

DEPARTMENT OF MECHANICAL ENGINEERING



CERTIFICATE

This is to certify that Thesis entitled “SIMULATION OF INERTIA FRICTION WELDING MILD STEEL AND ALUMINIUM USING FINITE ELEMENT METHOD ON ABAQUS” which is submitted by Pushpandra Nimesh (2K14/CDN/13) in partial fulfillment of the requirement for the award of degree M. Tech. in Department of Mechanical Engineering of Delhi Technological University, is a record of the candidate own work carried out by him under my supervision. The matter embodied in this thesis is original and has not been submitted for the award of any other degree/ certificate in any other institution/university.

(Dr. RAJIV CHAUDHARY)

Supervisor

(Dr. R.C. Singh)

Supervisor

DATE: 29/07/2016

PLACE: DELHI

ACKNOWLEDGEMENTS

It gives me a great sense of pleasure to present the Thesis of the M.Tech Major Project-IInd undertaken during M. Tech final Semester. I owe special debt of gratitude to Dr. Rajiv Chaudhary sir, Dr. R.S. Mishra sir (HOD), Dr. R.C. Singh Sir, Dr. Vikas Rastogi sir, Department of Mechanical Engineering, DTU, Mr. Radha Raman Sir, Department of Mechanical Engineering, JSS for their constant support and guidance throughout the course of our work. Their sincerity, thoroughness and perseverance have been a constant source of inspiration for me. It is only their cognizant efforts that our endeavors have seen light of the day.

I also do not like to miss the opportunity to acknowledge the contribution of all faculty members of the Department of Mechanical Engineering for their kind assistance and cooperation during the development of our project. Last but not the least I acknowledge my friends and family for their contribution in the completion of the project.

Signature

Name: PUSHPANDRA NIMESH

Roll No: 2K14/CDN/13

Date: 29/07/2016

DECLARATION

I hereby declare that the thesis entitled “SIMULATION OF INERTIA FRICTION WELDING MILD STEEL AND ALUMINIUM USING FINITE ELEMENT METHOD ON ABAQUS” submitted in mechanical engineering department of Delhi Technological University is my own work. It is further to declare that the matter embodied in thesis is original and has not been submitted for the award of any other degree/ certificate in any other institution/university.

Signature

Name: PUSHPANDRA NIMESH

Roll No: 2K14/CDN/13

Date: 29/07/2016

ABSTRACT

Friction welding is a welding technique involving green technology concept as it makes use of a non-consumable tool to produce coalescence between work-pieces by utilizing heat generated because of friction and plastic deformation at the interface of work-components affecting the formation of weld joint while the material being in solid state. Advantages of frictional welding process are low distortion of weld joint, absence of flash related defects and high strength of weld joints in those alloys and metals that are considered to be Non-Weldable by conventional fusion welding processes. Friction welding process is omitted of filler-induced defects as the inertia friction welding process requires no use of filler material and thus susceptible to hydrogen damage. The technique can be used to produce joints on equipments utilizing traditional machine technologies and it can be used to produce weld between varieties of similar and dissimilar metals and alloys and it can also be used for producing weld joint between metal reinforced composites. Use of friction welded joints leads to a significant reduction in weight and cost savings serving friction welding process as a reusable tool for industrial and manufacturing sectors. Apart from industrial and manufacturing level applications, inertia friction welding process finds its application in field of Navy, Medicinal applications. Friction welding process seems to be a simple process but this is not, instead it is a very complex process as it includes conversion of mechanical energy into thermal energy in form of heat due to frictional rubbing between work-pieces. So prediction of properties of weld formed at interface is difficult. Numerical simulation offers a way to tackle that problem and also a way to increase repeatability of the friction welding process at manufacturing level and also it opens new ways to understand the process's mechanics more efficiently. This thesis works review an introduction toward the friction welding process, work that had been performed in corresponding field and research work needed to be done in the corresponding field on the basis of research gap in the corresponding field. This project works consists of performing inertia friction welding process between mild steel and aluminum 6061 using lathe machine and then performing numerical simulation of the inertia friction welding process using finite element method on ANSYS and ABAQUS and then performing comparison of the data obtained both experimentally and numerically so as to increase the repeatability of the inertia friction welding process.

TABLE OF CONTENTS

	Page Number
CERTIFICATE.....	i
ACKNOWLEDGEMENT.....	ii
DECLARATION	iii
ABSTRACT.....	iv
TABLE OF CONTENTS.....	v
LIST OF TABLES.....	ix
LIST OF FIGURES.....	x
LIST OF GRAPHS.....	xiv
CHAPTER 1 GENERAL INTRODUCTION	
1.1 Introduction.....	1
1.2 Classification of friction welding.....	2
1.3 Principle.....	7
1.4 Procedure.....	8
1.5 Types of inertia friction welding process.....	9
1.5.1 Continuous motor drive friction welding process.....	9
1.5.2 Direct drive friction welding process.....	10
1.6 Inertia friction welding process parameters.....	10
1.7 Merits.....	10
1.8 De-merits.....	11
1.9 Applications of friction welding.....	11
1.9.1 Simulation of friction welding process.....	14
CHAPTER 2 LITERATURE REVIEW	
2.1 Summary of Literature.....	17
2.2 Summary of Research gap.....	22

CHAPTER 3 SELECTION OF MATERIALS AND PROCESS

3.1 Material Selection.....	24
3.1.1 Material Composition.....	24
3.2 Process selection.....	24
3.2.1 Experimentation approach toward inertia friction welding process.....	25
3.2.2 Finite element approach toward inertia friction welding process.....	25

CHAPTER 4 EXPERIMENTATION

4.1 Introduction.....	27
4.1.1 Preparation of special fixture.....	27
4.1.2 Construction of Design of experiment.....	28
4.2 Procedure.....	29
4.2.1 Pre-welding process.....	30
4.2.2 Welding process.....	30
4.2.2.1 Steps in performing welding process.....	30
4.2.3 Post-welding process.....	32
4.2.3.1 Measurement of target values.....	32
(I-) Hardness test.....	32
(II-) impact test.....	33

CHAPTER 5 NUMERICAL SIMULATION OF WELDING PROCESS

5.1 Introduction.....	35
5.2 Numerical simulation on ANSYS.....	36
5.3 Numerical simulation on ABAQUS.....	36
5.3.1 Introduction to ABAQUS.....	36
5.3.2 Thermal modeling of welding process.....	36
5.3.3 Finite element modeling of welding process.....	38
5.3.3.1 Introduction to finite element method.....	38
5.3.3.2 Steps taken during FEA modeling of inertia friction welding	39
(I-) Pre-processing module.....	39

(II-) Solver module.....	53
(III-) Post processing module.....	54

CHAPTER 6 RESULTS AND DISCUSSION

6.1 Introduction.....	55
6.2 Results.....	55
6.2.1 Distribution of contact shear stress.....	57
6.2.2 Distribution of elastic strain.....	57
6.2.3 Distribution of plastic strain.....	59
6.2.4 Distribution of stresses in work-pieces.....	59
6.2.5 Distribution of thermal strain.....	61
6.2.6 Distribution of strain energy.....	62
6.2.7 Distribution of heat flux.....	63
6.2.8 Distribution of temperature.....	64
6.2.9 Graphs.....	65
6.2.9.1 Heat flux distribution.....	65
6.2.9.2 Temperature distribution at weld zone.....	65
6.2.9.3 Temperature distribution at HAZ in mild steel.....	66
6.2.9.4 Temperature distribution at HAZ Al 6061.....	67
6.2.9.5 Heat flux at weld zone.....	67
6.2.9.6 Von-Mises stress at weld zone.....	68
6.2.9.7 Tresca stress at weld zone.....	68
6.2.9.8 Max. Principal stress at weld zone.....	69
6.2.9.9 Elastic strain at weld zone.....	69
6.2.9.10 Logarithmic strain at weld zone.....	70
6.2.9.11 Plastic strain at weld zone.....	70
6.2.9.12 Strain energy density at weld zone.....	71
6.2.9.12 Frictional energy generation at weld interface.....	71
6.3 Experimentally Calculated Results.....	72
6.3.1 Hardness Data for Al 6061 HAZ.....	72
6.3.2 Hardness Data for Mild steel HAZ.....	72

6.3.3 Hardness Data for Weld zone.....	72
6.3.4 Impact Energy Data for Weld Samples.....	73
6.3.5 Temperature Data for Welded Samples.....	73
6.4 Comparison between Experimentally Calculated Results and Numerically Simulated results.....	74
CHAPTER 7 CONCLUSIONS AND FUTURE WORK ASPECT.....	75
7.1 Conclusions.....	75
7.2 Future work aspect	

REFERNCES

LIST OF TABLES

Table Number	Page number
Table 1: Composition of mild steel.....	.24
Table 2: Composition of aluminum 6061.....	24
Table 3: Steps taken during a finite element method analysis.....	26
Table 4: Steps involved in Taguchi optimization technique.....	29
Table 6: Temp. Dependent properties of mild steel.....	37
Table 7: Temperature dependent properties of aluminum 6061.....	37
Table 8: Pressure load variation with according to time.....	49
Table 9: Angular velocity variation with according to time.....	49
Table 10: Elastic-plastic behavior of mild steel.....	51
Table 11: Elastic-plastic behavior of Aluminum 6061.....	51
Table 12: Johnson-cook model parameters for mild steel.....	52
Table 13: Johnson-cook model parameters for aluminum 6061.....	52
Table 14: Hardness values for Al 6061's heat affected zone.....	72
Table 15: Hardness values for Mild steel's heat affected zone.....	72
Table 16: Hardness value for Weld zone.....	72
Table 17: Impact energy data for welded samples.....	73

LIST OF FIGURES

Figure Number	Page Number
Fig 1: Linear friction welding principle.....	3
Fig 2: Spin welding principle.....	4
Fig 3: Friction stir welding principle.....	5
Fig 4: Friction surfacing process.....	5
Fig 5: Load application during a typical inertia friction welding process.....	7
Fig 6: Initial position of work-pieces.....	8
Fig 7: Application of friction pressure.....	8
Fig 8: Flash formation during plastic deformation.....	8
Fig 9: Application of forging pressure.....	9
Fig 10: Continuous direct drive inertia friction welding scheme.....	9
Fig 11: Direct inertia friction welding process.....	10
Fig 12: Automotive half-shaft.....	12
Fig 13: Jet engine compressor wheel.....	12
Fig 14: Friction welded mechanical hand tools.....	12
Fig 15: Aluminum Airbag Inflator.....	14

Fig 16: Finite element discretization.....	15
Fig 17: Finite element discretization in a mechanical component.....	15
Fig 18: Finite element discretization of a toothed gear assembly.....	16
Fig 19: Parent Metals for Welding.....	23
Fig 20: work pieces before welding process.....	27
Fig 21: Special fixture used in welding process.....	28
Fig 22: special fixture assembled on lathe machine.....	30
Fig 23: Welded samples.....	31
Fig 24: work-piece after welding and turning.....	32
Fig 25: work-piece after hardness testing.....	33
Fig 26: Weld specimen after making V-notch.....	33
Fig 27: Charpy testing machine.....	34
Fig 28: Weld specimen after Impact testing.....	34
Fig 29: Choosing of analysis type in ABAQUS workbench.....	40
Fig 30: Construction of geometry using ABAQUS design modeler.....	40
Fig 31: Element type provided in Abaqus element library.....	41
Fig 32: coupled field element provide in Abaqus element library.....	41
Fig 33: Selection of contact and target surface.....	42

Fig 34: Normal Lagrange contact formulation.....	43
Fig 35: Pure penalty contact formulation.....	44
Fig 36: Modified Lagrange contact formulation.....	44
Fig 37: Application of boundary condition no. I on work-pieces.....	45
Fig 38: Application of boundary condition no. II on work-pieces.....	46
Fig 39: Different mesh element type offered in abaqus workbench.....	47
Fig 40: Lagrangian type mesh algorithm.....	47
Fig 41: Eulerian type mesh algorithm.....	47
Fig 42: Mesh generation for working model.....	48
Fig 43: Structural load application in model.....	50
Fig 44: Step Manager.....	53
Fig 45: Step Definition.....	53
Fig 46: Step size and step size controls.....	54
Fig 47: Parent material work-pieces at starting of simulation process.....	55
Fig 48: Enlarged view near contact at starting of simulation process.....	56
Fig 49: Enlarged view near contact after completion of simulation process (Deformed shape).....	56
Fig 50: weld zone and heat affected zone.....	56

Fig 51: contact shear stress distribution.....	57
Fig 52: Elastic strain.....	57
Fig 53: Elastic strain density distribution.....	58
Fig 54: logarithmic strain distribution near weld zone and HAZ.....	58
Fig 55: Plastic strain.....	59
Fig 56: Von Mises stress distribution.....	59
Fig 57: Von Mises stress distribution near weld and HAZ.....	60
Fig 58: Tresca stress distribution near weld zone and HAZ.....	60
Fig 59: Maximum Principal stress distribution near weld zone and HAZ.....	61
Fig 60: Thermal strain distribution.....	61
Fig 61: Thermal strain distribution near weld zone and HAZ.....	62
Fig 62: Plastic dissipation energy near weld zone and HAZ.....	62
Fig 63: Heat flux distribution near weld zone and HAZ.....	63
Fig 64: Heat flux distribution near weld zone and HAZ with free cut.....	63
Fig 65: Temperature distribution near weld zone and HAZ.....	64
Fig 66: Experimentally calculated temperature data for Al 6061 work-piece at a distance of 2mm from weld interface.....	73
Fig 67: Comparison of upsetting length.....	74

LIST OF GRAPHS

Graph Number	Page Number
GRAPH 1: Heat flux distribution on mesh elements at weld zone and HAZ.....	65
GRAPH 2: Temperature distribution at weld zone with respect to time.....	65
GRAPH 3: Temperature distribution at HAZ of Mild steel with respect to time.....	66
GRAPH 4: Temperature distribution at HAZ of Al 6061 with respect to time.....	67
GRAPH 5: Heat flux distribution at weld zone with respect to time.....	67
GRAPH 6: Von-Mises stress distribution at weld zone with respect to time.....	68
GRAPH 7: Tresca stress distribution at weld zone with respect to time.....	68
GRAPH 8: Max. Principle stress distribution at weld zone with respect to time.....	69
GRAPH 9: Elastic strain distribution at weld zone with respect to time.....	69
GRAPH 10: Logarithmic strain distribution at weld zone with respect to time.....	70
GRAPH 11: Plastic strain distribution at weld zone with respect to time.....	70
GRAPH 12: Strain energy distribution at weld zone with respect to time.....	71
GRAPH 12: Frictional energy distribution of work-piece with respect to time.....	71