the work piece material beyond the boundary of tool shoulder. Therefore, the tool shoulder, rather than actively participating as a mean of material containment, it is giving rise to material expulsion in the form of excessive flash formation. Too much thermal softening can also lead to the thinning of the work piece material. The work piece material below the tool shoulder will reaches a point where it is no longer able to support the axial load placed upon it. Such a condition during processing causes 'excessive flash' of the work piece material.

A weld nugget collapse under too hot welding condition is another serious defect in FSW joints. It is not expected all the times that increase of tool rotational speed at constant tool travel speed causes increase in the size of weld nugget.

Colegrove et al.[19] author has observed that the nugget region for an Al-Cu-Mg-Mn 2024 alloy can actually decrease in size rather than increase in size when tool rotational speed is sufficiently increased. The thermal softening brought about by very hot processing condition can lead to slip between the tool pin and the work piece material, and thus decreases strain rates within the immediate vicinity of the tool pin. The weld nugget appears distorted. This weld nugget collapse is generally occurred in the retreating side of the stir zone.

2.8 Defects from too cold welds

Tool cold welding condition results in work hardening of the workpiece material. This causes the dry slip between the tool pin and the workpiece material. The lack of surface fills or voids and channel defect are the main defects arising due to insufficient heat generation. The insufficient heat generation causes improper material mixing and thus responsible for non-bonding [20].

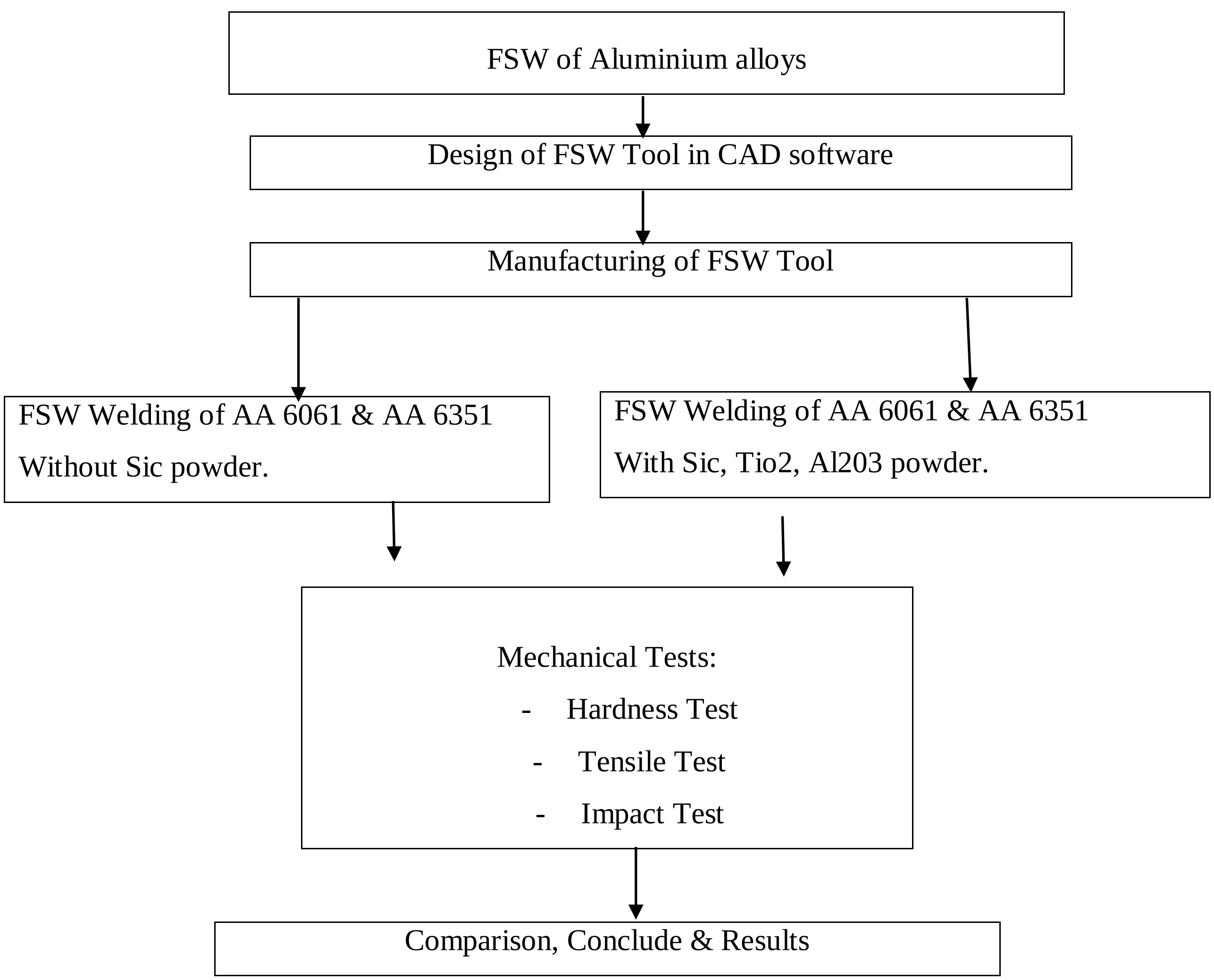
Cavaliere et al.[21] studied the FSW joint cross-sections and SEM observations of the fractured surfaces to characterize the weld performances. He studied the effect of the welding speed on the fractured surface of the tensile and fatigue tested specimens. The workpiece material investigated is AA 6082. The fractured surface appears populated of very fine dimples revealing a very ductile behavior of the material before failure. All the fatigue tested specimens was observed to fracture in the advancing side of the tool. It was observed that, at higher stresses the fatigue cracks started from the surface. Such big defects are often associated with the vortex formed in the material in the advancing side where a more chaotic flow is formed leading to the presence of voids of the mean dimension of hundreds of microns that represent the site of fatigue cracks initiation. By decreasing the stress amplitude a strong change in the crack behavior was detected, the crack appear to start from the forging defects inside the joints which are always present in this kind of welding. The failure is also related to the coalescence of many small voids and defects in the material. The presence of dimples on the surface revealed a local ductile behavior of the material prior to fracture. This is the case of such conditions in which the optimal solution between material mixing and grain refinementis obtained. By increasing the advancing speed of the tool the material is extruded too fast (high strain rates) and then they are not reached the conditions for the optimal mixing. The coupling of a high rotation speed and high advancing speed leads to a good material mixing but to a non-optimal grain structure. The too high strain rate, acting on the material during deformation, causes a boundary weakening of the recrystallized structure which can be visualized by cleavage fracture.

CHAPTER – 3

OBJECTIVE – METHODOLOGY

After extensive literature survey, it was found that very less work has been done on FSW of dissimilar alloys (AA 6061 and AA6351).So on the basis of literature survey project topic was finalized, research topic is "INVESTIGATION Of FRIFCTION STIR WELDING OF DISSIMILAR ALUMINIUM ALLOYS of AA 6061 and AA6351 USING SILICON CARBIDE, ALUMINIUM OXIDE, TITANIUM POWDER". Aluminium has following characteristics like high strength to weight ratio, easy availability on earth crust, high thermal and electric conductivity etc. Aluminium alloys are widely used in aerospace, automobile, and marine industries.

Methodology: the methodology adopted in this research work is as shown in figure below.



CHAPTER – 4

EXPERIMENTAL WORK

4.1 Materials Used

The materials Chosen for FSW in this research work are commercial AA6061 and AA6351 aluminium alloys and their dimensions are shown in table below.

NO.	ITEM	SPECIFICATION	NO.OF SHEETS
1	AA6061 sheet metal	100mm(length) x 100mm(width) x 5mm(thick)	4
2	AA6351 sheet metal	100mm(length) x 100mm(width) x 5mm(thick)	4

Table4.1: Type of work material used in present study

The chemical composition and physical properties of work materials are listed below in Table 4.2

Element	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
Wt. (%)	0.59	0.38	0.26	0.03	0.96	0.25	0.02	0.04	Balance

Table4.2: Nominal chemical composition of AA6061

Element	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
Wt. (%)	1.3	0.5	0.1	0.8	0.8	0.0	0.2	0.2	Balance

Table4.3: Nominal chemical composition of AA6351

Properties	**Melting point**	**Solidus temperature**	**Thermal conductivity (W/m-K)**	**Tensile strength (Mpa)/hardness**
AA6061	**652*C**	**582*C**	**167**	**353/96hv**
AA6351	**600*C**	**477*C**	**180**	**320/155hv**

Table4.4: physical properties of AA6061 &AA6351

4.1.1 Properties of aluminium alloy 6061

- It is a precipitation hardened aluminium alloy containing magnesium &silicon as major alloy components.
- It has good mechanical properties and good weldability.
- It is one of the most common alloys of aluminium for general purpose use.

4.1.2 Properties of aluminium alloy 6351

- It is a aluminium alloy, with zinc as the primary alloying element.
- It is strong, with strength comparable to many steels.
- It has good machinability and good fatigue strength.
- It has low resistance to corrosion.
- It is relatively high cost.

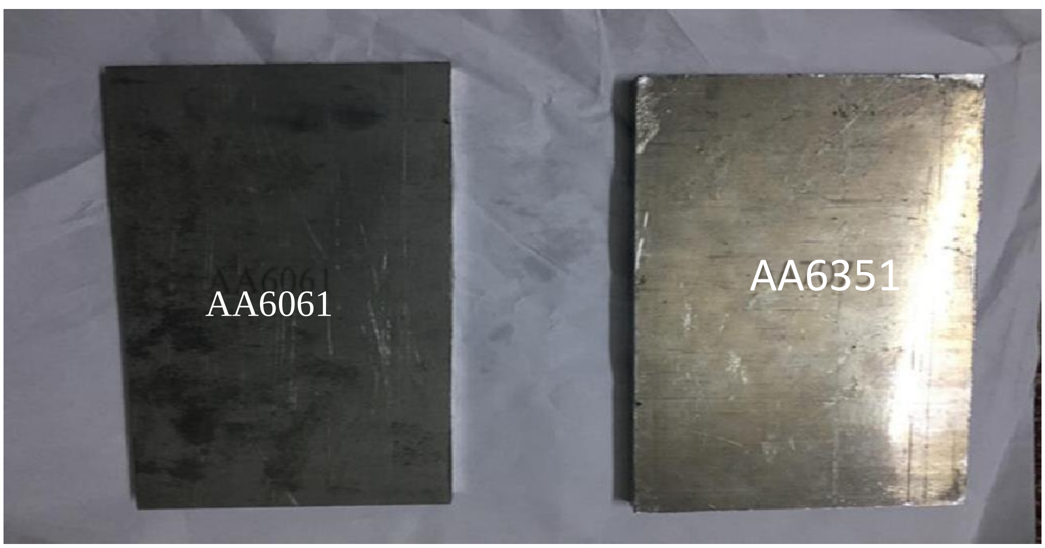


Figure4.1: images of material AA6061 & AA6351

4.2 Tool design and fabrication

Chemical composition of work piece AA6061 & AA6351 aluminium alloy is non-heat treatable series of aluminum alloys so non consumable tool with H13 tool steel has been designed using CAD software and has been fabricated and heat treated up to 54HRB.

H13 steel composition	
Elements	**Weight in %**
Carbon	0.32-0.45
Chromium	4.75-5.50
Molybdenum	1.10-1.75
Vanadium	0.80-1.20
Iron	Balance
Silicon	0.80-1.25
Sulpher	0.30 max
Phosphorus	0.30 max
Manganese	0.25-0.50

Table4.5: Chemical composition of H13 tool steel

The below figure shows CAD model of friction stir tool Dimensions which was used in welding.

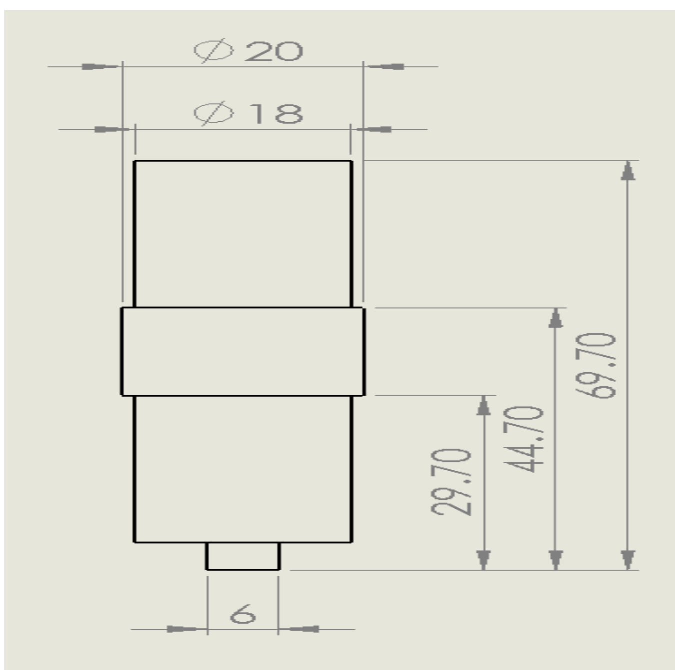


Fig4.2: 2-d model of designed tool in cad software in front view

The shoulder diameter was taken as 20 mm and the pin diameter was 6 mm.

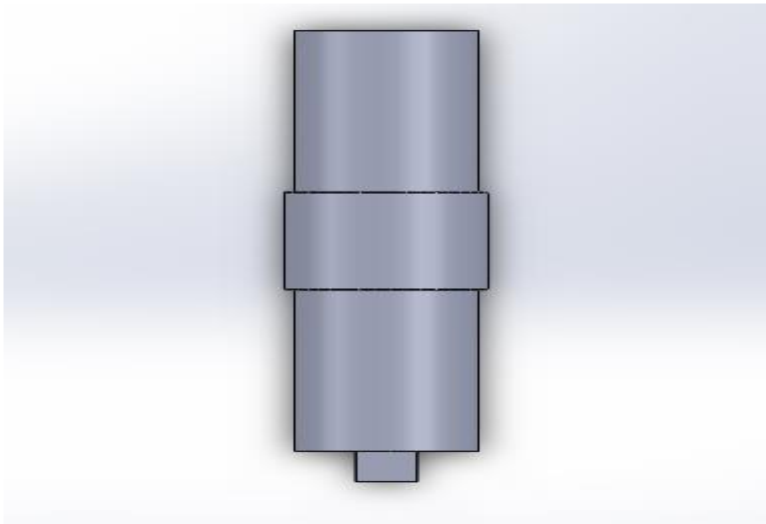


Fig4.3: 2-d model of designed tool in cad software

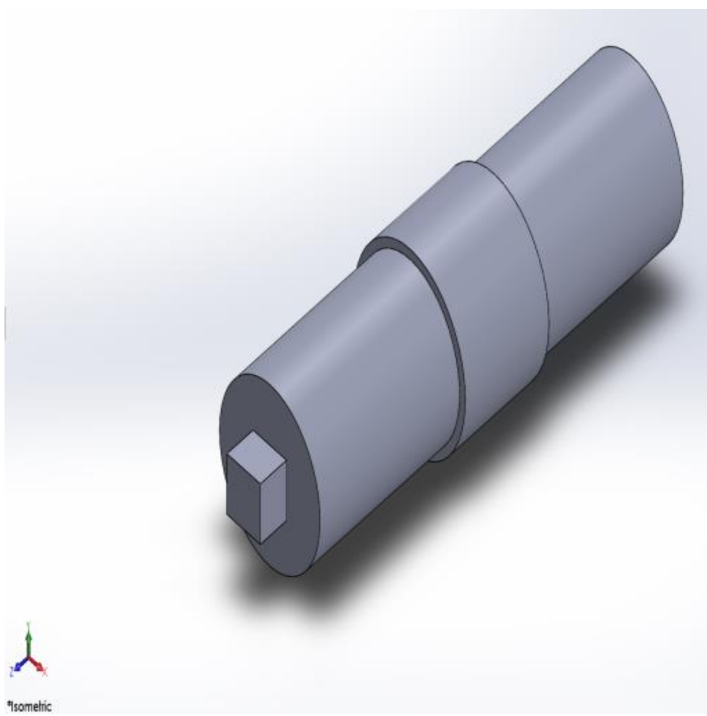


Figure4.4: showing the 3-d model of tool in CAD software

Friction stir welding tool (with convex shoulder), has been used for welding purpose. Using the tool, 8 welding joints have been fabricated with combination of 4 rotational speed and 4 welding speed and in total 8 experiments have been carried out on vertical milling machine. Dimensions of all tools have been kept same for all experiments and set up of vertical milling machine is kept same.

Figure4.5: Actual image of friction stir welding tool

4.3 Titanium, Silicon Carbide, Aluminium oxide powder

The powders used in the experimental procedure standard is 159 mesh and the properties are listed in the below table.

Figure4.6: powder

Properties	Titanium	Silicon Carbide	Aluminum oxide
Appearance	Silvery	Black	White
Melting Point	1668°C	660.3°C	2000 °C
Boiling Point	3560°C	2519°C	2980 °C
Density	4.54 g/cm³	3.1 g/m³	3.39 g/m³
Poisson's Ratio	0.32	0.14	0.21
Specific Heat	0.125 Cal/g/k @ 25°C	750 J/Kg *k	1430 J/Kg *k
Tensile Strength	140 Mpa	240 Mpa	240 Mpa
Thermal Conductivity	21.9 W/(m-k) @ 298.2 k	45 W/(m-k)	30 W/(m-k)
Vickers Hardness	830-3420 Mpa	2400-2800 Mpa	1440 Mpa
Young's Modulus	116 Gpa	300 Gpa	375 Gpa

Table4.6: Properties of Titanium, Silicon Carbide, Aluminium oxide powder

4.4 FSW machine and equipment

For conducting actual experiments it requires a fixture which can hold the welding plates firmly and prevents the rotary and translator motions. Fixture has been properly installed over milling machine bed is as shown in Fig (a).Fixture has been properly installed over the bed of VF3.5 knee type vertical milling machine which is shown in Fig. Material used to make a fixture is cast iron which has higher damping coefficient and shock absorbing capabilities so that it will sustain during the actual experiments and provides best clamping.

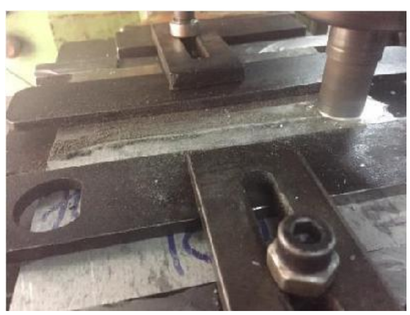


Figure4.7: Welding plates clamped over fixture

A HMT knee type vertical milling machine has been used to fabricate the joints is shown in Fig. Friction stir welding setup has been installed over this milling machine knee type vertical milling machine. This has a facility of rpm ranges from 50 to 1800 rpm and traverse speed ranges from 16 to 800 mm/min which made possible to do number of experiments by varying welding speed and rotational speed and tool holding spindle can be rotated either direction (clockwise or counter clockwise direction), maximum traverse length of machine table is 500 mm over which work piece is kept.

Figure4.8: HMT vertical milling machine

4.5 Experimental procedure

The AA6061 & AA6351 aluminium alloy sheet have been cut into desired dimensions of 100 x100x5 mm by power hacksaw and then milling. Square butt joint configuration, has been prepared to fabricate FSW joints. Single pass welding procedure has been used to fabricate the joints with friction stir welding tool with and without titanium, Silicon Carbide, Aluminium oxide powder and attempt has been made to find out effect of difference on mechanical properties of FSW joints. No preprocessing treatment was carried out before welding and testing. Non-consumable tools made ofH13 tool steel has been used to fabricate the joint.

AA6061 being the hard metal was placed on the advancing side and AA6351 being the soft metal was placed on the retreating side and the weld was carried out using the required parameters.

Figure4.9: AA6061 &AA6351 plates being welded without powder

For the joints made with powder a 2mm groove was made from the center of the plates i.e 5mm and to a depth of 1.5mm and the titanium powder was filled into the grooves manually and then the plates were fixed on to the fixture using the backing plate and fastened using bolts.

(a) (b)

Figure4.10: image (a) showing the groove made in the plates & image (b) showing the powder filled in the grooves

4.6 process parameters

There were totally four different process parameters used in the experimental procedure and 8 experiments were conducted in total four with titanium powder and four without titanium powder. The parameters are listed in the below table.

S. NO.	SPEED (RPM)	FEED RATE (mm/min)	Tilt Angle (degrees)
01	710 (without powder)	25	2
02	710 (with Sic powder)	25	2
03	710 (with Tio2 powder)	25	2
04	710 (with Al203)	25	2

Table4.7: showing the process parameters used for welding joints with and without powder

4.7 Weld joints

The weld joints produced using these parameters are shown in the below figure.

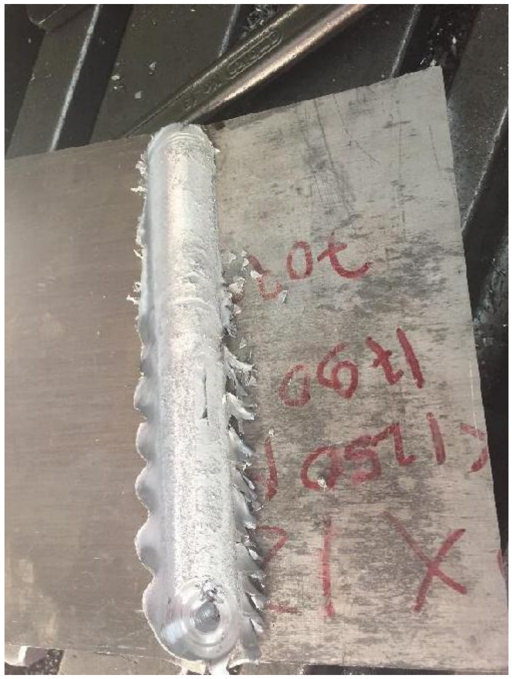


Figure4.11: showing the weld joint produced

4.8 Tensile test

The welded joints are sliced using power hacksaw and then machined to the required dimensions to prepare tensile specimens according to, American Society for Testing of Materials (ASTM E8M-04) guidelines is followed for preparing the test specimens. Tensile test has been carried out in 100 kN, electro-mechanical controlled Universal Testing Machine (INSTRON) as shown in Fig. The specimen is loaded at the strain rate of 2mm/min as per ASTM specifications, so that tensile specimen undergoes deformation as shown in Fig. The specimen finally fails after necking and the load versus displacement has been recorded. The 0.2% offset yield strength; ultimate tensile strength and percentage of elongation have been evaluated. Instron Ultimate Tensile Machine (UTM) is used for performed tensile test, and so on.

Figure4.12: specimen mounted over the universal testing machine (instron)

Tensile testing is also known as tension testing, which is a fundamental materials science test in which a sample is subjected to uniaxial tension until failure. Properties that are directly measured via a tensile test are ultimate tensile strength, maximum elongation and reduction in area. From these measurements the following properties can also be determined like Young's modulus, Poisson's ratio, yield strength, and strain-hardening characteristics.

Following figure is actual image of specimen for Ultimate tensile test and also 2Ddrawing of tensile test specimen with standard dimensions respectively.

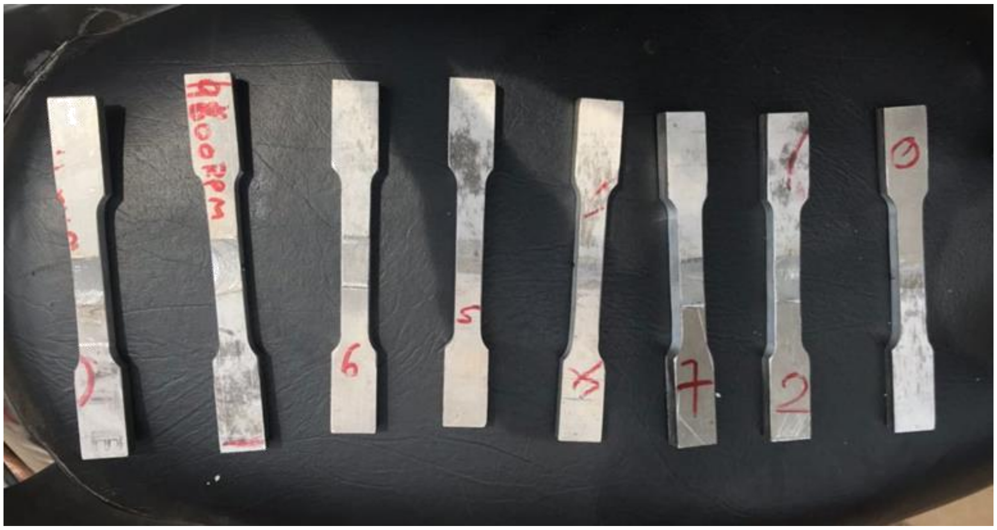


Figure4.13: image showing the samples for tensile test

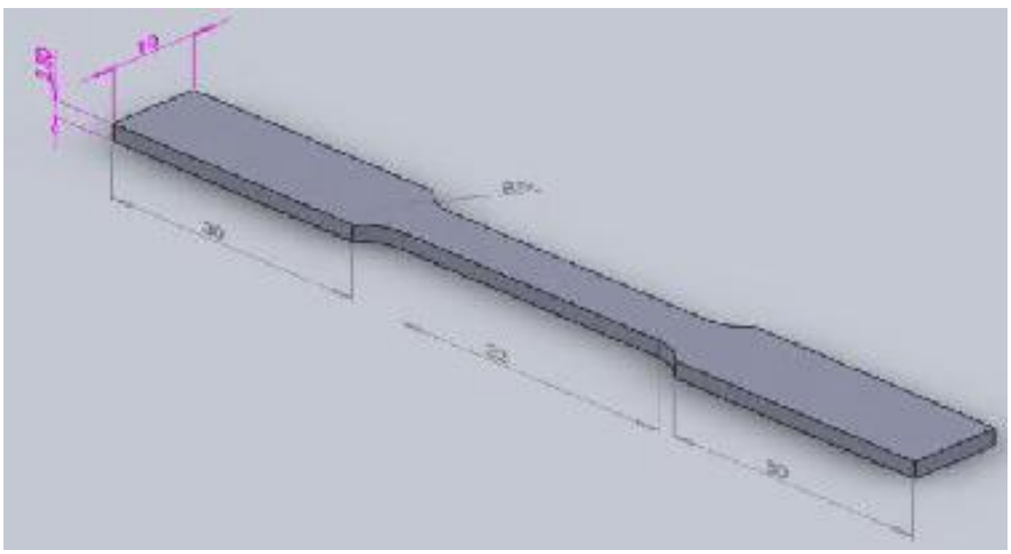


Fig 4.14: Tensile test specimen with dimensions

4.9 Rockwell hardness testing

The Rockwell test is generally easier to perform, and more accurate than other type of hardness methods. The Rockwell test method is used on all metals, except in condition where the test metal structure or surface conditions would introduce too much variations; where the indentations would be too large for the application; or where the sample size or sample shape prohibits its use.

The Rockwell method measures the permanent depth of indentation produced by a force/load on an indenter. First, a preliminary test force (commonly referred to as preload or minor load) is applied to a sample using a diamond or ball indenter. This preload breaks through the surface to reduce the effects of surface finish. After holding the preliminary test force for a specified dwell time, the baseline depth of indentation is measured.

Figure4.15: image showing hardness testing machine

The test was conducted on the Rockwell hardness testing machine with a load of 150kg and using a 1/16 inch ball indenter and the values were observed in HRF scale

4.10 Charpy's impact testing

The Charpy Impact Test entails striking a notched impact specimen with a swinging weight or a "tup" attached to a swinging pendulum. The specimen breaks at its notched cross-section upon impact, and the upward swing of the pendulum is used to determine the amount of energy absorbed (notch toughness) in the process. Energy absorption is directly related to the brittleness of the material. Since temperature can affect the toughness of a material, the charpy test is performed at a series of temperatures to show the relationship of ductile to brittle transition in absorbed energy.

Several machined bar specimens, sized at 1cm x 1cm x 5.5cm with a 2mm deep U-shaped notch at the middle of a specified flat surface, are required to perform some methods of charpy testing. The charpy V-notch impact test is also very common and requires a specimen with a V-shaped notch.

Figure4.16: image showing impact testing machine

CHAPTER – 5

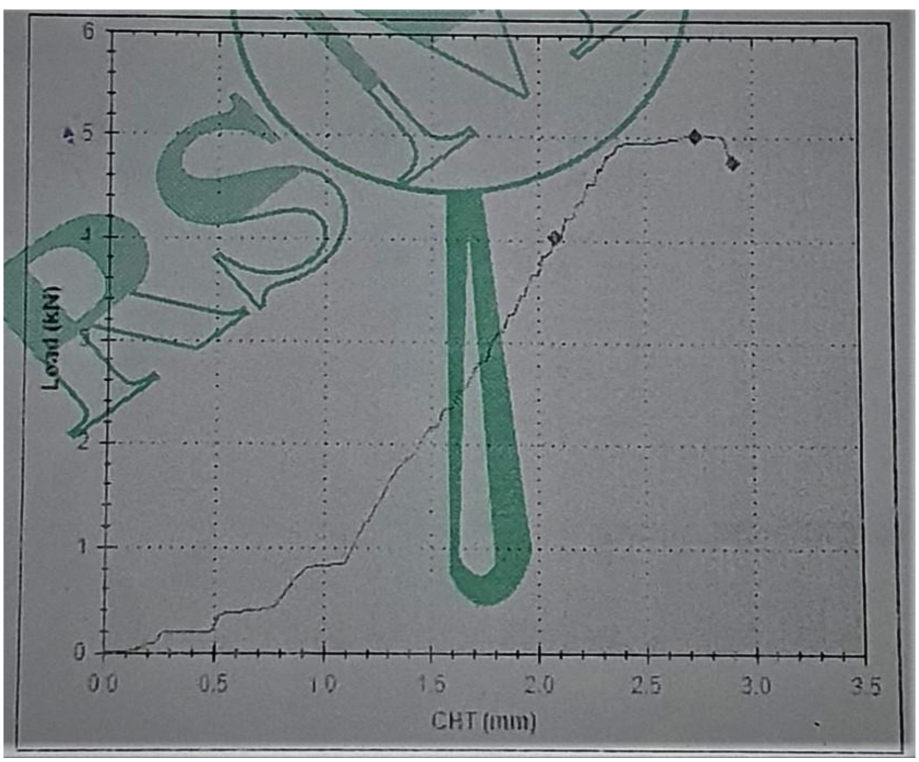
RESULTS AND DISCUISSION

5.1 Tensile strength:

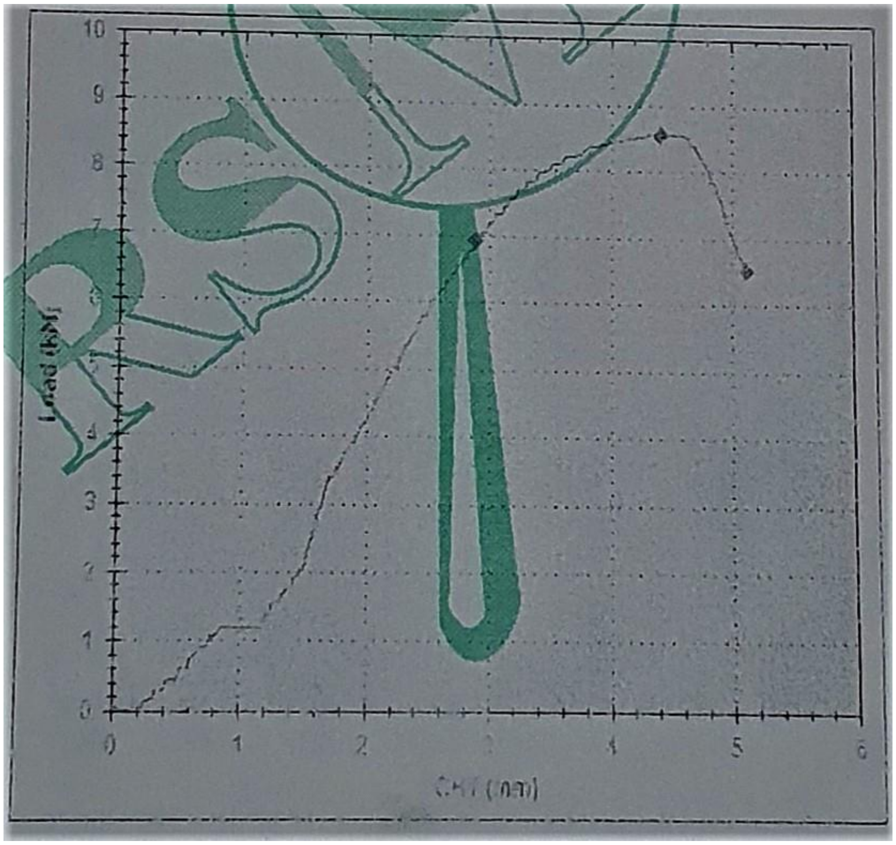
The welded plates with titanium and without titanium powder are sliced using power hacksaw and then machined in vertical milling machine to the required dimensions to prepare for tensile test and the specimens are as shown below in Fig.5.1. American Society for Testing of Materials (ASTME8M-04) guidelines were followed while preparing the specimens for test.

Fig.5.1 Tensile test specimen for welded material

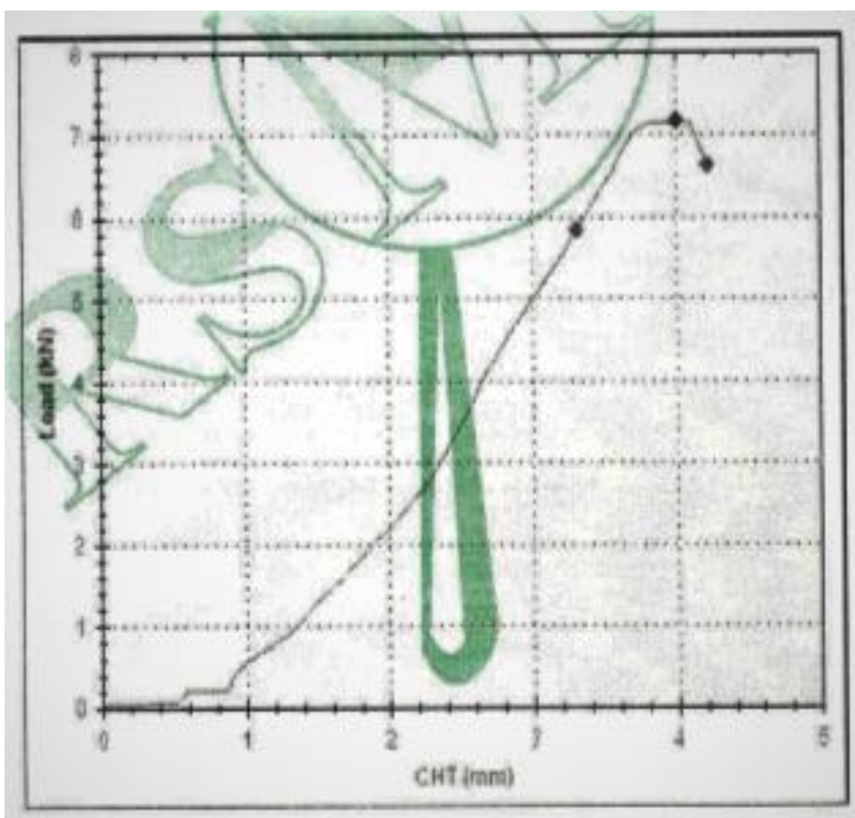
Tensile test were carried out over UTM and 0.2% offset yield strength, ultimate tensile strength and percentage of elongation have been evaluated. Engineering stress-strain curve for welded specimens s were obtained and are as shown in figure below.



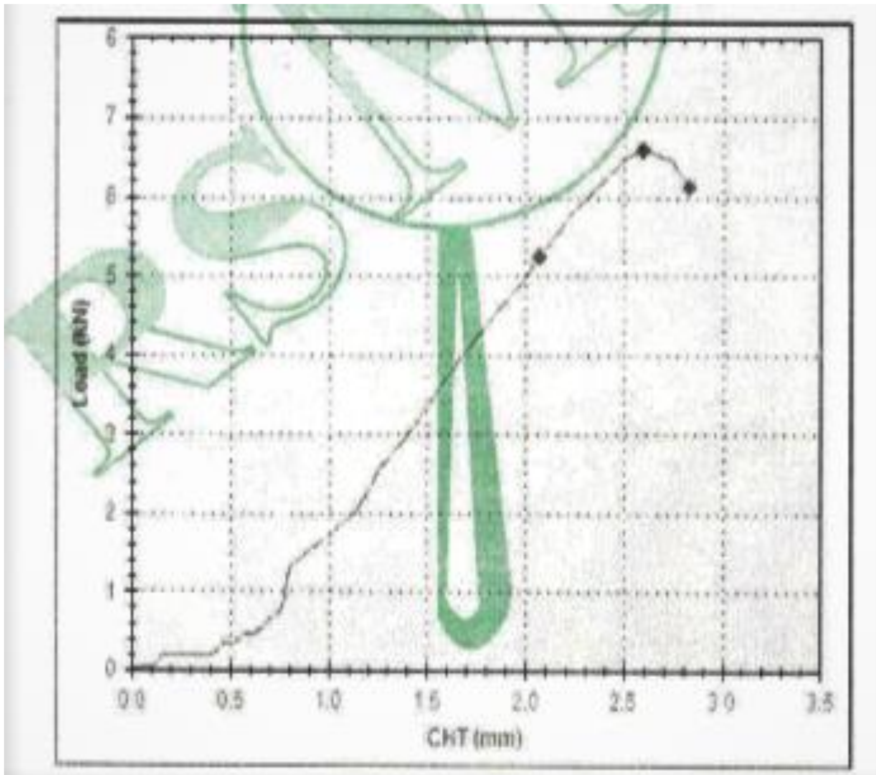
Graph.1 without powder



Graph.2 With Sic powder



Graph.3 With Al203 powder



Graph.4 With Ti02 powder

Transverse tensile properties of FSW joints such as ultimate tensile strength, yield Strength and percentage of elongation have been evaluated as shown in Table. Specimens were tested at each condition. It can be inferred that the tool shoulder geometry, welding speed and rotational speed are having influence on tensile properties of the FSW joints. Of the four joints, the joints fabricated with Silicon carbide powder exhibited superior tensile properties compared to joints produced using other powders.

Process	Tensile Strength (N/mm2)
Without powder	80.7
With Sic powder	136.4
With Al203 powder	102.2
With Tio2 powder	94.4

Table 5.1: Tensile test results

The tensile strength values were observed to be lower in the joints made with Titanium and Aluminium oxide powder compared to the joints made with Silicon carbide powder. Due to the grooves made in the plates there were air gaps created in between the weld joint. Second reason is that because of more stirring in nugget zone at high rotational speed and low welding speed that reduces grains size of particles thus hardness increases which cause brittleness in joint. Ultimate tensile stress as well as % of elongation is more in case of the weld joints made without Silicon carbide powder because there were no air gaps created in the weld zone. The best results were observed in the joint made with Silicon carbide powder at rpm 710 at a feed rate of 25 mm/min.

5.2 Hardness and Impact test properties

The hardness was best observed in the weld joint made with Aluminium oxide powder introducing it in the weld joint increased the hardness compared to the joints weld without powder.

Process	**Vickers Hardness**
Without powder	**54.5**
With Sic powder	**58.8**
With Al203 powder	**68.1**
With Tio2 powder	**51.2**

Table 5.2: hardness test results

Process	**Impact Energy (Joules)**
Without powder	**8**
With Sic powder	**12**
With Al203 powder	**10**
With Tio2 powder	**8**

Table 5.3: Impact test results

CHAPTER – 6

CONCLUSION

In this investigation an attempt has been made to study the effect of three different kind of powders are titanium powder, Silicon carbide powder, Aluminium oxide powder in the weld joint of dissimilar aluminium alloys AA6061 and AA6351. The tensile properties, hardness and impact properties have been obtained, it is concluded that

The tensile strength is higher in the joints made with Silicon carbide micro powder.

By using powder in the friction stir weld joints only the hardness has been improved and the other properties of the weld joint have reduced.

The optimum parameters that were observed in the investigation are were at 710 RPM, feed rate of 25 mm/min and tool angle 2 degrees.

CHAPTER – 7

FUTURE SCOPE

In this investigation an attempt has been made to study the effect of titanium powder, Silicon carbide powder, Aluminium oxide powder in the weld joint of dissimilar aluminium alloys AA6061 and AA6351. The tensile properties, hardness and impact properties have been obtained.

The investigation can be done by pre heating the powder and introducing it in the weld joint.

The welding parameters can be changed and also different tool geometries can be used to do the research.

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