



**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**OPTIMIZATION PARAMETER AND MECHANICAL  
PROPERTIES FOR ALUMINIUM 5052 – H32 BY MULTI -  
PASSES BUTT JOINT USING FRICTION STIR WELDING**

This report is submitted in accordance with the requirement of the Universiti  
Teknikal Malaysia Melaka (UTeM) for the Bachelor of Manufacturing Engineering  
Technology (Process and Technology) with Honours

by

**RIDUAN BIN HAIRUS SALEH**

**B071410038**

**910917-05-5453**

FACULTY OF ENGINEERING TECHNOLOGY

2017

## DECLARATION

I hereby, declared this report entitled Optimization Parameter and Mechanical Properties for Aluminium 5052 – H32 By Multi – Passes Butt Joint Using Friction Stir Welding is the results of my own research except as cited in references.

**Signature** : .....

**Name** : **RIDUAN BIN HAIRUS SALEH**

**Date** : .....

## **APPROVAL**

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering Technology (Process and Technology) with Honours. The member of the supervisory is as follow:

.....

(EN MOHD HAIRIZAL BIN OSMAN)

## **ABSTRACT**

This report is the result of an experiment to investigate the tensile strength of the welding joint. By using Fiction Stir Welding Machine to optimize the setting of welding parameter spindle speed (rpm) and weld rate (mm/s) on tensile strength of welding joint of Aluminium 5052 – H32 as a workpiece material. In the main, welding parameter will be influenced the result of tensile strength of welding joint. The design of experiment (DOE) by using Taguchi and ANOVA Method was created, the signal to noise ratio (S/N) was used to study the welding parameter effect to tensile strength of the welding joint (welding bead).

## **ABSTRAK**

Laporan ini adalah hasil daripada eksperimen untuk mengenal pasti kekuatan tegangan pada sambungan kimpalan. Dengan menggunakan mesin kimpalan geseran untuk mengoptimumkan penetapan pada parameter kelajuan pengumbar (rpm) dan pergerakan kimpalan (mm/s) pada bahan aluminium 5052 – H32 untuk menganalisis kekuatan tegangan pada sambungan kimpalan ini sebagai bahan kerja ujikaji. Kebiasaanya, parameter kimpalan ini akan mempengaruhi keputusan kekuatan tegangan pada sambungan kimpalan. Oleh itu, dengan penggunaan Kaedah Taguchi dan ANOVA dapat mencorak rekabentuk eksperimen (DOE) untuk menilai nisbah isyarat – hingar (S/N) digunakan untuk mengkaji atau analisis kesan parameter kimpalan terhadap kekuatan tegangan pada kawasan sambungan bahan yang dikimpal.

## **DEDICATIONS**

I dedicate my dissertation work to my family and all my friends, A special feeling of gratitude to my loving parents, Asmahniar Binti Sarrah and Hairus Saleh Bin Omar whose word of encouragement and always give positive vibes whenever me in depress. I also dedicate my dissertation to all my friends that support and contributed some of the ideas for this research. Thank you for everything.

## ACKNOWLEDGEMENT

Bismillahirrahmanirrahim,

I would like to express my appreciation to Allah S.W.T. for giving me grace, love and blessing, to help me to pursue my ambition up to this point of my life.

First of all, I would like to take this opportunity to express my gratitude to Sir Mohd Hairizal Bin Osman for fully support, guidance and encouragement throughout my study and research towards the completion of the project. My thesis will be become a frustrating and disappointed without his patience and timely wisdom in the period develops this project. In addition, I would like to express my appreciation to Puan NoorIrinah Binti Omar that willing to accept as the co-supervisor.

My appreciation also goes to my sincerely associate of my faculties technician, Sir Basri Bin Bidin, Sir Fakhrulnaim Bin Ibrahim and Sir Azizul Ikhwan Bin Mohd who always gave me conceptual understanding and clarify of comprehension, which ultimately made my job easier. The continuous support has given me the strength and confidence to complete the project without any difficulty.

At the same time, thanks also goes to my fellow friends in Faculty of Engineering Technology (FTK) at University Teknikal Malaysia Melaka (UTeM). Last but not least, I also would like to express my exceptional thanks to my beloved parents for their support and unending prayers and helps me directly or indirectly in successful finishing of my final year project.

# TABLE OF CONTENTS

<b>DECLARATION</b>	<b>i</b>
<b>APPROVAL</b>	<b>ii</b>
<b>ABSTRACT</b>	<b>iii</b>
<b>ABSTRAK</b>	<b>iv</b>
<b>DEDICATIONS</b>	<b>v</b>
<b>ACKNOWLEDGEMENT</b>	<b>vi</b>
<b>TABLE OF CONTENTS</b>	<b>vii</b>
<b>LIST OF TABLES</b>	<b>x</b>
<b>LIST OF FIGURES</b>	<b>xi</b>
<b>LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE</b>	<b>xiv</b>
<b>CHAPTER 1</b>	<b>1</b>
<b>INTRODUCTION</b>	<b>1</b>
1.1 Background of the study	1
1.2 Problem Statement	2
1.3 Objectives	3
1.4 Scope	3
<b>CHAPTER 2</b>	<b>6</b>
<b>LITERATURE REVIEW</b>	<b>6</b>
2.1 Literature Review	6
2.1.1 Solid State Welding	6
2.1.2 Aluminium	23
2.1.3 Parameter	26
2.1.4 Type of Joint	28
	vii



2.1.5	Tool Friction Stir Welding	30
2.1.6	Minitab Software	33
2.1.7	Material Testing Tensile Test	49
<b>CHAPTER 3</b>		<b>58</b>
<b>METHODOLOGY</b>		<b>58</b>
3.1	Project Preparation	58
3.1.1	Friction Stir Welding	58
3.1.2	Laser Machine	60
3.1.3	Aluminium	62
3.2	Process Parameter	63
3.3	Prepare Work Piece	64
3.4	Mechanical Testing	65
3.4.1	Universal Tensile Test	65
3.5	Taguchi and ANOVA Method Analyses	73
3.6	Jig and Fixture	74
3.6.1	Jig Friction Stir	74
3.7	Tools Friction Stir	75
3.7.1	Friction Stir Tool	75
3.8	Flow Chart	76
3.8.1	Flow Chart Process for PSM 1	77
3.8.2	Flow Chart Process for PSM 2	78
3.9	Gantt Chart	79

<b>CHAPTER 4</b>	<b>80</b>
<b>RESULT AND DICUSSION</b>	<b>80</b>
4.0 Introduction	80
4.1 Result	80
4.2 Analyse data by using Taguchi	90
4.3 Analysis of Variance (ANOVA)	96
4.4 Comparison between Taguchi and ANOVA Rank	100
4.5 Confirmation Test	101
<b>CHAPTER 5</b>	<b>103</b>
<b>CONCLUSION &amp; FUTURE WORK</b>	<b>103</b>
5.0 Introduction	103
5.1 Summary of Research	103
5.2 Achievement of Research Objective	104
5.3 Recommendation	105
<b>REFRENCES</b>	<b>106</b>
<b>APPENDICES</b>	<b>109</b>
APPENDIX A	109
APPENDIX B	110
APPENDIX C	111
APPENDIX D	113

## LIST OF TABLES

Table 1.1(a): Type of parameter	5
Table 1.1(b): Experimental layout using Taguchi Method	5
Table 2.1.3: Aluminium Table	25
Table 2.1.6(a): Level of Array (Level 9)	35
Table 2.1.6: Summary of ANOVA	47
Table 3.2: Parameter frictions stir welding	63
Table 3.5: Taguchi Experiment table	73
Table 3.9: Gantt chart of the Project	79
Table 4.2.2: Response Table of Signal to Noise Ratio (Larger is Better)	93
Table 4.2.3: Response Table for Means	93
Table 4.2.5: Predicted Value for the Best Parameter for Multi-Passes Friction Stir	95
Table 4.3.1: Data Analysis of Variance for SN Ratio	97
Table 4.3.2: Data Analysis of Variance Means	99
Table 4.4.1: Data parameter rank	100
Table 4.5.1: Data Actual and Predicted	102

## LIST OF FIGURES

Figure 1.1(a): Application Friction Stir Welding (Aerospace)	4
Figure 1.1(b): Application Friction Stir Welding (Automotive)	4
Figure 2.1(a): Three – stage mechanistic model of diffusion welding	8
Figure 2.1 (b): Plastic deformations through rolling	9
Figure 2.1.1(a): Forge welding	12
Figure 2.1.1(b): Cold welding process	14
Figure 2.1.1(c): Friction Stir Welding Process	16
Figure 2.1.1(d): Explosion welding	18
Figure 2.1.1(e): Diffusion welding	20
Figure 2.1.1(f): Ultrasonic welding	22
Figure 2.1.3: Bubble chart of Material selection ( CES Edupack )	24
Figure 2.1.4: Parameter	27
Figure 2.1.5(a): Butt joint	28
Figure 2.1.5 (b): Lap Joint	29
Figure 2.1.5(c): T - Joint	29
Figure 2.1.6(a): Tungsten friction stir tool	31
Figure 2.1.6(b): Steel shoulder	31
Figure 2.1.6(c): Bobbin tools	32

Figure 2.1.6(a): Level of Design	36
Figure 2.1.6(a): Level 4 Orthogonal Array Design	36
Figure 2.1.6(b): Level 9 Orthogonal Array Design	36
Figure 2.1.6(c): Level 16 Orthogonal Array Design	37
Figure 2.1.6(d): Level 9 Orthogonal Array Design	37
Figure 2.1.6 : Taguchi Method	42
Figure 2.1.7(a): Standard tensile test plate	51
Figure 2.1.7(b): Transverse tensile properties	53
Figure 2.1.7(c): HAZ minimum hardness	54
Figure 2.1.7(d): Advancing and retreating sides	55
Figure 2.1.7(e): Correlation strain maps near fracture load	57
Figure 3.1.1: Friction Stir Welding	59
Figure 3.1.2: Laser Machine	61
Figure 3.1.3: Aluminum 5052	62
Figure 3.3: Work pieces	64
Figure 3.4.1(a): Standard specification of sample dimension	66
Figure 3.4.2(b): Universal Tensile machine ( Instron 5669 )	67
Figure 3.4.1(c): Stress/Strain Diagram(O'Brien 1989)	69
Figure 3.4.1(d): Schematic stress – strain diagram	71
Figure 3.4.1(f) Geometry of tensile specimen	72
Figure 3.6.1: Jig at Flamefast machine	74

Figure 3.7.1: Friction Stir tools at Flamefast Machine	75
Figure 3.7: Flow chart of the process	76
Figure 4.1.1: Ultimate Tensile Strength Data Obtained for Trial 1	81
Figure 4.1.2: Ultimate Tensile Strength Data Obtained for Trial 2	82
Figure 4.1.3: Ultimate Tensile Strength Data Obtained for Trial 3	83
Figure 4.1.4: Ultimate Tensile Strength Data Obtained for Trial 4	84
Figure 4.1.5: Ultimate Tensile Strength Data Obtained for Trial 5	85
Figure 4.1.6: Ultimate Tensile Strength Data Obtained for Trial 6	86
Figure 4.1.7: Ultimate Tensile Strength Data Obtained for Trial 7	87
Figure 4.1.8: Ultimate Tensile Strength Data Obtained for Trial 8	88
Figure 4.1.9: Ultimate Tensile Strength Data Obtained for Trial 9	89
Figure 4.2: Tensile test result by Microsoft Excel	90
Figure 4.2.1: Data Obtained from the Friction Stir Parameter	91
Figure 4.2.2: Formula of Signal to Noise Ratio	92
Figure 4.2.4: Graph for Main Effect Plot for SN Ratio and Means	94
Figure 4.3.1: Taguchi data by using for ANOVA analysis method	96
Figure 4.3.2: Main Effect Plot for SN Ratio Signal to Noise (Larger is better)	98
Figure 4.3.3: Main Effect Plot for Means	99
Figure 4.4.1: Taguchi VS ANOVA	100
Figure 4.5.1: Predicted Value	101
Figure 4.5.2: Confirmation Test Data	102

## **LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE**

ANOVA	-	Analysis of variance
Al	-	Aluminium
FSW	-	Friction Stir Welding
FOW	-	Forge welding
CW	-	Cold welding
EXW	-	Explosive welding
DFW	-	Diffusion welding
rpm	-	Rotation per minute
OA	-	Orthogonal Arrays
DoE	-	Design of experiment
S/N	-	Signal-to-Noise ratios
AISI	-	America Iron and Steel Institute
ASTM	-	American Standard Testing and Material
UTS	-	Ultimate Tensile Strength
HAZ	-	Heat affected zone
TMAZ	-	Thermo mechanical affected

F	-	F test (ANOVA)
P	-	P test (ANOVA)
Adj SS	-	Adjusted Sum of sequences (ANOVA)
Adj MS	-	Adjusted Mean of sequences (ANOVA)



# CHAPTER 1

## INTRODUCTION

This chapter will be explaining the overview of the experiment study of friction stir welding similar join for multi - passes. This chapter includes the background, objective, scope, and problem statement to achieve study is going to be conducted.

### 1.1 Background of the study

In industry now a day, material use for fabrication of automotive part, aerospace, ship building and fabrication is aluminum 3, 5, 6 and 7 series of materials. These materials basically use fabrication of oil tank, rim wheel, marine building body and bracket aerospace and etc. This application of material normally use because this type of material have good mechanical properties, good for fabrication, light weight and anti-corrosion.

However, Minitab 15 software has many type of method for research application. In this experiment study, use two methods at Minitab 15 software is Taguchi and ANOVA to analyze and determine the optimization of parameter at friction stir welding process the output. The Orthogonal Array (OA), Signal to Noise (SN) ratio, predicted value and analysis of Variance applied for the data analysis respectively.

In this experiment, used the flamefast friction stir welding to analysis the process of experiment for multi – passes joining process, the material use in this experiment is material aluminum 5052-H3 for multi-passes joining. From this research and development for multi-passes joining to measure or identify the strength of mechanical properties, to analyze the significant value of parameter using the Taguchi Method and ANOVA to measure the significant parameter of multi – passes based on two type of parameter friction stir welding is Spindle Speed (rpm) and Weld Rate (mm/s). In this experiment for analysis the tensile strength of joining using the Universal Tensile Test Machine INSTRON 5669 to measure the strength of multi-passes joining. Tensile test it also known as tension test is probably the most fundamental type of mechanical test that can be performing on welding part to see the strength of welding area. Tensile test are simple, relatively, inexpensive, and fully standardized. By pulling on something, you will very quickly determine how the material will react to forces being applied in tension.

## **1.2 Problem Statement**

In the friction stir welding is one of the important factors the effect the welding strength. These frictions stir parameter consists such as spindle speed (rpm) weld rate (mm/s) and plunge depth. The microstructure can be analysis such as the defect into the zone of friction stir welding is stir zone (welding bead), flow arm zone, thermo – mechanical affected zone (TMAZ) and heat- affected zone (HAZ). The analysis of the mechanical testing all specimens tested, using Universal Tensile Test Machine. By using the Taguchi and ANOVA Method, we are going to achieve the optimize parameter friction stir welding for aluminum 5052 using two variables of parameter at three level. The result from the tensile test will be determined the best parameter or significant value parameter will be presented using Taguchi and ANOVA Method.

### 1.3 Objectives

The general objective of this project is to:-

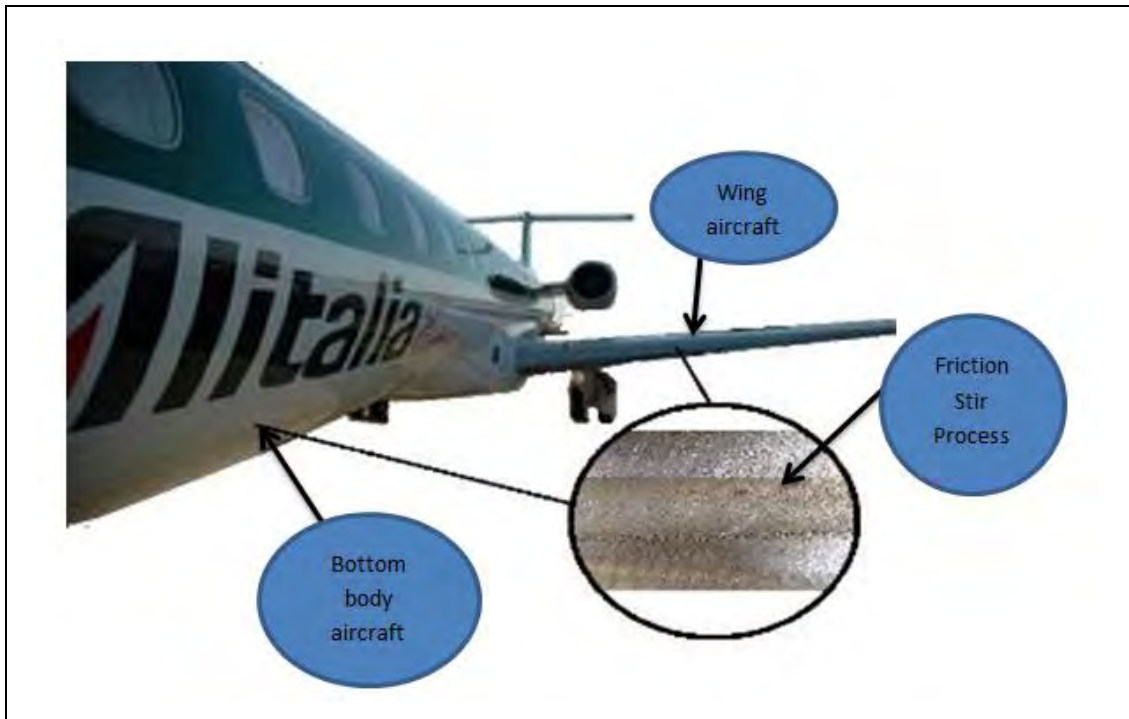
- I. To optimize parameter of multi passes for friction stir welding.
- II. To identify the welding strength factor of mechanical properties for multi – passes friction stir welding.
- III. To determine the most significant level of parameter using the Taguchi and ANOVA method

### 1.4 Scope

In this research, things included and limitation of parameter for Multi – Passes for Friction Stir Welding will discussed. The area of study is optimal parameter and mechanical properties for tensile strength. The machine that will be used is Flamefast Friction Stir Welding. This is due to easy preparation of the machine. This machine also can do different parameter for spindle speed (rpm) and weld rate (mm/s) kind of process that we will use when running the experiment. The process that will involve in this experiment is parameter of Multi - Passes. These processes will use the same friction stir tool, the same parameter and same material. At the end of the process, the result of the Multi – Passes Friction Stir Welding Butt Joint that are being used in this research.

After finish the Multi – Passes process welding, the part will be examined on the tensile test of the specimen. The tensile tester will be used to determine the value of the strength of joining. Then the part will be compared the data using the Taguchi and ANOVA to determine the best parameter and Rank of parameter Multi – Passes Friction Stir Welding using the Minitab software.

The material that will be used in the experiment is aluminium 5052 – H32. These materials will undergo the machining process under parameter that has been set. This research will only focus the two main things that are tensile strength and significant parameter.



**Figure 1.1(a): Application Friction Stir Welding (Aerospace)**



**Figure 1.1(b): Application Friction Stir Welding (Automotive)**

**Table 1.1(a): Type of parameter**

PARAMETER	LEVEL			OBSERVED VALUE (Mpa)
Spindle speed (rpm)	800	900	1200	Tensile Strength
Weld Rate (mm/s)	5.0	7.0	9.0	

**Table 1.1(b): Experimental layout using Taguchi Method**

No	Spindle speed (rpm)	Weld rate (mm/s)	Tensile specimen				
			T1	T2	T3	T4	T5
1	800	5.0					
2	900	7.0					
3	1200	9.0					
4	800	5.0					
5	900	7.0					
6	1200	9.0					
7	800	5.0					
8	900	7.0					
9	1200	9.0					

## **CHAPTER 2**

### **LITERATURE REVIEW**

In this chapter, we will discuss literature review of this project. A literature review is based on searching, collecting, analyze, studying and write the conclusion from all debates and issues raised in the relevant body of the literature. In this project literature review will be focusing on the research of various theory and basic knowledge that are related to the friction stir welding joining. The relevant case study will be providing on this chapter as previous research are to be determined and compared with the similar.

The similar material joining part is yet to be determined after several studies on other related researches. The purpose of this chapter is, review the best type of the similar material joint for friction stir for the aluminum 5052.

#### **2.1 Literature Review**

##### **2.1.1 Solid State Welding**

In solid state welding have many type of the joining processes, type in the solid state welding is brazing, soldering, adhesive and mechanical fastening. These solid states welding commonly apply in industry aerospace, automotive, shipping build and rail.

For solid state welding three types is chemical, electrical and mechanical. For mechanical has type of welding is forge, cold, roll, hot pressure, diffusion, friction,

friction stir, and ultrasonic, this all type for solid state is joint takes place without fusion welding at the interface of the two parts to be welded, this process no liquid or molten phase is present in the joint. The processes are automated by using robotics, vision systems, sensors, and adaptive computer controls for the cost reduction, consistency, reliability of weld quality, and higher productivity. This solid state welding involves one or more phenomena are diffusion, pressure and relative interfacial movements.

Diffusion is the transfer of atoms across an interface causing diffusion bonding will be apply external heat improves strength of the bond between the two surfaces being joined, this heat may be generated internally by friction, electrical resistance heating and externally by induction heating. Solid state welding is a welding process in which two work pieces are joined under pressure providing an intimate contact between them and intimate contact between them and at a temperature essentially below the melting point of the parent material.

The advantages of solid state welding:

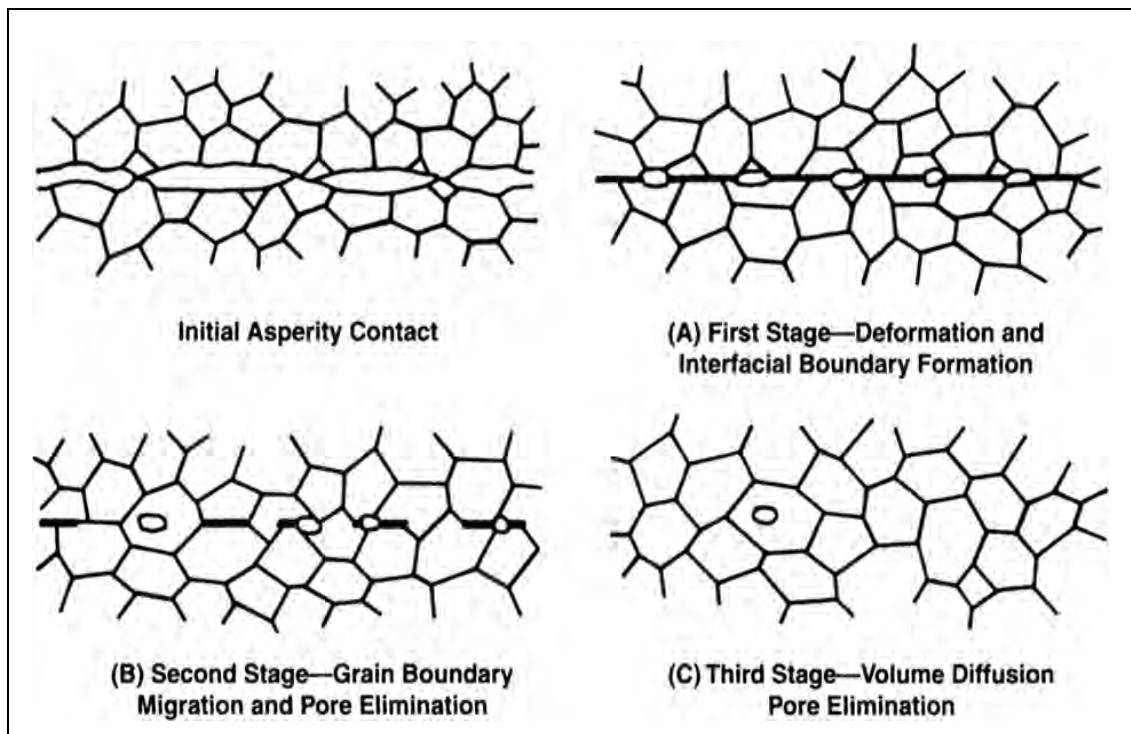
- Weld bonding is free from microstructure defect.
- Mechanical properties of the weld are similar to those of the parent metal.
- No consumable materials are required.
- Dissimilar metal may be joined.

The disadvantages of solid state welding

- Expensive equipment.

This solid state welding have 6 type of solid state welding is:

- Forge welding (FOW)
- Cold welding (CW)
- Friction Stir welding (FSW)
- Explosive welding (EXW)
- Diffusion welding (DFW)
- Ultrasonic welding (USW)



**Figure 2.1(a): Three – stage mechanistic model of diffusion welding**

**Adapted from: [thermalscieneapplication.com](http://thermalscieneapplication.com)**