CERTIFICATE

FILE AND LINK No: MRP-7019/16 (SERO/UGC)

NAME OF THE PRINCIPAL INVESTIGATOR: Dr. G.Amarendar Rao

Vignana Bharathi Institute of Technology,

Aushapur, Hyderabad, Pin: 501301

1. **TITLE OF THE PROJECT**: Heat Transfer Characteristics of Dissimilar Friction Stir Welded Components

Certified that the project has been successfully completed and Executive summary of the report, Research documents, monograph, academic papers published under Minor research project has been posted on the website of the college

Signature of the Principal Investigator

Signature of the Principal
With seal and stamp

PRINCIPAL
Vignana Bharathi Institute of Technology
Aushapur(V), Ghatkesar(M), Medchal Dist-501 301

SWAMY VIVEKANANDA EDUCATIONAL TRUST
VBIT College Buildings
Aushapur(V), Ghatkesar(M), Medchal-501 301

ACCESSION CERTIFICATE

This is to certified that Dr. G. Amarendar Rao, Department of Mechanical Engineering , Hyderabad has handed over the following books and journals purchased under the scheme of Minor Research Project to the Library of Vignana Bharathi Institute of Engineering & Technology, Hyderabad. The following are books and journals handed over by Dr. Amarendar Rao (MRP-7019/16 (UGC/SERO).

S. No	Item	Qty.
1	Print out of FSW books	1
2	Heat Transfer Book(Glen E Mayers)	1
3	Print of Journal papers	1

Signature of the Principal Investigator

Signature of the Librarian

SRINIVASA RAO GANTA
Asst. Professor in LIS
& Librarian VBIT

Signature of the Principal

PRINCIPAL
Vignana Bharathi Institute of Technology
Aushapur(V), Ghatkesar(M), Medchal Dist-501 301

ASSETS CERTIFICATE

This is to certified that Dr. G.AmarendarRao, Department of Mechanical Engineering, Hyderabad has handed over the following equipment purchased under the scheme of Minor Research Project to the Department of Mechanical Engineering, Vignana Bharathi Institute of Engineering & Technology, Hyderabad. The following are equipments handed over by Dr. G.Amarendar Rao (MRP-7019/16 (UGC/SERO).

S. No	Particulars	Company	Qty.
1	Laser Thermocouple	Tools and Spares Corporation	1
2	File Rack	Sri Sai Dutta Furniture	1
3	Polishing Papers	Seco Enterprises	48
4	Emery Papers	Seco Enterprises	72
5	10ml Measuring Cylinder	Shetty Chemicals and Solvents	2
6	50ml Measuring Cylinder	Shetty Chemicals and Solvents	2
7	100ml Measuring Cylinder	Shetty Chemicals and Solvents	1
8	HF 500ml	Shetty Chemicals and Solvents	1
9	HNO_3 500ml	Shetty Chemicals and Solvents	1
10	HCL 500ml	Shetty Chemicals and Solvents	1
11	Silica powder	Shetty Chemicals and Solvents	1
12	Beaker	Shetty Chemicals and Solvents	6
13	Pettit dish	Shetty Chemicals and Solvents	4
14	Reagent Bottle	Shetty Chemicals and Solvents	6
15	Pipette 10 ml	Shetty Chemicals and Solvents	3
16	Pipette 5 ml	Shetty Chemicals and Solvents	3

17	Conical flask	Shetty Chemicals and Solvents	6
18	Cotton Roll	Shetty Chemicals and Solvents	1

Signature of the Principal Investigator

Signature of the Head of the Dept.

HOD MECHANICAL
VIGNANA BHARATHI
INSTITUTE OF TECHNOLOGY
GHATKESAR, R.R.DIST

Signature of the Principal

PRINCIPAL
Vignana Bharathi Institute of Technology
Aushapur(V), Ghatkesar(M), Medchal Dist-501 301

Settlement proforma

UTILISATION CERTIFICATE

FILE AND LINK No: MRP-7019/16 (SERO/UGC)

NAME OF THE PRINCIPAL INVESTIGATOR: Dr. G.Amarendar Rao

Vignana Bharathi Institute of Technology,

Aushapur, Hyderabad, Pin: 501301

TITLE OF THE PROJECT: "Heat Transfer Characteristics of Dissimilar Friction Stir Welded Components".

Certified that the grant of Rs. 1,58,000/ (Rupees one lakh fifty eight thousand only) approved by UGC and the grant received Rs1,45,000/(Rupees one lakh fourty five thousand only) from the University Grants Commission under the scheme of support for Minor Research Project entitled “"Heat Transfer Characteristics of Dissimilar Friction Stir Welded Components". ", vide UGC letter No. F. MRP-7019/16 (SERO/UGC) dated 27/11/2017 **has been fully utilized for the purpose for which it was sanctioned and that the balance of Rs.13000 has been spent by institute which has to be released from UGC in accordance with the terms and conditions laid down by the University Grants Commission. If as a result of check or audit objection, some irregularity is noticed at a later stage, action will be taken to refund or regularize the objected amount.**

SIGNATURE OF THE PRINCIPAL INVESTIGATOR

PRINCIPAL with Seal and Stamp

PRINCIPAL
Vignana Bharathi Institute of Technology
Aushapur(V), Ghatkesar(M), Medchal Dist-501 301

VIGNANA BHARATHI INSTITUTE OF TECHNOLOGY
VBIT
Aushapur (V), Ghatkesar (M)
MEDCHAL DIST-501 301

9-1-2020

STATUTORY AUDITOR with Seal and Stamp

CA. L. JANARDHAN RAO
Chartered Accountant
M.No: 18474

UDIN 20018474AAAAB4725

Annexure - III

UNIVERSITY GRANTS COMMISSION
BAHADUR SHAH ZAFAR MARG
NEW DELHI – 110 002

STATEMENT OF EXPENDITURE IN RESPECT OF MINOR RESEARCH PROJECT (II YEAR)

1. Name of Principal Investigator: Dr. G.Amarendar Rao
2. Dept. of PI: Mechanical Engineering
   Name of College: Vignana Bharathi Institute of Technology
3. UGC approval Letter No. and Date: MRP-7019/16 (SERO/UGC), 27/10/2017.

4.Title of the Research Project: "Heat Transfer Characteristics of Dissimilar Friction Stir Welded Components".

4. Effective date of starting the project: 07/11/2017
5. a. Period of Expenditure: From 29-01- 2019 to 07/11/2019
   b. Details of Expenditure

S.No.	Item	Amount Approved (Rs.)	Amount Received (Rs.)	Expenditure Incurred (Rs.)	Amount to be released by UGC
i.	Books & Journals	00	00	00	
ii.	Equipment	00	00	00	
iii.	Contingency including special needs	25,000	20,000	25,000	5,000
iv.	Field Work/Travel (Give details in the proform) a	15,000	12,000	15,000	3,000
v.	Hiring Services	10,000	8,000	10,000	2000
vi.	Chemicals & Glassware	15000	12000	15000	3000
GRAND TOTAL		**65,000**	**52,000**	**65,000**	**13,000**

7. If as a result of check or audit objection some irregularly is noticed at later date, action will be taken to refund, adjust or regularize the objected amounts.

8.It is certified that the grant of Rs. **65,000/** (Rupees sixty five thousand only) approved by UGC and the grant received Rs **52,000** (Rupees Fifty two thousand only) from the University Grants Commission under the scheme of support for Minor Research Project entitled "Heat Transfer Characteristics of Dissimilar Friction Stir Welded Components", vide UGC letter No. F. MRP-7019/16 (SERO/UGC) dated 27/10/2017 has been fully utilized for the purpose for which it was sanctioned and that the balance of Rs.**13,000** has been spent by institute which has to be released from UGC in accordance with the terms and conditions laid down by the University Grants Commission.

SIGNATURE OF PRINCIPAL INVESTIGATOR

PRINCIPAL

PRINCIPAL
Vignana Bharathi Institute of Technology
Aushapur(V), Ghatkesar(M), Medchal Dist-501 301

(Seal)

VIGNANA BHARATHI INSTITUTE OF TECHNOLOGY
VBIT
Aushapur (V), Ghatkesar (M)
MEDCHAL DIST-501 301

Annexure – V

UNIVERSITY GRANTS COMMISSION
BAHADUR SHAH ZAFAR MARG
NEW DELHI – 110 002

Utilization certificate (II YEAR)

Certified that the grant of Rs. 65,000/ (Rupees sixty five thousand only) approved by UGC and the grant received RS 52,000(Rupees twenty five thousand only) from the University Grants Commission under the scheme of support for Minor Research Project entitled "Heat Transfer Characteristics of Dissimilar Friction Stir Welded Components", vide UGC letter No. F. MRP-7019/16 (SERO/UGC) dated 27/11/2017 has been fully utilized for the purpose for which it was sanctioned and that the balance of Rs.13000 has been spent by institute which has to be released from UGC in accordance with the terms and conditions laid down by the University Grants Commission.

SIGNATURE OF THE PRINCIPAL INVESTIGATOR

PRINCIPAL (Seal)

PRINCIPAL
Vignana Bharathi Institute of Technology
Aushapur(V), Ghatkesar(M), Medchal Dist-501 301

VIGNANA BHARATHI INSTITUTE OF TECHNOLOGY
VBIT
Aushapur (V), Ghatkesar (M)
MEDCHAL DIST-501 301

STATUTORY AUDITOR (Seal)

9-5-2020

JANARDHAN RAO HYDERABAD CHARTERED ACCOUNTANT

CA. L. JANARDHAN RAO
Chartered Accountant
M.No: 18474

UDIN 20018474AAAAAB4725

Annexure - III

UNIVERSITY GRANTS COMMISSION
BAHADUR SHAH ZAFAR MARG
NEW DELHI – 110 002

STATEMENT OF EXPENDITURE IN RESPECT OF MINOR RESEARCH PROJECT (CONSOLIDATED, I & II Year)

1.Name of Principal Investigator: Dr. G.Amarendar Rao

2.Dept. of PI: Mechanical Engineering

Name of College: Vignana Bharathi Institute of Technology

3.UGC approval Letter No. and Date: MRP-7019/16 (SERO/UGC), 27/10/2017.

4.Title of the Research Project: "Heat Transfer Characteristics of Dissimilar Friction Stir Welded Components".

5.Effective date of starting the project: 7/11/2017

6. a. Period of Expenditure: From 10/02/2018 to 07/11/2019

b. Details of Expenditure

S.No.	Item	Amount Approved (Rs.)	Amount Received (Rs)	Expenditure Incurred (Rs.)	Amount to be released by UGC
i.	Books & Journals	10,000	10,000	10,000	00
ii.	Equipment	18,000	18,000	18,000	00
iii.	Contingency including special needs	50,000	45,000	50,000	5,000
iv.	Field Work/Travel (Give details in the profor ma).	30,000	27,000	30,000	3,000
v.	Hiring Services	20,000	18,000	20,000	2,000
vi.	Chemicals & Glassware	30,000	27,000	30,000	3,000
GRAND TOTAL		**1,58,000**	**1,45,000**	**1,58,000**	**13,000**

7.if as a result of check or audit objection some irregularly is noticed at later date, action will be taken to refund, adjust or regularize the objected amounts.

8.It is certified that the grant of Rs. 1,58,000/ (Rupees one lakh fifty eight thousand only) approved by UGC and the grant received Rs.145,000/- from the University Grants Commission under the scheme of support for Minor Research Project entitled "Heat Transfer Characteristics of Dissimilar Friction Stir Welded Components", vide UGC letter No. F. MRP-7019/16 (SERO/UGC) dated 27/11/2017 has been fully utilized for the purpose for which it was sanctioned and that the balance of Rs.13000 has been spent by institute which has to be released from UGC in accordance with the terms and conditions laid down by the University Grants Commission.

SIGNATURE OF PRINCIPAL INVESTIGATOR

PRINCIPAL

PRINCIPAL
Vignana Bharathi Institute of Technology
Aushapur(V), Ghatkesar(M), Medchal Dist-501 301

(Seal)

VIGNANA BHARATHI INSTITUTE OF TECHNOLOGY
VBIT
Aushapur (V), Ghatkesar (M)
MEDCHAL DIST-501 301

Annexure – V

UNIVERSITY GRANTS COMMISSION
BAHADUR SHAH ZAFAR MARG
NEW DELHI – 110 002

Utilization certificate (Consolidated, I & II Year)

Certified that the grant of Rs. 1,58,000/ (Rupees one lakh fifty eight thousand only) approved by UGC and the grant received Rs1,45,000/(Rupees one lakh fourty five thousand only) from the University Grants Commission under the scheme of support for Minor Research Project entitled "Heat Transfer Characteristics of Dissimilar Friction Stir Welded Components", vide UGC letter No. F. MRP-7019/16 (SERO/UGC) dated 27/11/2017 has been fully utilized for the purpose for which it was sanctioned and that the balance of Rs.13000 has been spent by institute which has to be released from UGC in accordance with the terms and conditions laid down by the University Grants Commission.

9-1-2020

SIGNATURE OF THE PRINCIPAL INVESTIGATOR

PRINCIPAL

(Seal)

PRINCIPAL
Vignana Bharathi Institute of Technology
Aushapur(V), Ghatkesar(M), Medchal Dist-501 301

VIGNANA BHARATHI INSTITUTE OF TECHNOLOGY
VBIT
Aushapur (V), Ghatkesar (M)
MEDCHAL DIST-501 301

STATUTORY AUDITOR

(Seal)

L. JANARDHAN RAO
HYDERABAD
CHARTERED ACCOUNTANT

CA. L. JANARDHAN RAO
Chartered Accountant
M.No: 18474

UDIN 20018474AAAAAB4725

Annexure - IV

UNIVERSITY GRANTS COMMISSION

BAHADUR SHAH ZAFAR MARG

NEW DELHI – 110 002

STATEMENT OF EXPENDITURE INCURRED ON FIELD WORK (II Year)

Name of the Principal Investigator: Dr. G. Amarendar Rao

Name of the Place visited	Duration of the Visit		Mode of Journey	Purpose of Journey	Expenditure Incurred (Rs.)
	From	To			
VIT , Vellore	Hyderabad	Vellore	Travels Bus	To submit samples for UTM test	3,000
	Vellore	Hyderabad			3,000
VIT, Vellore	Hyderabad	Chennai	Travels Bus	To get back samples of UTM test	1,088
	Tambaram	Secunderabad	IRCTC		1,956
Sri Venkateswara Industries	VBIT Balanagar	Balanagar VBIT	Cab	To submit samples for EDM cutting	2,500
Sri Venkateswara Industries	VBIT Balanagar	Balanagar VBIT	Cab	To get back samples for EDM cutting	2,500
Missilenous (Auto Charges and Petrol Charges)				For getting chemicals needed for microstructure testing	960
GRAND TOTAL					15,004

Certified that the above expenditure is in accordance with the UGC norms for Major Research Projects

SIGNATURE OF PRINCIPAL INVESTIGATOR

PRINCIPAL
Vignana Bharathi Institute of Technology
Aushapur(V), Ghatkesar(M), Medchal Dist-501 301

PRINCIPAL
(Seal)

VIGNANA BHARATHI INSTITUTE OF TECHNOLOGY
VBIT
Aushapur (V), Ghatkesar (M)

Annexure - IV

UNIVERSITY GRANTS COMMISSION

BAHADUR SHAH ZAFAR MARG

NEW DELHI – 110 002

STATEMENT OF EXPENDITURE INCURRED ON FIELD WORK Name of the Principal Investigator: Dr. G. Amarendar Rao

I YEAR

Name of the Place visited	Duration of the Visit		Mode of Journey	Purpose of Journey	Expenditure Incurred (Rs.)
	From	To			
Hyderabad Central University	Secunderabad Gachibowli	Gachibowli Secunderabad	Cab	To understand about testing processes	1293/-
Sri venkateswara Industries	Ghatkesar	Balanagar	Cab	To get to know the various hiring facilities available	820/-
Srivenkateswara Industries	Balanagar	Secunderabad	Bike	Experiment done	300/-
SK Profiles	Ghatkesar Prashanth nagar	Prashanth nagar Ghatkesar	Bike	Quotation for material	300/-
SK Profiles	Ghatkesar	Prashanth nagar	Bus, Bike	Material purchase	140/-
Acro Therm Pvt.Ltd,	Secunderabad	Narsapur X road	3 people	To enquire about	975

			2 Bikes	thermocouple setups	
BITS	Tarnaka	Balapur	Cab	To confirm UTM testing	418/-
BITS	Balapur	shameerpet	cab	To confirm UTM testing	1310/-
Jyothi Labs	Shameerpet	Balanagar	Cab	To give samples for Chemical analysis	672/-
Jyothi Labs	Balanagar	Moula Ali	Cab	To collect the results	429/-
SK Profiles, Chowdar Metals	VBIT Prashanthnagar	Prashanthnagar VBIT	Cab	Material purchase	2192/-
Srivenkateswara Industries	VBIT Balanagar	Balanagar VBIT	Cab	Experiment done	2000/-
ARCI,Balapur	VBIT Balapur	Balapur VBIt	Cab	To enquire slot size for testing's done on various samples	2000/-
ASL,DRDL	VBIT Kanchanbagh	Kanchanbagh VBIT	Cab	To enquire slot for Micro structure SEM testing	2000/-
Miscellaneous					150/-
GRANDTOTAL					15,000/-

II YEAR

Name of the Place visited	Duration of the Visit		Mode of Journey	Purpose of Journey	Expenditure Incurred (Rs.)
	From	To			
VIT , Vellore	Hyderabad	Vellore	SRS Travels	To submit samples for UTM test	3,000
	Vellore	Hyderabad			3,000
VIT, Vellore	Hyderabad	Chennai	V Kaveri Travels	To get back samples of UTM test	1,088
	Tambaram	Secunderabad	IRCTC		1,956
Sri Venkateswara Industries	VBIT Balanagar	Balanagar VBIT	Cab	To submit samples for EDM cutting	2,500
Sri Venkateswara Industries	VBIT Balanagar	Balanagar VBIT	Cab	To get back samples for EDM cutting	2,500
Missile nous (Auto Charges and Petrol Charges)				For getting chemicals needed for microstructure testing	960
GRAND TOTAL					15,000

Certified that the above expenditure is in accordance with the UGC norms for Major Research Projects

GRAND TOTAL : 30,000/

SIGNATURE OF PRINCIPAL INVESTIGATOR

PRINCIPAL
Vignana Bharathi Institute of Technology
Aushapur(V), Ghatkesar(M), Medchal Dist-501 301

PRINCIPAL

(Seal)

VIGNANA BHARATHI INSTITUTE OF TECHNOLOGY
VBIT
Aushapur (V), Ghatkesar (M)
MEDCHAL DIST-501 301

STATEMENT OF EXPENDITURE INCURRED ON HIRING

Name of the Principal Investigator: Dr. G. Amarendar Rao

S.No	Place	Service	Amount
1	Sri Venkateswara Industries	EDM Cutting(for bending)	4,000/-
2	Sri Venkateswara Industries	EDM Cutting(for microstructure)	4,000/-
3	Sri Venkateswara Industries	Hiring for microstructure analysis	2,000/-
GRAND TOTAL			10,000/-

SIGNATURE OF PRINCIPAL INVESTIGATOR

PRINCIPAL
(Seal)

PRINCIPAL
Vignana Bharathi Institute of Technology
Aushapur(V), Ghatkesar(M), Medchal Dist-501 301

VIGNANA BHARATHI INSTITUTE OF TECHNOLOGY
VBIT
Aushapur (V), Ghatkesar (M)
MEDCHAL DIST-501 301

STATEMENT OF EXPENDITURE INCURRED ON HIRING (I & II years)

Name of the Principal Investigator: Dr. G. Amarendar Rao

I YEAR

S.No	Place	Service	Amount
1	Sri Venkateswara Industries	Friction Stir Welding	10,000/-

II YEAR

S.No	Place	Service	Amount
1	Sri Venkateswara Industries	EDM Cutting(for bending)	4,000/-
2	Sri Venkateswara Industries	EDM Cutting(for microstructure)	4,000/-
3	Sri Venkateswara Industries	Hiring for microstructure analysis	2,000/-
GRAND TOTAL			10,000/-

GRAND TOTAL : 20,000/-

SIGNATURE OF PRINCIPAL INVESTIGATOR

PRINCIPAL
(Seal)

PRINCIPAL
Vignana Bharathi Institute of Technology
Aushapur(V), Ghatkesar(M), Medchal Dist-501 301

VIGNANA BHARATHI INSTITUTE OF TECHNOLOGY
VBIT
Aushapur (V), Ghatkesar (M)
MEDCHAL DIST-501 301

DETAILED STATEMENT OF EXPENDITURE INCURRED ON CONTINGENCY

Name of the Principal Investigator: Dr. G. Amarendar Rao

S.No	Item Description	Bill No	Date	GST	Amount
1	File Rack	049	23/07/2019	1053	6903
2	Polishing Papers	1875	24/07/2019	175	2294
3	Bending test	20393	20/12/2019		972
4	EDM cut: Tensile Flexural Microstructure	69	25/11/2019		8000
5	Tensile Test(27 samples)	69	25/11/2019		6830
	GRAND TOTAL				25000

Signature of Principal investigator **Signature of the Principal** **Signature of Statuary Auditor**

9-1-2020

PRINCIPAL
Vignana Bharathi Institute of Technology
Aushapur(V), Ghatkesar(M), Medchal Dist-501 301

L. JANARDHAN RAO HYDERABAD CHARTERED ACCOUNTANT

CA. L. JANARDHAN RAO
Chartered Accountant
M.No: 18474

UDIN 20018474AAAAB4725

DETAILED STATEMENT OF EXPENDITURE FOR CONTINGENCY (incl. Special needs) I &II YEAR

UGC Reference No. F: MRP-7019/16 (SERO/UGC)

Name of the Principal Investigator: Dr. G.AmarendarRao

Title of research project: "Heat Transfer Characteristics of Dissimilar Friction Stir Welded Components"

I YEAR

S.No	Item Description	Bill No	Date	GST	Amount
1	Tool Cutting	46	7/7/2018		1778.00
2	Al Plates 6061 T6	00200	23/6/2018	2322	15,222.00
3	Tool Holder/Collet/Spanner	588	5/2/2018	335	4400.00
4	TPC 2/14	2181	5/2/2018	604	3965.00
	GRAND TOTAL				25365.00

NOTE: 365/- adjusted from CHEMICALS AND GLASS WARE

II YEAR

S.No	Item Description	Bill No	Date	GST	Amount
1	File Rack	049	23/07/2019	1053	6903
2	Polishing Papers	1875	24/07/2019	175	2294
3	Bending test	20393	20/12/2019		972
4	EDM cut: Tensile Flexural Microstructure	69	25/11/2019		8000
5	Tensile Test(27 samples)	69	25/11/2019		6830
	GRAND TOTAL				25000

GRAND TOTAL (I & II YEAR) = 50,365/-

Signature of the Principal Investigator

Signature of the Principal

PRINCIPAL
Vignana Bharathi Institute of Technology
Aushapur(V), Ghatkesar(M), Medchal Dist-501 301

Signature of the Statutory Auditor

2?-1-2020

CA. L. JANARDHAN RAO
Chartered Accountant
M.No: 18474

UDIN 20018474AAAAAB4725

DETAILED STATEMENT OF EXPENDITURE INCURRED ON CHEMICALS AND GLASS WARE

Name of the Principal Investigator: Dr. G. Amarendar Rao

S.No	Item Description	Invoice No.	Date	Qty	Rate	GST	Amount
1	Shetty Chemicals and Solvents	800	6/01/2020	1	6348	571	8000
2	Sri Venkateswara Industries	008	8/01/2020				8000
3	Miscellaneous(Auto Charges)						200
	GRAND TOTAL						16,216

Signature of Principal investigator **Signature of the Principal** **Signature of Statuary Auditor**

9-10-2020

PRINCIPAL
Vignana Bharathi Institute of Technology
Aushapur(V), Ghatkesar(M), Medchal Dist-501 301

L. JANARDHAN RAO HYDERABAD CHARTERED ACCOUNTANTS

CA. L. JANARDHAN RAO
Chartered Accountant
M.No: 18474

UDIN 20018474AAAAAB4725

DETAILED STATEMENT OF EXPENDITURE INCURRED ON CHEMICALS AND GLASS WARE (I & II years)

Name of the Principal Investigator: Dr. G. Amarendar Rao

I YEAR

S.No	Item Description	Invoice No.	Date	Qty	Rate	GST	Amount
1	Infrared Thermometer	458232	23/6/2018	1	1450	130	1711.00
2	Charges of Chemical Testing	HEL/1022	25/6/2018	2	300	108	708.00
3	Chemical Etching	43	7/7/2018	27 pieces	11,000		11,000.00
	GRAND TOTAL						13,419.00

NOTE: 1216/- is left over unused will be added to amount in next year.

II YEAR

S.No	Item Description	Invoice No.	Date	Qty	Rate	GST	Amount
1	Shetty Chemicals and Solvents	800	6/01/2020	1	6348	571	8000
2	Sri Venkateswara Industries(Charges for microstructure analysis)	008	8/01/2020				8000
3	Miscellaneous(Auto Charges)						200
	GRAND TOTAL						16,216

GRAND TOTAL : 29,635 /-

+365(Used in contingency in first year)

Signature of Principal Investigator

Signature of the Principal

PRINCIPAL
Vignana Bharathi Institute of Technology
Aushapur(V), Ghatkesar(M), Medchal Dist-501 301

Signature of Statuary Auditor

9-1-2020

CA. L. JANARDHAN RAO
Chartered Accountant
M.No: 18474

UDIN 20018474AAAAB4725

Annexure -VI

UNIVERSITY GRANTS COMMISSION
BAHADUR SHAH ZAFAR MARG
NEW DELHI – 110 002.

Final Report of the work done on the Minor Research Project. (Report to be submitted within 6 weeks after completion of each year)

1. Project report No. Final: Second (After two years)   dated: 25/11/2019
2. UGC Reference No. F: MRP-7019/16 (SERO/UGC)
3. Period of report: from: 27/11/2017 to 07/11/2019
4. Title of research project: "Heat Transfer Characteristics of Dissimilar Friction Stir Welded Components"
5. (a) Name of the Principal Investigator: Dr. G.Amarendar Rao

   (b) Deptt: Mechanical Engineering

   (c) College where work has progressed: Vignana Bharathi Institute of Technology
6. Effective date of starting of the project: 07/11/2017
7. Grant approved and expenditure incurred during the period of the report:

   a. Total amount approved Rs. 1,58,000/

   b. Total expenditure Rs. 1,58,000/

   c. Report of the work done: (Copy attached)

   i. Brief objective of the project:

(i) . Objective of the Project:

FSW is an important metal joining process particularly with dissimilar methods. This process is used in many advanced applications like automobiles, spacecrafts, marine engines etc., Complete understanding of FSW components is essential its durability and functional requirements. Such an analysis involves heat transfer characteristics of the components. Among all parameters thermal conductivity is an important property since it has a direct influence on heat transfer rate. In the literary review, it is observed that a very little work is done in this direction. Present work certainly improvers the understanding of Dissimilar FSW welds

- Work done so far and results achieved and publications, if any, resulting from the work (Give details of the papers and names of the journals in which it has been published or accepted for publication:

ii. **Publication/Communication:**

Publication:

Published in International Journal of Research in Advent Technology E-ISSN - 2321-9637

Presentation:

- Participated and presented the paper entitled "ANALYSIS OF TEMPERATURE PROFILE ON FRICTION STIR WELDED AA6061 and AA7075 ALUMINIUM ALLOYS" Organized by Dept. of ME, Nalla Narasimha Reddy Group of Institutions- Integrated Campus

iii. Has the progress been according to original plan of work and towards achieving the objective. YES.

iv. Please enclose a summary of findings of the study. One bound copy of the final report of work done may also be sent to the concerned Regional Office of the UGC.

SIGNATURE OF THE PRINCIPAL INVESTIGATOR

PRINCIPAL
(Seal)

PRINCIPAL
Vignana Bharathi Institute of Technology
Aushapur(V), Ghatkesar(M), Medchal Dist-501 301

VIGNANA BHARATHI INSTITUTE OF TECHNOLOGY
VBIT
Aushapur (V), Chatkesar (M)
MEDCHAL DIST-501 301

Annexure – VII

UNIVERSITY GRANTS COMMISSION
BAHADUR SHAH ZAFAR MARG NEW
DELHI – 110 002

PROFORMA FOR SUBMISSION OF INFORMATION AT THE TIME OF SENDING THE FINAL REPORT OF THE WORK DONE ON THE PROJECT

1. Title of the Project: "Heat Transfer Characteristics of Dissimilar Friction Stir Welded Components"
2. NAME AND ADDRESS OF THE PRINCIPAL INVESTIGATOR: Dr. G.Amarendar Rao, VBIT, Hyderabad.
3. NAME AND ADDRESS OF THE INSTITUTION: Vignana Bharathi Institute of Technology, Aushapur, Hyderabad
4. UGC APPROVAL LETTER NO. AND DATE: MRP-7019/16 (SERO/UGC), 27/11/2017
5. DATE OF IMPLEMENTATION: 07/11/2017
6. TENURE OF THE PROJECT : Two years
7. TOTAL GRANT ALLOCATED: 1,58,000/-
8. TOTAL GRANT RECEIVED: 1,45,000/-
9. FINAL EXPENDITURE: 1,58,000/-
10. TITLE OF THE PROJECT: "Heat Transfer Characteristics of Dissimilar Friction Stir Welded Components"
11. OBJECTIVES OF THE PROJECT:

FSW is an important metal joining process particularly with dissimilar methods. This process is used in many advanced applications like automobiles, spacecrafts, marine engines etc., Complete understanding of FSW components is essential its durability and functional requirements. Such an analysis involves heat transfer characteristics of the components. Among all parameters thermal conductivity is an important property since it has a direct influence on heat transfer rate. In the literary review, it is observed that a very little work is done in this direction. Present work certainly improvers the understanding of Dissimilar FSW welds

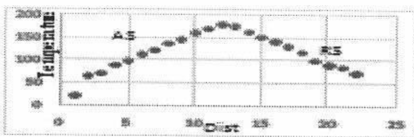
12. WHETHER OBJECTIVES WERE ACHIEVED: YES

The temperature distribution of different areas on the work specimen is made available in the table below.

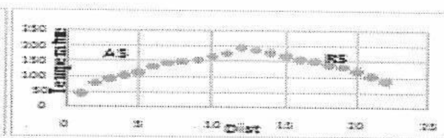
Table 7: Experimental observations at various process parameters

TRS	WS	OFFSET	PINS	AS temp.	Tool temp.	RS temp.
710	40	0	Triangular	208	230	203
710	60	0.5	Cylindrical	215	228	201
710	50	1	Pentagonal	250	253	239
900	40	0.5	Pentagonal	239	258	224
900	60	1	Triangular	208	250	200
900	50	0	Cylindrical	208	220	200
1120	40	1	Cylindrical	208	223	200
1120	60	0	Pentagonal	208	214	200
1120	50	0.5	Triangular	200	225	200

AA 2014-AA7075



EXPERIMENT 1



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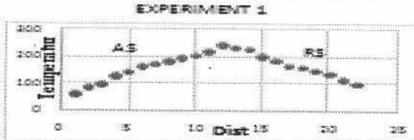

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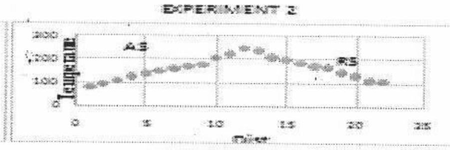

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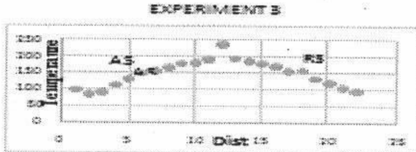

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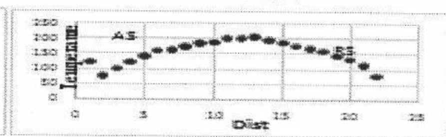

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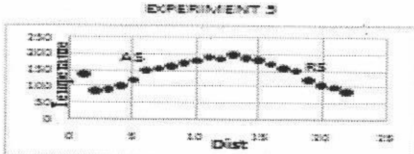

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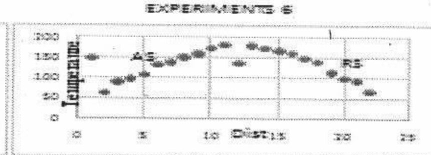

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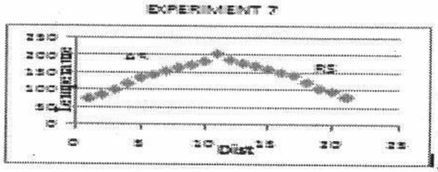
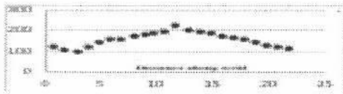


EXPERIMENT 9

AA6061-AA7075



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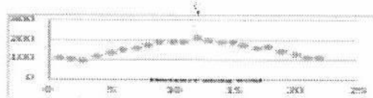

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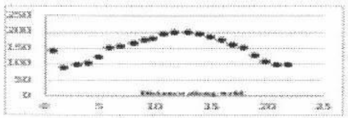

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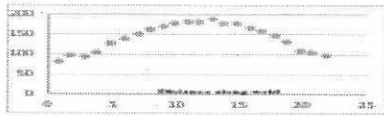

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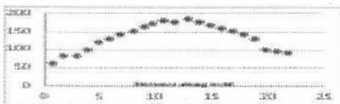

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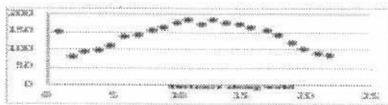

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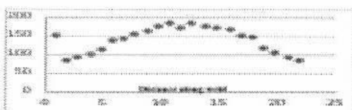

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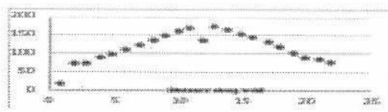

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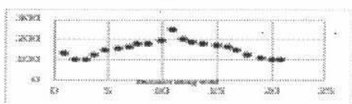
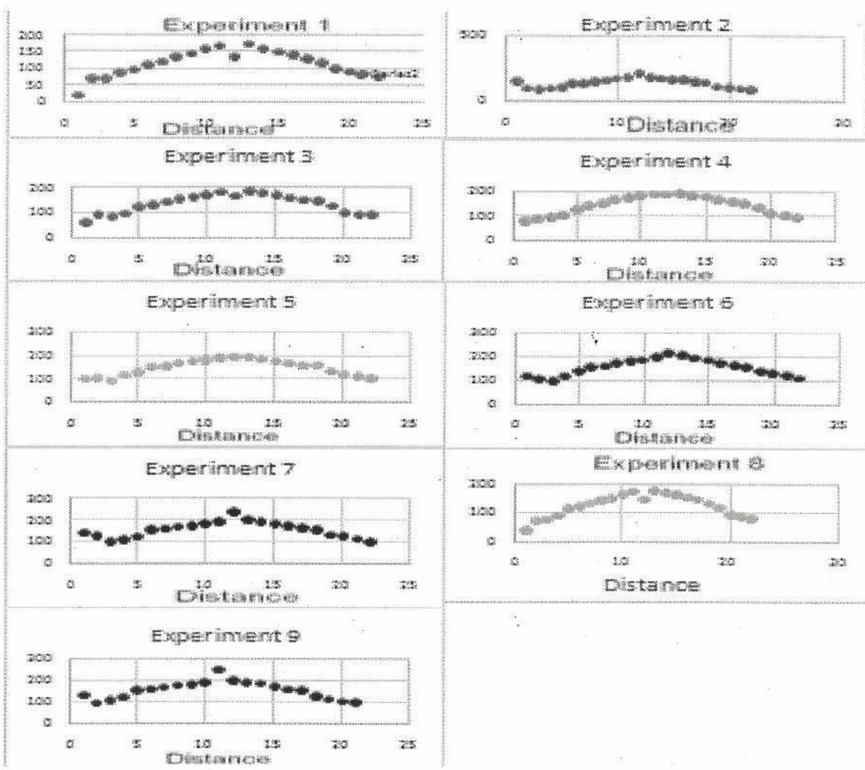


Experiment 9

AA2014-6061



Thermal conductivity is is defined as ability of material to transmit heat. The objective of this work is to accurately measure the transient temperatures at the tool-workpiece interface during friction stir welding (FSW) using thermocouples that are embedded in the tool.

$$q = kA^{d}T/L$$

q= input given in W

A =area of Cross section

^{d}T=temperature variation

L =length of specimen

K= thermal conductivity.

K of the FSW aluminium pieces is identified to be varying between 123W/m-k and 150W/m-k which represents that the nugget zone welded material is able to sustain its thermal conductivity without a drop in its value.

ACHIEVEMENTS FROM THE PROJECT: The study enables the evolution of FSW in various industries which help in better welding of dissimilar alloys which increase their mechanical and thermal properties.

WHETHER ANY PH.D. ENROLLED/PRODUCED OUT OF THE PROJECT: NO

NO. OF PUBLICATIONS OUT OF THE PROJECT: One (paper is attached)

(PRINCIPAL INVESTIGATOR)

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THESIS

Title of the Minor Research project: Heat Transfer Characteristics of Dissimilar Friction Stir Welded Components

Name of the Principal Investigator: Dr. G. Amarendar Rao,

Prof. of Mechanical Engineering & Principal, Vignana Bharathi Institute of Engineering & Technology, Aushapur, Hyderabad

UGC Reference No: MRP-7019/16 (SERO/UGC)

<u>FINAL REPORT OF THE MINOR RESEARCH PROJECT IN MECHANICAL ENGINEERING</u>

Title of Minor Research Project: "<u>Heat Transfer Characteristics of Dissimilar Friction Stir Welded Components</u>".

Principal Investigator: Dr.G.Amarendar Rao, Principal, Professor, Dept. of ME, Vignana Bharathi Institute of Technology, Aushapur, Hyderabad.

UGC Reference No. F: MRP-7019/16 (SERO/UGC)

Abstract

The presented work investigates on effect of temperature distribution on different grades of aluminum alloy joints. The experiments were performed on dissimilar combinations of AA6061, AA2014 and AA7075 in butt fashion. The process parameters like TRS, WS, tilt angle, tool offset and pin profile plays a key role in produce the defect free welds. Cylindrical, pentagonal and triangular hybrid tool pin profiles are considered at weld speeds of 40,50,60 mm/min and tool rotation of 710, 900, 1120 rpm with an tool offset of 0-1mm and constant tilt angle of head 2^0. The numbers of trail runs are selected by using Taguchi technique (L9) orthogonal array with four factors each at three levels to provide the interaction between the parameters. The temperature history at nugget zone, HAZ and the zones close to TMAZ are measured using thermocouples. The temperature distribution curves were drawn and it is identified from the investigation that more temperature transfer was done towards low melting point alloy.

CHAPTER	Pg. No

1. INTRODUCTION

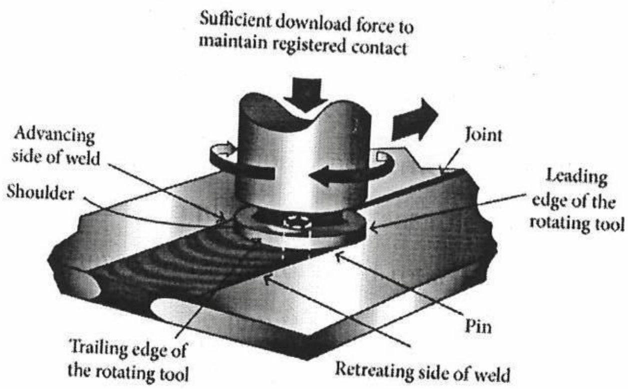
Historians say the earliest examples of joining metals took place in Europe and the Middle East during the Bronze Age and Iron Age. The Middle Ages and Renaissance brought advances in forge welding, and the industry continued to grow in the following centuries. The discovery of the electric arc in 1800 by Sir Humphry Davy led to many more advances in welding, including the invention of metal and carbon electrodes later in the 19th century. The inventions of resistance welding, thermite welding and oxyfuel welding all brought more possibilities to the industry, and in the 1920s, alternating current welding became popular. World War-I led to a surge in the use of welding processes, as various countries began manufacturing more and more metal goods. Throughout the following decades, the industry continued to advance as the introduction of new fuels and shielding gases continued to expand the applications and practicality of welding. Continued innovation and technological breakthroughs have helped the industry continue to evolve to what is now a thriving global industry.

Welding is a technique used for joining metallic parts usually through the application of heat. This technique was discovered during efforts to manipulate iron into useful shapes. Welded blades were developed in the first millennium ad, the most famous being those produced by Arab armourers at Damascus, Syria. The process of carburization of iron to produce hard steel was known at this time, but the resultant steel was very brittle. The welding technique which involved interlayering relatively soft and tough iron with high-carbon material, followed by hammer forging produced a strong, tough blade. In modern times the improvement in iron-making techniques, especially the introduction of cast iron, restricted welding to the blacksmith and the jeweler. Other joining techniques, such as fastening by bolts or rivets, were widely applied to new products, from bridges and railway engines to kitchen utensils. Modern fusion welding processes are an outgrowth of the need to obtain a continuous joint on large steel plates. Riveting had been shown to have disadvantages, especially for an enclosed container such as a boiler.

Various types of welding processes such as: Gas welding, arc welding, and resistance welding all appeared at the end of the 19th century. The first real attempt to adopt welding processes on a wide scale was made during World War I. By 1916 the oxyacetylene process was well developed, and the welding techniques employed then are still used. The main improvements since then have been in equipment and safety. Arc welding, using a consumable electrode, was also introduced in this period, but the bare wires initially used produced brittle welds. A solution was found by wrapping the bare wire with asbestos and an entwined aluminum wire. The modern electrode, introduced in 1907, consists of a bare wire with a complex coating of minerals and metals. Arc welding was not universally used until World War II, when the urgent need for rapid means of construction for shipping, power plants, transportation, and structures spurred the necessary development work. Resistance welding, invented in 1877 by Elihu Thomson, was accepted long before arc welding for spot and seam joining of sheet. Butt welding for chain making and joining bars and rods was developed during the 1920s. In the 1940s the tungsten-inert gas process, using a non consumable tungsten electrode to perform fusion welds, was introduced. In 1948 a new gas shielded process utilized a wire electrode that was consumed in the weld. More recently, electron-beam welding, laser welding, and several solid-phase processes such as: diffusion bonding, friction welding, and ultrasonic joining have been developed

Aluminum is light in weight, and offer good corrosion resistance with high strength to weight ratio along with additional properties needed for aerospace, defense, marine, automotive, ammunition and for other fields of applications aluminum is the best ideal material. Indian launch vehicles mostly limited to main four key alloys as AA2014, AA2219, AA6061 and AA7075 with this the main objective the of the research is fabricate the joints with dissimilar combinations of these materials, and improve the joint strength along with mechanical properties of heat treatable Al-alloys, still now lot of work is limited to join those materials in similar fashion with limited thickness up to 8 mm. In this paper the research is focus on fabrication of butt joint of 10 mm thick dissimilar Al-alloys.

Friction stir welding (FSW) was invented by W.M. Thomas at The Welding Institute (TWI) of UK in1991. It is quite different and serves major needs when compared to other welding processes. That is the reason why it is emerging as a major method of welding in the industries of aerospace, ship-building, automotive, and railway industries,. It utilizes a non-consumable electrode and welds two dissimilar base metals below their solidus temperatures. At high temperatures below the melting point of the work piece, atoms are allowed to diffuse across the interface to fill in any remaining voids and complete the joining process. This helps to retain the same phase of the base metal before and after completion of the welding process. Apart from this it has a variety of other uses which include advantages such as excellent tensile and fatigue strength, No splatter, no fume, Low energy consumption, Low shrinkage, No filler wire, Simple preparation of the weld seam, Good mechanical reproducibility, No welder certification required. It is more often used for soft materials like aluminium [1].The tool used in this process has a specially designed tip having a suitable profile for obtaining the higher quality of the weld. Tool travelling and rotation speeds, among other welding parameters, are most important variables that may affect the joint properties. Alongside of these parameters the distribution of the temperature also plays a important role because ,during the process of Friction stir welding the tool tip undergo translatory and rotary motions due to which a tremendous plastic deformation takes place and the temperature increases rapidly at the weld zone and there might me a slight change in the nature of base metals around the heat affected zone[2].There comes the need of studying the temperature distribution profile on the both sides of the weld region. By, this we can find the nature of heat distribution and further we can make necessary research to minimize the heat affected zone and at the same time increase the quality of the weld.



The linear reciprocating process also requires movement of the parts being joined. This process uses a straight-line back and forth motion between the two parts to generate the friction. Regularity of the parts being joined is not as necessary with this process; however, movement of the part during welding is essential. The obvious limitation of both these processes is the joint design and component geometry restriction. At least one of the parts being joined must have an axis of symmetry and be capable of being rotated or moved about that axis.

Friction stir welding (FSW) is capable of fabricating either butt or lap joints, in a wide range of materials thickness and lengths. During FSW, heat is generated by rubbing a non-consumable tool on the substrate intended for joining and by the deformation produced by passing a tool through the material being joined. The rotating tool creates volumetric heating, so as the tool is progressed, a continuous joint is created. FSW, like other types of friction welds, is largely solid state in nature. As a result, friction stir welds are not susceptible to solidification related defects that may hinder other fusion welding processes.

The parts intended for joining are usually arranged in a butt configuration. The rotating tool is then brought into contact with the work pieces. The tool has two basic components: the probe, which protrudes from the lower surface of the tool, and the shoulder, which is relatively large diameter. The length of the probe is typically designed to match closely the thickness of the work pieces. Welding is initiated by first plunging the rotating probe into the work pieces until the shoulder is in close contact with the component top surface. Friction heat is generated as the rotating shoulder rubs on the top surface under an applied force. Once sufficient heat is generated and conducted into the work piece, the rotating tool is propelled forward. Material is softened by the heating action of the shoulder, and transported by the probe across the weld line, facilitating the joint.

One limitation of the FSW process is mechanical stability of the tool at operating temperature. During FSW, the tool is responsible for not only heating the substrate material to forging temperatures, but also providing the mechanical action of forging. Therefore, tool material must be capable of sustaining high forging loads and temperatures in contact with the deforming substrate material without either excessive wear or deformation. As a result, the bulk of the FSW applications have involved low forging temperature materials. Of these, the most important class of materials has been aluminum. A range of virtually all classes of aluminum alloys have been successfully friction stir welded. These include the 1xxx, 2xx, 3xxx, 4xxx, 5xxx, 6xxx and 7xxx alloys, as well as the newer Al-Li alloys. Each alloy system is metallurgical distinct. Furthermore, different alloys within the given class may have different forging characteristics. As a result, processing for each alloy may vary. However, high-integrity joints can be obtained in all classes.

2. LITERATURE SURVEY

In the research done previous it is proved that any of these metals alone cannot perform well up to the desired level. So, welding of two different alloy materials is encouraged. For this, purpose the perfect welding parameters are chosen and the welding is done accordingly.

Suresh Babu et al In the past two decades friction stir welding has been evolved as a successful welding technique for joining all hard materials and metal matrix composites in addition to aluminium. This is possible because, joining is established by means grain refinement which will also lead to increase in mechanical properties. During joining, the number of parameters required to control is limited and which can be easily controlled to produce the sound weld. Machine controllable parameters are having direct proportional relation with mechanical properties except welding speed. FSP and FSSW are the two variants in friction stir welding. Former can become a successful method to produce surface composites, super plastic forming, later can be a good alternate method to resistance spot welding. Friction stir welding joints are prone to different types of defects which we can eliminate by choosing the proper tool design and process parameters. This process is less tried to weld hard materials due to the Lack of tool material and tool design. Tool wear will be the major problem while welding the metal matrix composites due to the presence of hard ceramic particles. More work has to be done in online monitoring of the process, online defect detection, controlling the temperature during the process.[9]

Aluminium alloys due to their high flexible properties is used for the different mechanical structures. Alloy systems are classified by a number system (ANSI) or by names indicating their main alloying constituents. Selecting the right alloy for a given application entails considerations of its mechanical properties like tensile strength, density, ductility, formability, workability, weldability, and corrosion resistance, to name a few. Aluminium alloys are used extensively in aircraft due to their high strength-to-weight ratio. On the other hand, pure aluminium metal is much too soft for such uses, and it does not have the high tensile strength that is needed for airplanes and helicopters. That is the reason aluminium alloys are important due to their improvised mechanical properties and chemical properties .out of all the available aluminium alloys the series 6000 is very commonly used in the industry due to its properties.AA6061 alloys which belongs to the series 6000are having high strength, high corrosion resistance and lightweight aluminium that have high ductility and toughness. On the other side, AA7075,which belongs to the series 7000 exhibit super high strength that has been used more often used in aircraft component and other highly stressed applications. Both materials of AA6061 series and AA7075 series are extensively employed in marine fittings, automobiles and aircraft applications. Unfortunately, if we study literature less work is done on both the alloys in spite of their well known uses [7]. Thus, to incorporate these dissimilar aluminium materials joint, the feasibility friction stir welding parameters is important in order to produce better bond strength [8]. So, research is being done in the field of joining these two dissimilar metals to improve the scope of applications. The chemical as well as the physical properties of both materials should be given prior importance before conducting the friction stir welding process. The chemical compositions of both the metals are given below. In the research done previous it is proved that any of these metals alone cannot perform well up to the desired level. So, welding of two different alloy materials is encouraged. For this, purpose the perfect welding parameters are chosen and the welding is done accordingly.

The Space Shuttle Program of NASA implemented this new weld technique in its manufacturing process of the external tank in 2001. The first friction stir welded tank flew in 2009. Since then, NASA has developed multiple tools and advanced processes to enhance its welding capabilities on aerospace hardware [5].So, from this it is clear that any misweldings leads to great losses in the industry of manufacturing process. To obtain a very good and precise quality of weld it is very essential to take a very special care on the welding parameters and study various working conditions extensively. Two aluminium alloys AA7075-T651 andAA6061-T651 under better mixing of both materials the good strength of weld is obtained at 900 rpm, 90mm/mm with taper cylindrical threaded tool [3].Over further optimization of friction stir welding parameters for A356 and AA6061 by varying the tool rotational speeds of 1000-1400 rpm and traversing speeds of 80-240 mm/min there will a change in total heat input, and cooling rate during FSW process the weld obtained is very perfect. Joint improvement of the weld strength is produced at lowest tool traversing and rotational speed which more than 98 % of 6061 alloy [4]. In addition to this, the defect-free friction stir welds of dissimilar alloys system of

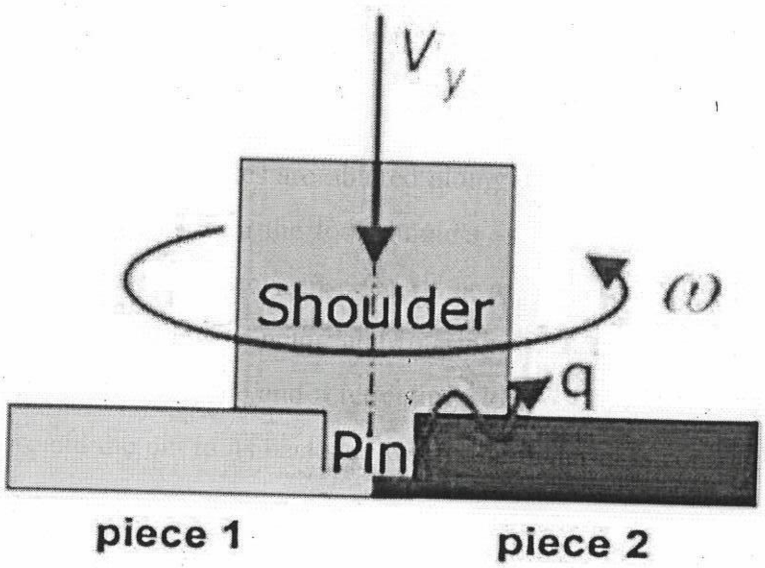
AA2024-T351 andAA6056-T4 in the preliminary study on the microstructure and mechanical properties in aircraft alloys are also affected by the transverse and rotational speeds of the tool tip [6]. Furthermore, tensile tests have shown reasonable joint efficiencies in terms of ultimate tensile strength which produces around *56%* of the 2024.-T351 and about 90% of the 6056-T4 alloy strength. It is proved that improved weld strength of dissimilar welded AA6063 and AA5052 is achieved by using a further designed tool of quench hardening W9Mo3Cr4V type with some geometric improvements. Other than that, the studies show that the material position at there treating side benefited the formation of the weld and the interfacial gap between lap materials is reduced in the feasibility research on FSW process of the new-typed lap butt joint of dissimilar Al alloys. After carefully studying this literature deeply we came to a conclusion on accuracy in welding process and fixed standard welding parameters for obtaining well. weld which helps in the experimentation process.

3. WORKING PRINCIPLES OF FRICTION STIR WELDING

Friction Stir Welding features have led to the application of leaders for micro joining of electronic components, but the process is also being applied to the fabrication of automotive components and precision machine tool parts in heavy section steel.

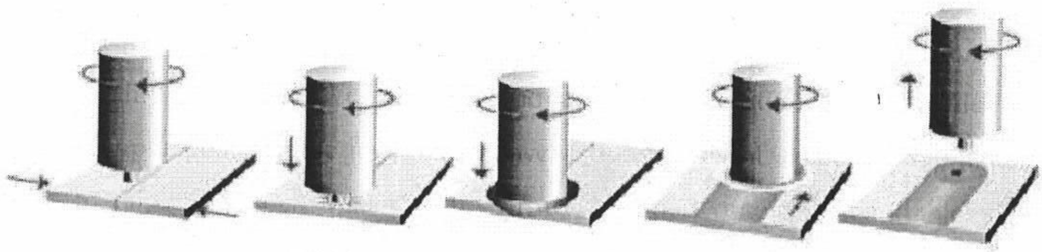
Principle of operation:

At first, the sheets or plates are abutted along edge to be welded and the rotating pin is sunken into the sheets/plates until the tool shoulder is in full contact with the sheets or plates surface. Once the pin is completely inserted, it is moved with a small rotating angle in the welding direction. Due to the advancing and rotating effect of the pin and shoulder of the tool along the seam, an advancing side and a retreating side are formed and the softened and heated material flows around the pin to its backside where the material is consolidated to create a high-quality, solid-state weld.



Theory of FSW:

In Friction Stir Welding, a cylindrical shouldered tool with a profiled probe is rotated and slowly plunged into the joint line between two pieces of sheet or plate material, which are butted together. The parts have to be firmly clamped onto the worktable in a manner that prevents the joint faces from being forced apart. Frictional heat is generated between the wear resistant welding tool and the material of the work piece as shown in Fig. (b). This heat causes the latter to soften without reaching the melting point and allows passing of the tool along the weld line as shown in Fig. (c). The plasticized material is transferred from the leading edge of the tool to the trailing edge of the tool probe and is forged by the intimate contact of the tool shoulder and the pin profile. It leaves a solid phase bond between the two pieces.



(a) (b) (c) (d)

Figure : Schematic Drawing for Working Processes: (a). Start of joining, (b). Insert joining tool, (c). Joining and (d). Pull away joining tool (end)

A significant benefit of Friction Stir Welding is that it has significantly fewer process elements to control. In a Fusion weld, there are many process factors that must be controlled– such as purge gas, voltage and amperage, wire feed, travel speed, shield gas, arc gap. However, in Friction Stir Weld there are only three process variables to control: rotation speed, travel speed and pressure, all of which are easily controlled. The increase in joint strength combined with the reduction in process variability provides for an increased safety margin and high degree of reliability for the External Tank.

Friction Stir Welding works as; first a dowel is rotated between 180 to 300 revolutions per minute, depending on the thickness of the material. The pin tip of the dowel is forced into the material under 5,000 to 10,000 pounds per square inch (775 to 1550 pounds per square centimetre) of force. The pin continues rotating and moves forward at a rate of 3.5 to 5 inches per minute (8.89 to 12.7 centimetres per minute).

As the pin rotates, friction heats the surrounding material and rapidly produces a softened "plasticized" area around the pin. As the pin travels forward, the material behind the pin is forged under pressure from the dowel and consolidates to form a bond. Unlike fusion welding, no actual melting occurs in this process and the weld is left in the same fine grained condition as the parent metal.

Material flow and mechanism of joining:

The rotating tool provides a continual hot working action that moves material around a pin at temperatures well below the melting point of the materials to be processed, plasticizing metal within a narrow zone, while transporting metal from the leading face of the pin to its trailing edge.

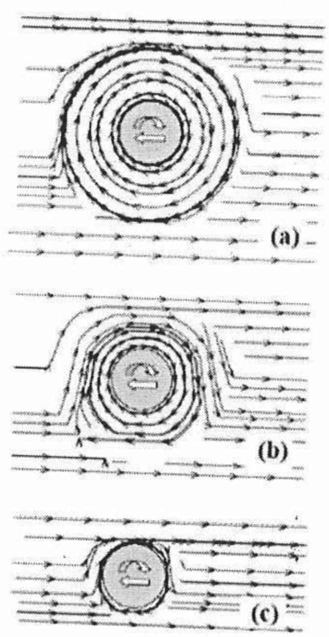


Figure : Stream traces on different horizontal planes (a) 0.35 mm, (b) 1.59 mm and (c) 2.28 mm below the top surface

The current understanding is that FSW is a process that moves material around a pin at temperatures well below the melting point of the materials to be welded. The material is thought to be in a plastic state and therefore can be pushed around. The pin pressure and torque provide the energy to create a material with an apparent viscosity, allowing it to flow around the pin. Since the fluidic layer acts as a boundary layer between the solid parent material and the pin, one can visualize that this boundary layer is pushed away, or reduced in thickness at the leading edge of the pin. If the traverse speed is too high, this viscous layer will be pushed away completely, and the pin will contact the parent material, which leads to excessive pin force and tool failure.

Viscous State of the Material may be considered as a Layer Surrounding the Pin Boundary Layer is pushed away, or Reduced in thickness at the Leading Edge of the Pin Frictional heat is generated between the wear resistant welding tool shoulder and nib, and the material of the work pieces. This heat, along with the heat generated by the mechanical mixing process and the adiabatic heat within the material, cause the stirred materials to soften without reaching the melting point (hence cited a solid-state process), allowing the traversing of the tool along the weld line in a plasticized tubular shaft of metal. As the pin is moved in the direction of welding, the leading face of the pin, assisted by a special pin profile, forces plasticized material to the back of the pin while applying a substantial forging force to consolidate the weld metal. The welding of the material is facilitated by severe plastic deformation in the solid state, involving dynamic recrystallization of the base material for different thickness

Generation and Flow of Heat:

For any welding process it is, in general, desirable to increase the travel speed and minimize the heat input as this will increase productivity and possibly reduce the impact of welding on the mechanical properties of the weld. At the same time it is necessary to ensure that the temperature around the tool is sufficiently high to permit adequate material flow and prevent flaws or tool fracture. When the traverse speed is increased, for a given heat input, there is less time for heat to conduct ahead of the tool and the thermal gradients are larger. At some point the speed will be so high that the material ahead of the tool will be too cold and the flow stress too high, to permit adequate material movement, resulting in flaws or tool fracture. If the "hot zone" is too large then there is scope to increase the traverse speed and hence productivity. The welding cycle can be split into several stages during which the heat flow and thermal profile will be different:

Dwell: The material is preheated by a stationary, rotating tool in order to achieve a sufficient temperature ahead of the tool to allow the traverse. This period may also include the plunge of the tool into the workpiece.

Transient heating: When the tool begins to move there will be a transient period where the heat production and temperature around the tool will alter in a complex manner until an essentially steady-state is reached.

Pseudo steady-state: Although fluctuations in heat generation will occur the thermal field around the tool remains effectively constant, at least on the macroscopic scale.

Post steady-state: Near the end of the weld heat may "reflect" from the end of the plate leading to additional heating around the tool.

Heat generation during friction-stir welding arises from two main sources: friction at the surface of the tool and the deformation of the material around the tool. The heat generation is often assumed to occur predominantly under the shoulder, due to its greater surface area, and to be equal to the power required to overcome the contact forces between the tool and the workpiece.

The contact condition under the shoulder can be described by sliding friction, using a friction coefficient and interfacial pressure P, or sticking friction, based on the interfacial shear strength and tor; at an appropriate temperature and strain rate. Mathematical approximations for the total heat generated by the tool shoulder Qtotal have been developed using both sliding and sticking friction models:

$$Qtotal = 2/3\Pi p\mu\omega(R^{3} - R^{3}) \text{ (sliding)}$$

$$Qtotal=2/3\ \pi T\omega\ (R^{3}shoulder-R^{3}pin)\text{(sticking)}$$

Where ω is the angular velocity of the tool, Rshoulder is the radius of the tool shoulder and Rpin that of the pin. Several other equations have been proposed to account for factors such as the pin but the general approach remains the same.

A major difficulty in applying these equations is determining suitable values for the friction coefficient or the interfacial shear stress. The conditions under the tool are both extreme and very difficult to measure. To date, these parameters have been used as "fitting parameters" where the model works back from measured thermal data to obtain a reasonable simulated thermal field. While this approach is useful for creating process models to predict, for example, residual stresses it is less useful for providing insights into the process itself.

4. EXPERIMENTATION

Alloy plates of 10 mm thick AA6061,AA2014 and AA7075 are initially machined for 100X150X10 mm size are cut from the stock and they are further machined to remove the grease and dirt particles from the surfaces. The process is carried on vertical milling machine. The maximum spindle speed is 2000 rpm, power capacity of 11 KW with a test speed of 0.5mm/sec, maximum table length as 600 mm and a width of 300mm with a maximum collar size of 30mm. The Chemical composition and mechanical properties of parent materials was tested as per ASTM standards and listed below. Specially designed tools are used to join the plates; tool material was made up of H13 tool steel with different pin profiles. The tools are prepared by considering the previous literatures to design the shoulder and pin profiles and the experimental process was carried out with different process parameters like tool rotational speed, welding speed, tilt angle, tool offset and pin profiles.

The selection of number process parameters with their levels were selected by using L9 orthogonal array, the presented work was carrying with 4 parameters. The experiments are performed at a rotational speed of 710-1120, traverse speed of 40-90, tool offset of 0-1, with three hybrid pin profiles (T, Cy, P) at a constant tilt angle of 2^0. The previous literatures strongly recommended that, the hard material is always kept an advanced side (AS) and the soft material is placed on retreating side (RS). In FSW process the material in stir zone was experienced by the thermo mechanical cycle, in this stage Al alloys are highly involved in hot working process, the temperatures at stir zone (SZ), AS and RS side of parent metal are observed.

Chemical Composition of Base Metal:

AA 6061	Mg	Si	Fe	Cu	Cr	Mn	Ti	Zn	Al
Standard	0.8-1.2	0.4-0.8	Max 0.7	0.15-0.4	0.040.35	Max 0.15	Max 0.15	Max 0.25	Bal
Tested	1.02	0.611	0.261	0.192	0.145	0.108	0.016	0.008	Bal

AA 7075	Zn	Mg	Cu	Cr	Fe	Si	Mn	Ti	Al
Standard	5-6	2.1-2.9	1-2	0.18 -0.28	Max 0.5	Max 0.4	Max 0.3	Max 0.2	Bal
Tested	5.63	2.37	1.70	0.215	0.175	0.0769	0.0499	0.0201	Bal

AA 2014	Cu	Mn	Si	Mg	Fe	Ti	Zn	Cr	Al
Standard	3.90-5	0.40-1.20	0.50-1.2	0.20-0.80	0.70	0.15	Max 0.25	Max 0.10	Bal
Tested	3.92	0.458	0.636	0.472	0.185	0.056	0.210	0.017	Bal

Base material Mechanical properties:

Parent Material	AA7075	AA2014	AA6061
Tensile strength(MPa)	568	170.21	270
Yield strength (Mpa)	514	153.4	214
% of elongation	11	7.65	22

Tool Material:

Materials such as aluminium or magnesium alloys, and aluminium matrix composites (AMCs) are commonly welded using steel tools. Steel tools have also been used for the joining of dissimilar materials in both lap and butt configurations. Lee et al. welded Al–Mg alloy with low carbon steel in lap joint configuration using tool steel as tool material without its excessive wear by placing the softer Al–Mg alloy on top of the steel plate and avoiding direct contact of the tool with the steel plate. In butt joint configuration, the harder work piece is often placed on the advancing side and the tool is slightly offset from the butt interface towards the softer work piece.

We have chosen H13 tool steel for making FSW tool to join aluminum alloys.

Table : Chemical composition of H-13 Tool Steel.

Alloy details	C %	Mn %	Si %	S %	P %	Cr %	Ni %	Mo %	V %	Cu %
H-13 alloy composition	0.32-0.45	0.20-0.50	0.80-1.50	0.030 Max	0.030 Max	4.75-5.50	0.30Max	1.10-1.75	0.80-1.20	0.25 Max
H-13certificate	0.358	0.375	0.967	0.004	0.011	5.34	0.148	1.33	0.946	0.071

Table : Mechanical properties of H-13 Tool Steel.

Material	Ultimate Tensile Strength	Tensile Yield Strength	Reduction of Area	Thermal Conductivity	Melting Point
H13 Tool	1200-1590 MPa	1000-1380 MPa	50%@20 °C	28.6W/mK @215 °C	

TOOL PROFILE:

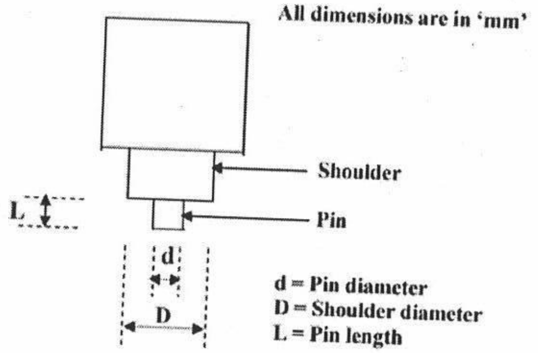
Tool Pin:

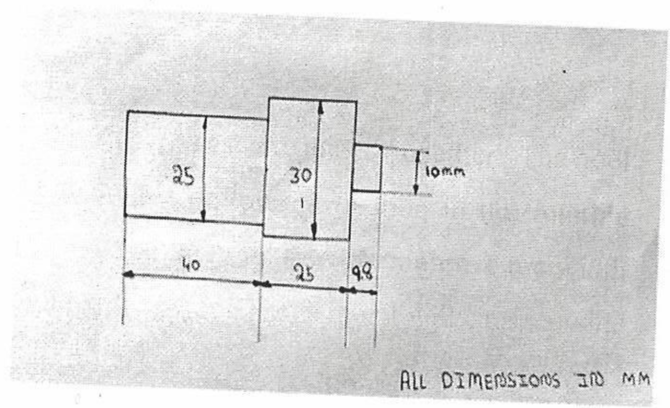
As shown the pin is cylindrical. The pin diameter is usually taken to be equal to the thickness of the plates to be welded. This satisfies the requirement that the head pin is small enough to penetrate the two plates. The length of the tool pin must be slightly less (by a fraction of a mm) than the thickness of the plates, so the pin penetrates the surface from one side only and at the same time forces the material to flow around it. The geometry of tool pin for FSW tools is shown in Fig.

Tool Shoulder:

The tool shoulder is also cylindrical in shape as shown in Figs. 5.2. Due to the heat dissipation from the friction between the shoulder and the surface of the plates (in addition to the pin action), the material undergoes plastic deformation and the two plates are joined together. The tool shoulder length is irrelevant, but it must be long enough to allow its fixation in the rotating machine tool holder. The shoulder diameter must be not too large in order to minimize the width of the welding zone line. In other words, if the shoulder diameter is too large, it will cause a wide section of the plate to be plasticized.

According to Y.N.Zang formulae and from the previous researches it has been absorbed that the pin diameter is equal to the plate thickness and shoulder diameter is varying with some empirical relations. For our study we have taken shoulder diameter is 3 times the pin diameter.





INPUT PARAMETERS:

The main input parameters in friction stir welding are as follows:

Rotational Speed of Tool:

The rotational speed of tool also known as machine spindle rpm affects the quality of joint. With increase in tool rotational speed the tool, the heat generated by friction also increases which directly affects temperature at welding position. Proper temperature is required for desired welding there for the rotational speed of tool must be selected properly.

Feed rate:

The welding feed speed which can also be termed as tool advancing speed also affects the quality of welded joints. With decrease in tool rotational speed the tool, the time for which tool is in contact with material increases, so the heat generated by friction also increases which directly affects temperature at welding position. Proper temperature is required for desired welding there for the welding feed speed must be selected properly.

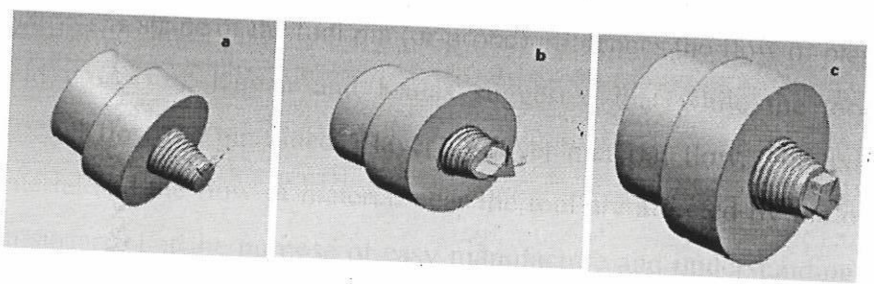
Pin (Probe) Geometry:

The shape of the tool pin (or probe) influences the flow of plasticized material and affects weld properties. Kumar and Kailas suggested that while the tool shoulder facilitated bulk material flow the pin aided a layer by layer material flow. The axial force on the work piece material and the flow of material near the tool are affected by the orientation of threads on the pin surface. For the purpose of easy manufacture and understanding we selected 3 pin profiles, which are

(a) Cylindrical

(b) Hybrid Triangular

(c) Hybrid Pentagon



Depth of Cut (AxialForce):

The depth of cut in FSW also termed as axial force applied affects the quality of the welding output. If we increase the thickness of the material plates to be welded, the required depth of cut to properly join the material increases, so the required axial force will also increases. There is certain limit of axial force that can be applied based on machine specification. So we have limited range of thickness that can be welded by machine based on its capability to apply axial force.

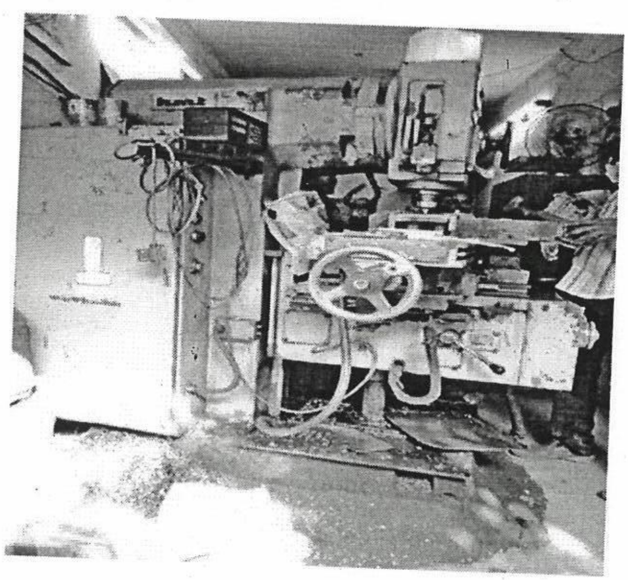
According to Taguchi Orthogonal L9 Array, we have arranged process parameters as follows:

Table : Taguchi Orthogonal array of process parameters

710	40	0	Tri
710	60	0.5	Cyl
710	50	1	Pen
900	40	0.5	Pen
900	60	1	Tri
900	50	0	Cyl
1120	40	1	Cyl
1120	60	0	Pen
1120	50	0.5	Tri

Friction Stir Welding on Vertical Milling Machine:

On vertical milling center machine we have done friction stir welding. The input parameters as mentioned before were taken for machine process parameters.



We have cut the sheet metal into the required dimensions of 150×75×10. After cutting of plates we have finished the edges of plates by rough and smooth files. Then two plates were clamped on machine bed tightly such that it can withstand the force of tool motion without dislocating from its size. Plate with higher hardness is placed in advancing side. With using drill bit a hole is drilled at the interaction of the two plates to place the tool for welding.

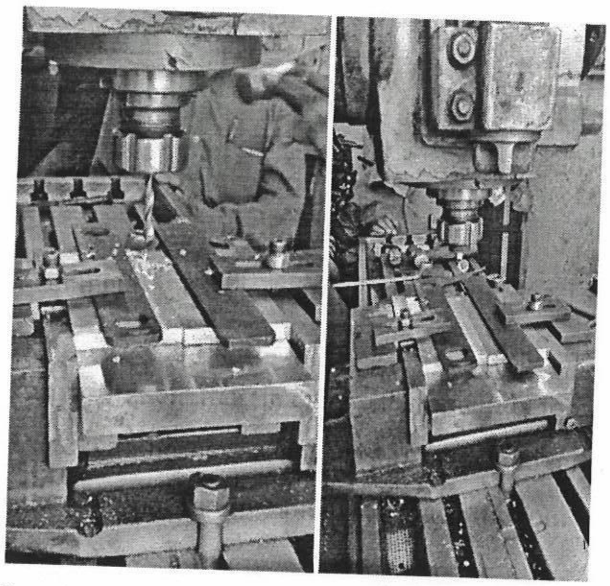
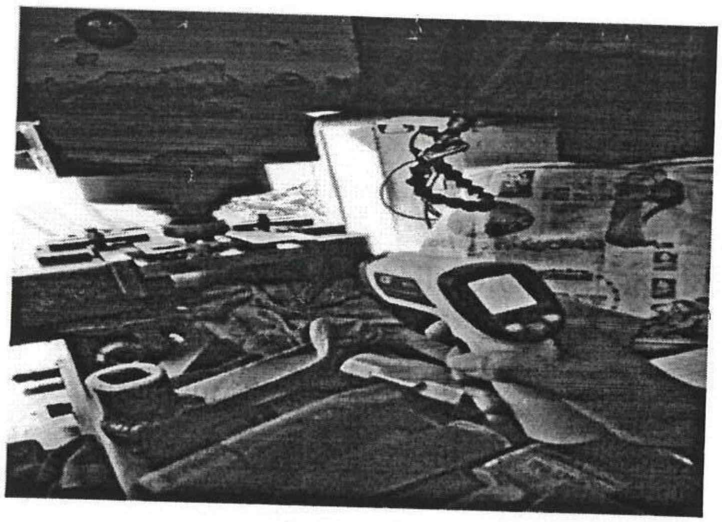


Fig : (a) Drilling a hole, (b) Placing the tool for welding

5. RESULTS AND DICUSSIONS

Temperature Measurement:

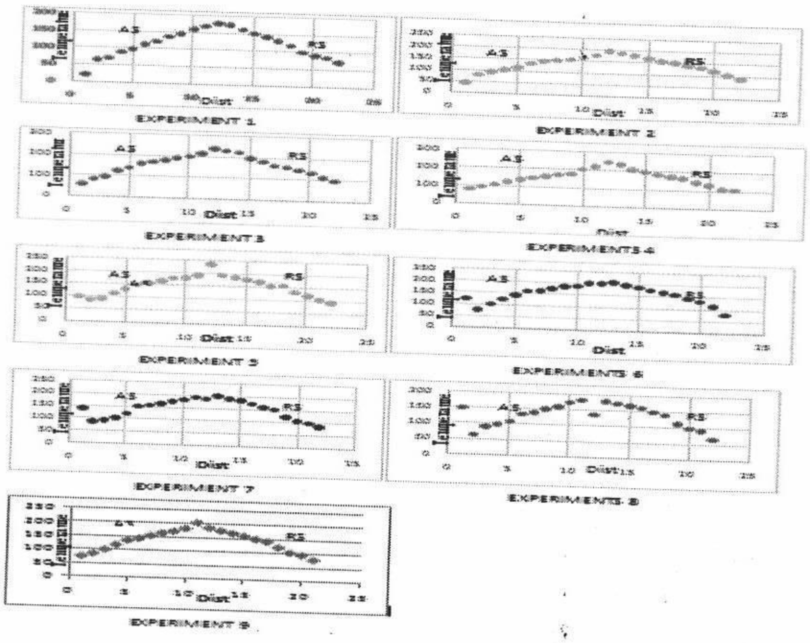
Temperature is measured during welding process to identify maximum temperature in the process. Temperature is measured with the help of the laser gun.



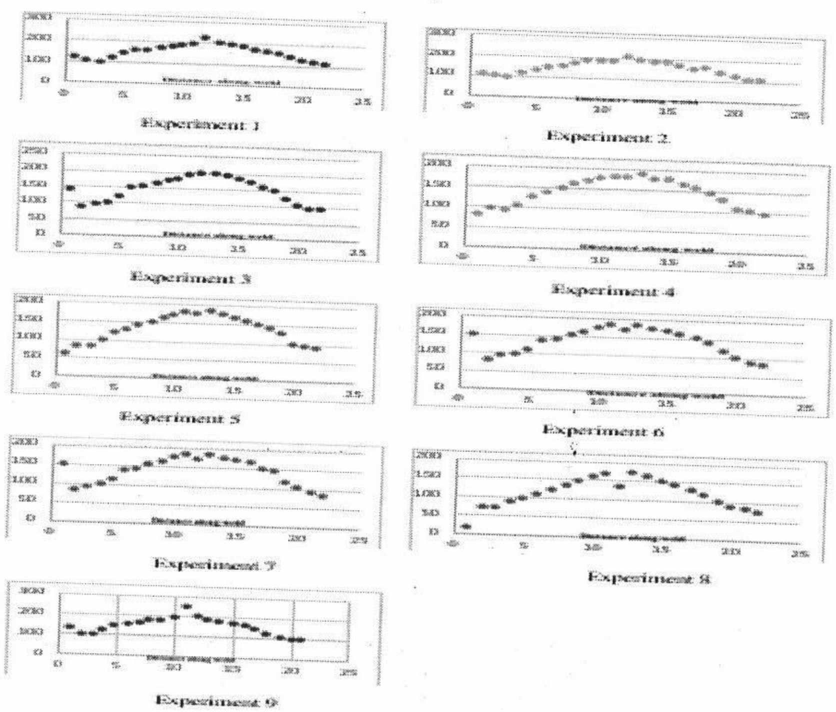
Temperature at different locations such as TMAZ, Nugget zone, Tool and at base materials is measured and maximum temperature zones are identified for further development of process parameters and tool profiles.

The temperature plots were drawn between weld length and temperature values were shown in figures below.

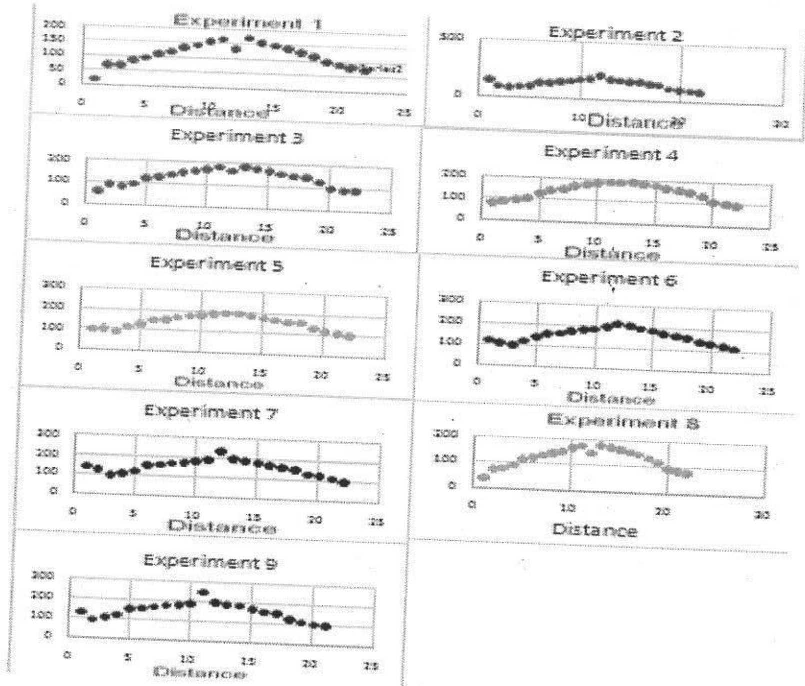
Profiles of AA2014-7075



AA6061-AA7075



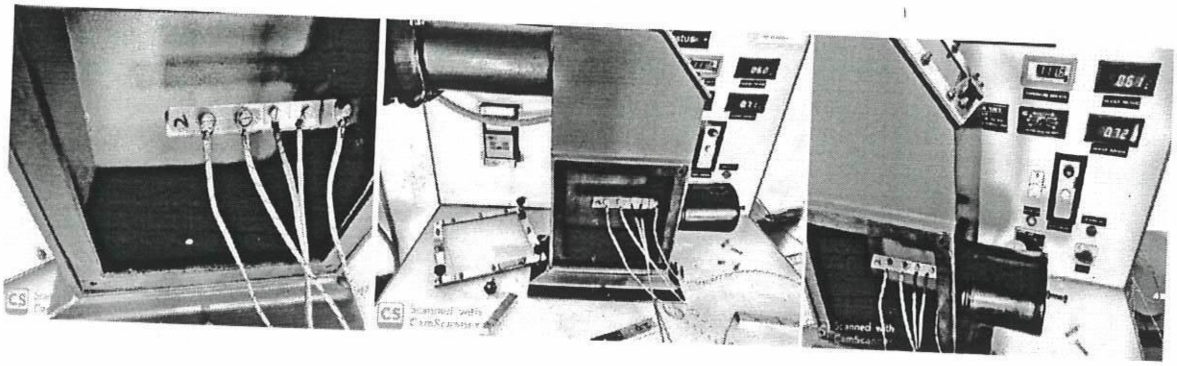
AA2014-6061



Thermal Conductivity(K):

Conduction is a process of heat transfer through solids. When a temperature gradient exists in a body, experience has shown that there is a transfer of heat from the high temperature region to low temperature region given by $q/A = -K\,dT/L$

Thermal conductivity λ is defined as ability of material to transmit heat and it is measured in watts per square metre of surface area for a temperature gradient of 1 K per unit thickness of 1 m".



Thermal Conductivity of work piece is found using conductivity apparatus. Using the temperature variation , voltage values the thermal conductivity at nugget zone is calculated for pieces. At a constant current value of 72 V ,the temperature at 5 positions of the respective piece is calculated placing thermocouples as shown in above pictures. The thermal conductivity of the nuggest zone is found to be more than 80% of the base metal in all the cases.

6. CONCLUSIONS

- The temperature generation during the process is observed that the temperature on advancing side is higher as compared to retreating side which varied between 200- 2500 C.
- Temperature generation during FSW process mainly depends on process parameters.
- The temperature profile shows that all the joints are made below solidification temperature of the base material and its value lies between 0.4-0.5 times of melting point of the base material.
- The sample no.4 processed at TRS 900 rpm, WS 40 mm/min, offset 0.5 mm with pentagonal pin profile produce the highest temperature.
- It is clearly observed that the temperature measured about AS is greater than RS side.It is a good sign for intermixing of materials.
- The thermal conductivity of the nuggest zone is found to be more than 80% of the base metal which shows good welds .

SCOPE OF WORK

The various mechanical properties which are the major parameters to determine the strength of the weld ,the microstructure analysis which can define the strength of grain structure in the nugget zone is proposed to be carried forward.

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Analysis of Temperature Profile on Friction Stir Welded Aa6061 And Aa7075 Aluminium Alloys

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Abstract: The study of temperature distribution during FSW process with dissimilar Aluminium alloys is needed a clear observation on heat generation during process. Low and High strength AA 6061 and AA7075 with 10mm thickness are chosen for welding. The process parameters like TRS, WS, Pin profiles, tool offset and tilt angle plays a crucial role to produce the sound welds. Cylindrical, pentagonal and triangular hybrid tool pin profiles are considered at weld speeds of 40,50,60 mm/min and tool rotation of 710,900,1120 rpm with a tool offset of 0, 0.5, 1mm. The tilt angle which is considered as another parameter is constant at 2^0 throughout the process The numbers of trail runs are selected by using Taguchi technique (L9) orthogonal array with four factors each at three levels to provide the interaction between the parameters. The temperature history at nugget zone, HAZ and the zones close to TMAZ are measured using thermocouples for either of the Al alloys. The temperature distribution curves were drawn and it is identified from the investigation that more temperature transfer was done towards AA6061.

Keywords: Aluminium alloys, Friction Stir welding, Process parameters, Temperature distribution.

1. INTRODUCTION

Aluminum is light in weight, and offer good corrosion resistance with good strength to weight ratio along with additional properties needed for aerospace, defense, marine, automotive, ammunition and for other fields of applications aluminum is the best ideal material. Indian launch vehicles mostly limited to main four key alloys as AA2014, AA2219, AA6061 and AA7075 with this the main objective the of the research is fabricate the joints with dissimilar combinations of these materials, and improve the joint strength along with mechanical properties of heat treatable Al-alloys, still now lot of work is limited to join those materials in similar fashion with limited thickness up to 8 mm. In this paper the research is focus on fabrication of butt joint of 10 mm thick dissimilar Al-alloys.

Friction stir welding (FSW) was invented by W.M. Thomas at The Welding Institute (TWI) of UK in1991. It is quite different and serves major needs when compared to other welding processes. That is the reason why it is emerging as a major method of welding in the industries of aerospace, ship-building, automotive, and railway industries. It utilizes a non-consumable electrode and welds two dissimilar base metals below their solidus temperatures. At high temperatures below the melting point of the work piece, atoms are permitted to diffuse along the weld joint to fill in any remaining voids and complete the joining process. This helps to retain the same phase of the base metal before and after completion of the welding process. Apart from this it has a variety of other uses such as Excellent tensile and fatigue strength, no splatter, no fume, Low energy consumption, Low shrinkage, no filler wire, Good mechanical reproducibility, no skilled welder required. It is more often used for soft materials like aluminium [1]. The tool used in this process has a specially designed tip having a suitable profile for obtaining the higher quality of the weld. Tool travelling and rotation speeds, among other welding parameters, are most important variables that may affect the joint properties. Alongside of these parameters the distribution of the temperature also plays a important role because ,during the process of Friction stir welding the tool tip undergo translatory and rotary motions due to which a tremendous plastic deformation takes place and the temperature increases rapidly at the weld zone and there might me a slight change in the nature of base metals around the heat affected zone[2].There comes the need of studying the temperature distribution profile on the both sides of the weld region. By, this we can find the nature of heat distribution and further we can make necessary research to minimize the heat affected zone and at the same time increase the quality of the weld. The schematic diagram of FSW process is shown in figure below.

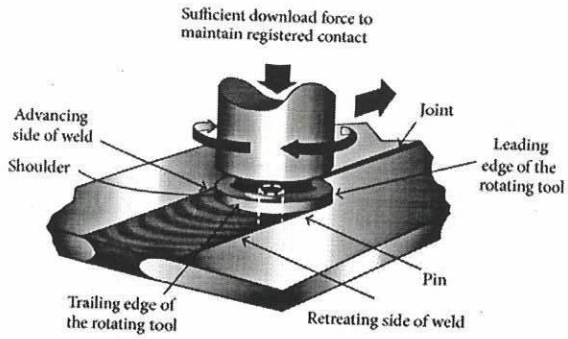

Fig. 1: Schematic diagram of FSW process

Aluminium alloys due to their high flexible properties are used for different industrial purposes. Aluminium alloys are used mainly in aircraft constructions because of their high strength-to-weight ratio. That is the reason aluminium alloys are important due to their improvised mechanical properties and chemical properties .out of all the available aluminium alloys the series 6000 is very commonly used in the industry due to its properties. Both materials of AA6061 and AA7075 are mainly used in various engineering applications. Unfortunately, if we study literature less work is done on both the alloys in spite of their well known uses [3]. The feasibility of friction stir welding process is used to join dissimilar Al alloys with excellent bond strength [4]. So, research is being done in the field of joining these two dissimilar metals to improve the scope of applications.

The chemical as well as the physical properties of both materials should be given prior importance before conducting the friction stir welding process. The chemical compositions of both the metals are given below.

In the research done previous it is proved that any of these metals alone cannot perform well up to the desired level. So, welding of two different alloy materials is encouraged. For this, purpose the perfect welding parameters are chosen and the welding is done accordingly.

The Space Shuttle Program of NASA implemented this new weld technique in its manufacturing process of the external tank in 2001. The first friction stir welded tank flew in 2009. Since then, NASA has developed multiple tools and advanced processes to enhance its welding capabilities on aerospace hardware [5]. So, from this it is clear that any mis welding's leads to great losses in the industry of manufacturing process. To obtain a very good and precise quality of weld it is very essential to take a very special care on the welding parameters and study various working conditions extensively. Two aluminium alloys AA7075-T651 and AA6061-T651 under better mixing of both materials the good strength of weld is obtained at 900 rpm, 90mm/mm with taper cylindrical threaded tool[6]. FSW welds were made with A356 and AA6061 by changing the process parameters TRS (1000-1400 rpm) ,and weld speed of (80-240 mm/min) there will be a change in heat input and process parameters were optimised. [7]. The preliminary investigation on microstructure and mechanical properties of dissimilar AA2024-T351 and AA6056-T4 aircraft alloy welds are affected by the transverse and rotational speeds [8]. In dissimilar welds AA2024-T351 and AA6056-T4 ,the material location at the RS exhibit formation of good welds which is about 90% of AA6056-T4 alloy.

After carefully studying this literature deeply we came to a conclusion on accuracy in welding process and fixed standard welding parameters for obtaining well weld which helps in the experimentation process.

2. EXPERIMENTATION

Aluminium Alloy plates of 10 mm thick AA6061 and AA7075 are initially machined for 100X150X10 mm size are cut from the stock and they are further machined to remove the grease and dirt particles from the surfaces. The process is carried on vertical milling machine. The Chemical composition and mechanical properties of parent materials was tested as per ASTM standards and listed below. Specially designed tools are used to join the plates; tool material was made up of H13 tool steel with different pin profiles. The tools are prepared by considering the previous literatures to design the shoulder and pin profiles and the experimental process was carried out with different process parameters like rotational speed, welding speed, tilt angle, tool offset and pin profiles.

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Tested	1.02	0.611	0.261	0.192	0.145	0.108	0.016	0.008	Bal

AA 7075	Zn	Mg	Cu	Cr	Fe	Si	Mn	Ti	Al
Standard	5-6	2.1-2.9	1-2	0.18 -0.28	Max 0.5	Max 0.4	Max 0.3	Max 0.2	Bal
Tested	5.63	2.37	1.70	0.215	0.175	0.0769	0.0499	0.0201	Bal

Table2: Mechanical properties of base metals:

Parent Material	AA7075	AA6061
Tensile strength (MPa)	568	270
Yield strength (Mpa)	514	214
% of elongation	11	22

3. DESIGN AND DEVELOPMENT OF PIN PROFILES

From the previous studies, it has reported that FSW process mainly depend on the tool profiles, because it is responsible to produce the sufficient amount of heat to soften the base materials. A special care and design consideration has to be taken to design the pin profiles to join 10 mm thick dissimilar Al alloys. It is very important to note that the concept of swept volume plays an important role in deciding the tool profile.

Swept volume is the total volume that can be accommodated or used at the weld during the welding process. We have different swept volumes for different shaped profiles. In this experiment different pin profiles like Triangle, Square, Pentagon, Hexagon and Octagon, Cylindrical profiles are designed by considering the swept volume values. The swept volume of Triangle, Square and Pentagon profiles have the higher value than the other profiles so Triangle, Square and Pentagon are used in fabrication.

Table 3: Swept volume values for selected tools

S NO	Tool profile	Swept volume
1	Triangle	2.4
2	Cylindrical	1
3	Pentagon	1.45

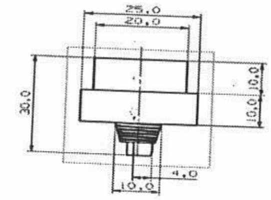

Fig.2:Dimensions of pin profile

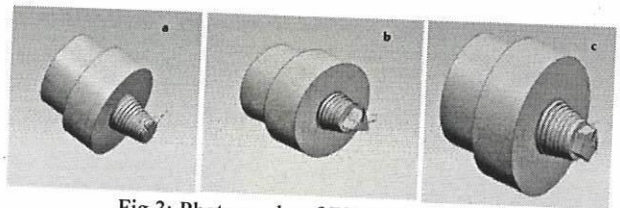

Fig.3: Photographs of FSW pin profiles

The thickness of the plates are uniform throughout the length, so fixed type pin profiles selected for this process and the tool dimensions are taken as per the standard ratios of shoulder to pin dimensions published in previous article [9]. It is strongly recommended from the previous studies that the ratio between tool shoulder to pin diameter as 3 (D/d=3). The pin length has a stronger affect on the traverse force than the pin diameter.

Table 4: Chemical composition of tool material:

H13 Tool Steel	Cr	Mo	Si	V	C	Mn	Ni	Cu	P	S
Standard	4.75-5.50	1.1-1.75	0.8-1.5	0.8-1.2	0.32-0.45	0.2-0.5	Max0.3	Max 0.25	Max 0.030	Max 0.030
Tested	5.29	1.39	1.04	0.896	0.359	0.275	0.223	0.086	0.011	0.002

The prepared pin profiles are further processed to heat treatment to improve the Hardness, Toughness and other mechanical properties

Temperature profile:

Fig.4: Temperature measurement with infrared thermometer

There are different factors which effects on temperature profile during the process are pin profile, spindle speed and welding speed, when spindle speed was increases heat generation was high, which cause to increasing the interface temperature, whereas higher traverse speed causes more heat exerted from the weld zone.

The temperature profile of the weld zone and its surroundings can be calculated by using two methods: one among them is calculating the temperature directly by using the laser thermometer, the second option available is by calculating it with the help of formulae available.

4. RESULTS AND DISCUSSIONS

The observations shows that more than 80% of the heat taken between the tools pins to work pieces, it's a good sign for producing sound welds and also help to reduce the defects occurring during the process. An appropriate amount of heat generation is required for softening of joining materials which cause to reduce the thermo mechanical stresses on tool during processes.

To understand the effect of temperature on hardness, the maximum temperature observed on AS and RS of the welds made by different pin profiles.

Table 5: Experimental observations at various process parameters

TRS	WS	OFFSET	PINS	AS temp.	Tool temp.	RS temp.
710	40	0	Triangular	208	223	200
710	60	0.5	Cylindrical	200	208	195
710	50	1	Pentagonal	195	200	188
900	40	0.5	Pentagonal	224	258	208
900	60	1	Triangular	195	210	191
900	50	0	Cylindrical	206	212	201
1120	40	1	Cylindrical	200	228	192
1120	60	0	Pentagonal	212	239	202
1120	50	0.5	Triangular	218	248	205

FSW weld images:

The welds processed at various conditions are ordered by using L-9 orthogonal array and the images of the same are shown below.

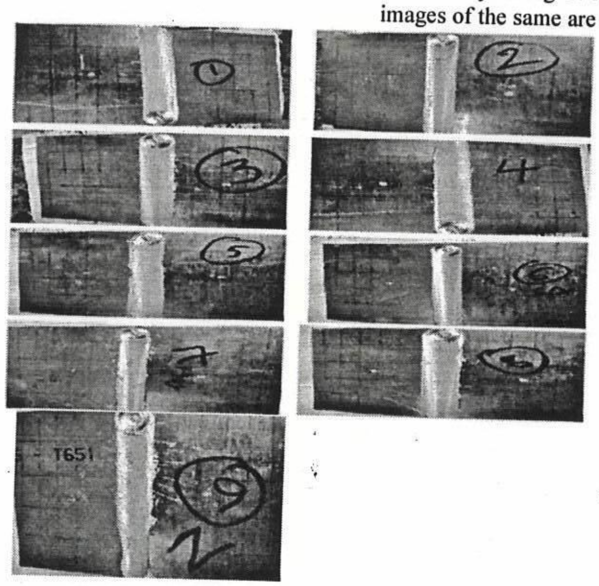

Fig5: weld images

Temperature profile graphs:

The temperature profile measured along the length of the weld measured with the help of infrared thermometer and the measured values plotted in graphs are shown below.

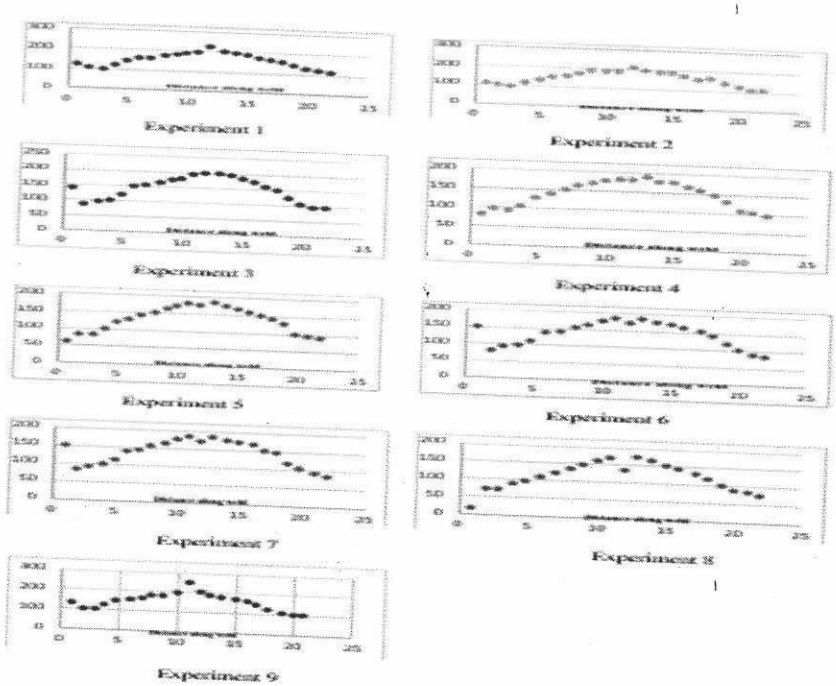

Fig.6: Temperature Distribution profiles

The temperature distribution of the welded samples throughout the length and their comparison is shown in the given figure.

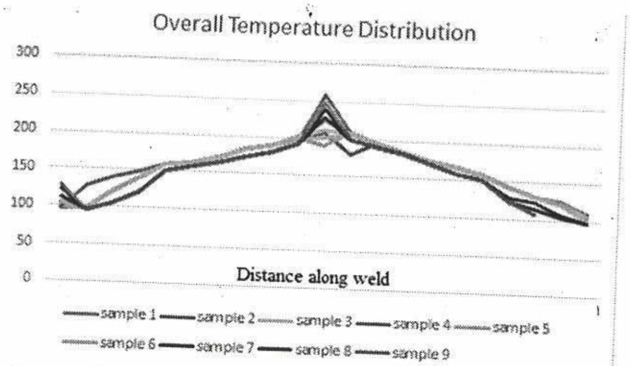

Fig.7: Comparision of temperature distribution among the samples

5. CONCLUSION

From the experimental study the observed results are concluded as follows,

- Temperature generation during FSW process mainly depends on process parameters.
- The temperature profile shows that all the joints are made below solidification temperature of the base material and its value lies between 0.4-0.5 times of melting point of the base material.
- The sample no.4 processed at TRS 900 rpm, WS 40 mm/min, offset 0.5 mm with

pentagonal pin profile produce the highest temperature.

- It is clearly observed that the temperature measured about AS is greater than RS side.It is a good sign for intermixing of materials.

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