CERTIFICATION OF APPROVAL

Carbon Nanotube Reinforced Aluminium Matrix Produced by Friction Stir Processing

by

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A project dissertation submitted to the

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Approved by,

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(Dr. Mokhtar Bin Awang)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

May 2013

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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NOR FAKHRUL BIN MOHD NOOR

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ABSTRACT

Friction Stir Processing (FSP) is the technique derived from the Friction Stir Welding (FSW) that has been introduced since in 1991. Many researchers developed new Metal Matrix Composite (MMC) in order to enhance the mechanical and physical properties of the base material. The base material also known as matrix functions to spread the force applied over the surface and to protect the structure of the reinforcement. In this study, the MMC is form compose of Carbon Nanotube as the reinforcement material and Aluminium as the matrix by FSP technique. Many studies have been carried out by the scientist and researches about the MMC produced by FSP with different reinforcement and matrix materials. So, the main objective of this study is to analyse the effect of Carbon Nanotube as the reinforcement material of the Aluminium Matrix Composite in term of tensile strength. There are several major steps done in order to complete the study. Firstly, Carbon Nanotube reinforced Aluminium Matrix Composite is produced by using the CNC Bridgeport Machine. Secondly, cut the MMC produced into the dogbone shape for the tensile test by using the EDM Wire-Cut Machine and lastly, test the samples for the tensile strength by using the Ultimate Tensile Machine thus analyse the results. The results show that the Carbon Nanotube give effect for the Aluminium Matrix Composite as the tensile strength of the MMC are decreased from the base material, Aluminium. But the ductility MMC is improved compared to the base material. Lastly, this study will give good contribution for the material and manufacturing study.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Metal Matrix Composite (MMC) is the combination of the two or more types of metal in order to enhance the properties such as strength, stiffness and elastic modulus. Therefore, in this study the Aluminium plate as the base material was combined with Carbon Nanotubes as the reinforcement material by using Friction Stir Processing (FSP) technique in order to produce a unique MMC. The Carbon Nanotubes Aluminium Matrix Composite then tested and analysed its mechanical properties which is the tensile strength.

A Carbon Nanotube is discovered in 1991 by Lijima, is a tube shaped material made of carbon molecules, which sizes about one ten-thousandth of the human hair and as it named ‘Nano’ means that the size of the particle is between 1 to 100nm. A Carbon Nanotube is likely as a sheet of graphite bonded together and rolled into a cylindrical shape and districtive hexagonal latticework making up the sheet. Figure 1 shows the shape of the Carbon Nanotube.

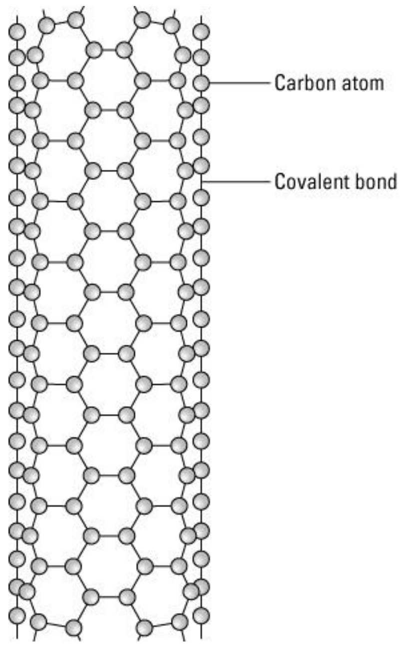
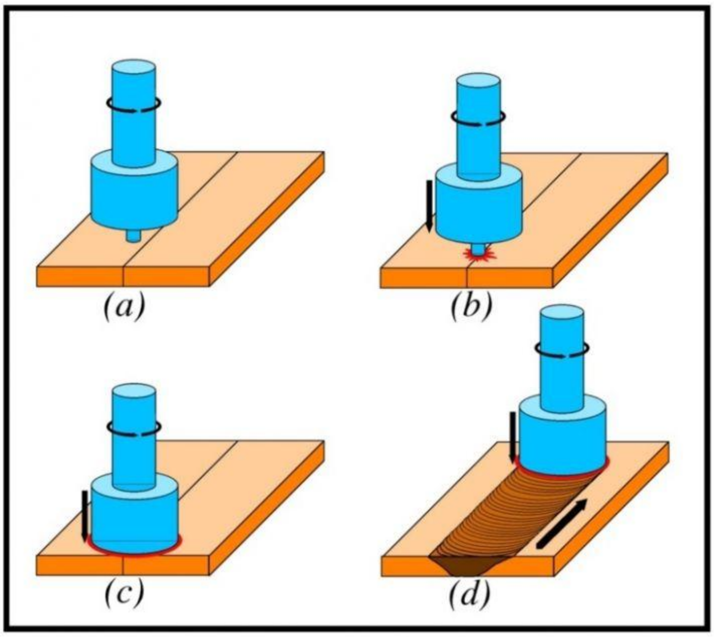


Figure 1: A Carbon Nanotube

Nowadays due to the incredible mechanical and physical properties, Carbon Nanotube are commercially used in electronic packaging industry, automobile industry, sports industry, space applications, and aerospace industry. Other than that, the MMC of Carbon Nanotube is widely used as catalysts and sensors. [3]

FSP is joining technology introduced in 1991 by The Welding Institute (TWI) at United Kingdom. The FSP is very effective in order to produce the MMC especially for Aluminium alloy. The two material; Aluminium-based and reinforcement will be composed by plunging the spinning tools into the joint of both material and then the rotating tools will be transverse along the interface. Figure 2 shows sequence of the FSP.



(a) Unconsumable welding tool rotates, (b) frictional heat is generated by contact between probe of the rotating tool and workpiece, (c) the probe is plunged into the workpiece, and (d) the rotating tool moves along the butt line of the workpiece.

Figure 2: The sequence of the FSP

The concepts of the FSP are low amount of heat generated, extensive plastic flow of the materials, and very fine grain size in the stirred region, healing of flaws and casting porosity, random misorientation of grain boundaries in the stirred region, and mechanical mixing of the surface and subsurface layers of the sample. [6]

FSP can produce fine-grained micorstructure through the thickness to impart the superplasticity. Superplasticity is the ability of a metallic material to exhibit more the 200% of uniform tensile elongation. Thus, the FSP can contribute the good mechanical properties; tensile and fatique strength to the composite if compared to fusion welded processes. [6]

In FSP, the common issues like porosity, solute redistribution, solidification cracking and liquation cracking not arise as it is dealing with solid state deformation involving dynamic recrystallation of the base material.

Furthermore, due to the superplasticity performed by FSP, the technique also has been used for MMC, homogenization of powder metallurgy aluminium alloys, cast aluminium alloys, and fabrication of a surface composite on aluminium substrate.

FSP provides much of advantages in the processing technique to produce the composite:

i) The technique is used short-route, solid-state processing which achieve microstructural refinement, homogeneity and densification.
ii) Accuracy controlled by optimizing the tool design, FSP parameters, and active cooling can increase the microstructure and mechanical properties of the processed zone.
iii) The flexible length of tools and pin can process the the sample in the depth of several hundread micrometers and tens of millimeters which this condition difficult to achieve by other metalworking technique such as fusion welding.
iv) The FSP suitable for fabrication, processing, and synthesis of materials as the techique is versatile with comprehensive function.
v) FSP is environmental clean and energy efficient technique compared to conventional welding as it is not emits deleterious gas, eradiation and noise because the technique comes from friction and plastic deformation.
vi) Result of the FSP; the shape and size of the sample will not change as only the microstructure and grain at the processed zone area affected.

Due to great advantages of FSP technique, nowadays the technique commercially used in the industries for example, shipbuilding and offshore structure, aerospace body and component fabrication, engine tunnel for automotive manufacturing field, railway rolling stock, personal computers, and fabrication of the vessels.

Therefore, by using the special design tools or pin for the FSP, the technology is suitable in develop the Carbon Nanotube reinforced Aluminium-based Composite because the process not involved the gases and melting metals like traditional welding method which can destroy the engineered microstructure of composites thereby destroy or damage its unique properties. Instead, the joint of composite is formed by plastic deformation of the pieces of both materials. [1]

1.2 PROBLEM STATEMENT

Aluminium as the base material combine with different particles as the reinforcement produced by FSP technique gives different effect in tensile strength. The tensile strength of the Silicon Carbide (SiC) and Graphite (Gr) Aluminium Matrix Composite are lower than the base material, which is Aluminium.[8] Whereas the results from the Magnesium (Mg) and Silicon (Si) as the reinforcement which produced by the same tehnique, have improved the tensile strength. Thus, this study is to analyse the effect of the Carbon Nanotubes to the Aluminium as the base material in term of tensile strength. [9]

1.3 OBJECTIVES

- To study the effect of Carbon Nanotube Reinforced Aluminium (Al1100) Matrix Composite on its strength.

1.4 SCOPE OF STUDY

This study is focusing on:

i. Carbon Nanotube as the reinforcement material for the MMC,
ii. Friction Stir Processing (FSP) as the technique to produced the MMC
iii. Tensile test of the MMC produced by the FSP by comparing the results to the base material which is Aluminium Al-1100

CHAPTER 2

LITERATURE REVIEW

2.1 MMC PRODUCED BY FSP

Since the FSW developed in 1991 which is the enhancement from Friction Stir Welding, many researches have done the study and experiment focussing on the MMC, Aluminium as the base material whereby the fibers and particles as the reinforcement material. The MMC produced then analysed for mechanical properties and physical properties. The researches found that the different reinforcement give different effect as compared to the properties of the base material.

Firstly, the research by Z.Y MA in 2008 for the Copper (Cu) reinforced with Aluminium Matrix has shows great ultra-fined-grained structure which increased the hardness and the compressive strength of the composite. Other than that, Titanium (Ti) reinforced Aluminium Matrix produced by FSP shows that the composite give good result in tensile strength, which increased from the origin base material but reduced in term of ductility. [6]

Whereas, the research carried by Devaraju et al. [8], in 2012 mostly focus on the Silicon Carbide (SiC) and Graphite (Gr) as the reinforcement to the Aluminium as the matrix produced using the FSP shows the tensile strength of the composite is lower than base material. The experiment is focused on the effect of the rotational speed of the FSP tools and wear properties of the material in order to determine the optimum parameters for developing the MMC. The study shows that the brittle material affects the composite's ductility which decreased from the base material (Aluminium).

There are many patterns of findings towards the mechanical properties especially the tensile test of the MMC produced by the FSP. Mostly, the findings more on the improvement for the MMC compare to the base material.

For example, the article by Mohsen et al. [11], discussed about the optimum parameters of the FSP for Copper as the base material reinforced by the SiC particle in order to enhance the mechanical properties. The copper used not as the two separate plates but at the single plate, the groove shape at the middle of the plates are designed to place the SiC particles. The results for the study show that the Yield Strength of the FSPed with SiC particles is 95 MPa whereas the FSPed without the SiC particle is 73 MPa. The Ultimate Strength for the FSPed with SiC particles is 164 MPa, but the FSPed without is 175 MPa, which more than the reinforced specimen.

Other than that, the study carried in 2009 by Liming et al. [10], shows that the ultimate strength of the Aluminium Nickel composite (144MPa) produced by the FSP is higher than the base material, Aluminium (84 MPa). The results from the stress-strain graph proved that the presence of the reinforcement improved the strength of the composite produced by the FSP.

CHAPTER 3

METHODOLOGY

3.1 PROJECT WORK

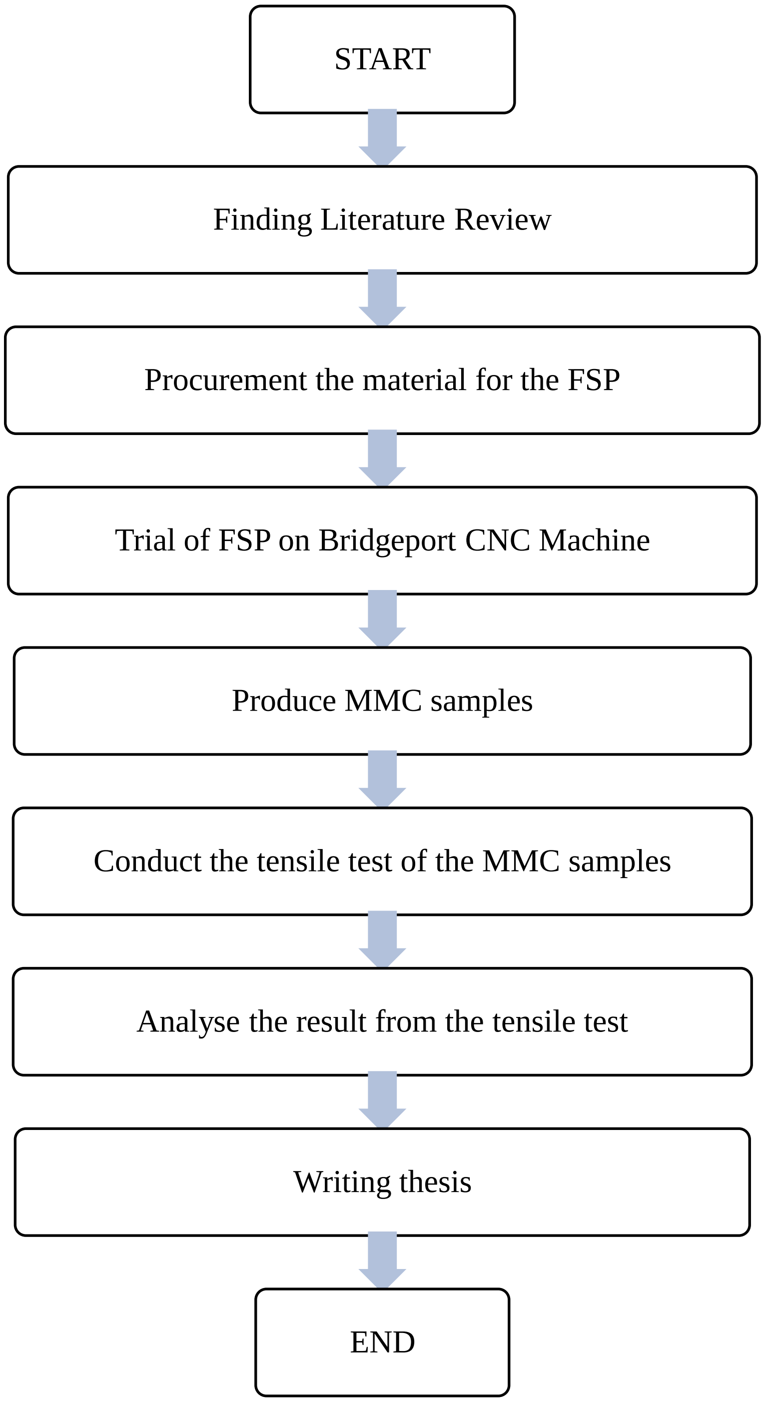


Figure 3: Flow Chart for the Project Work

Project work started with finding the literature review related to the project which is the effect of different reinforcement material for MMC produced by FSP on its tensile strength. Next, procument of the material for the FSP is done by ordering Aluminium (Al-1100) as the base material from the supplier. The trial of FSP is done by using the CNC Bridgeport Machine and the base material used is Aluminium (Al-6061). The purpose of the trial experiment of the FSP is to observe the physically change of the base material after reinforced with the Carbon Nanotube. Then, samples of the MMC are produced by using the same machine but different base material which is Aluminium (Al-1100) and parameters. The samples produced then trimmed into the dogbone shape by using the EDM Wire-Cut Machine to test for the tensile strength. The results from the tensile test then analysed in order to study the effect of Carbon Nanotube reinforced Aluminium matrix produced by FSP compared to the tensile strength of the base material. Finally, all the informations, procedures, and results of this project are documented in the thesis.

3.2 RESEARCH METHODOLOGY

The literature review is done in order to gain information, knowledge and items regarding to the project. The sources came from the handbook of Composite Material (Metal Matrix Compostie), FSP, Tensile test for the FSP samples, e-journal, and research article and selected scientific link.

The steps of research:

3.2.1 Prepare the FSP samples

The samples are produced by FSP technique using CNC Bridgeport Machine at Block N.

In order to produce the Carbon Nanotube Aluminium Matrix Composite, the jig and tool need to be prepared before start the experiment. The function of the jig is to clamp tightly the Aluminium plates and support the samples during the process when the tool is used to stir the joint of the material due to high form of vibration.

Table 1 shows the parameters of the experiment.

Table 1: The parameters used in the project

<table>
<tr><th>No</th><th>Label</th><th>Feedrate, mm/min</th><th>Spindle Speed, rpm</th><th>Tilting</th></tr>
<tr><td>1</td><td>50 mm/min</td><td>50</td><td>1200</td><td rowspan="3">2.25°</td></tr>
<tr><td>2</td><td>75 mm/min</td><td>75</td><td>1400</td></tr>
<tr><td>3</td><td>100 mm/min</td><td>100</td><td>1400</td></tr>
</table>

The experiment is conducted using different parameters in order to examine and analyse the different outcome and effect on the strength of MMC.

The steps of process the FSP using Bridgeport machine is as follows:

i) Four aluminium plates are joined as lap joint and placed inside the prepared jig. Figure 4 shows the Aluminium plates and the jig.

Figure 4: The Aluminium plates placed inside the jig

ii) Carbon Nanotube then inserted into the gap of plates joint. The sample is then tightened up using the bolt and nuts at the jig.

iii) The jig then placed inside the Bridgeport CNC Milling machine and clamped to fix and stabilized tightly. Figure 5 shows the jig and Aluminium plates inside the CNC Bridgeport Machine before start the experiment.

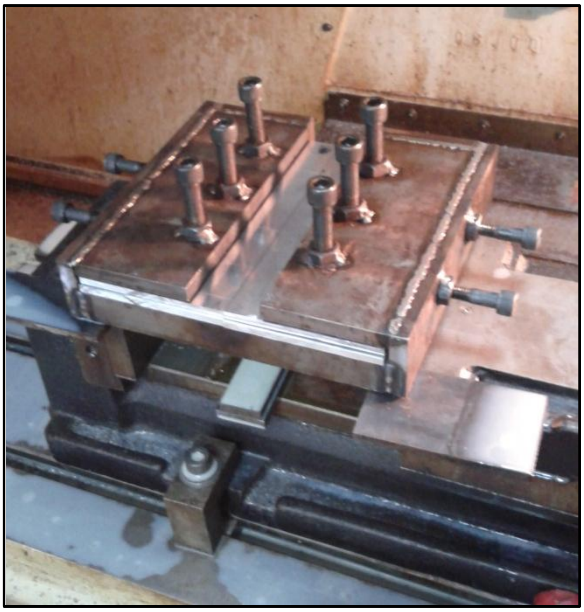


Figure 5: Jig and Aluminium plates inside the CNC Bridgeport Machine

iv) The parameters of the process is set up

v) The safety door will be closed as the process begins for the safety precautions. Figure 6 shows the FSP tool move in transverse direction.

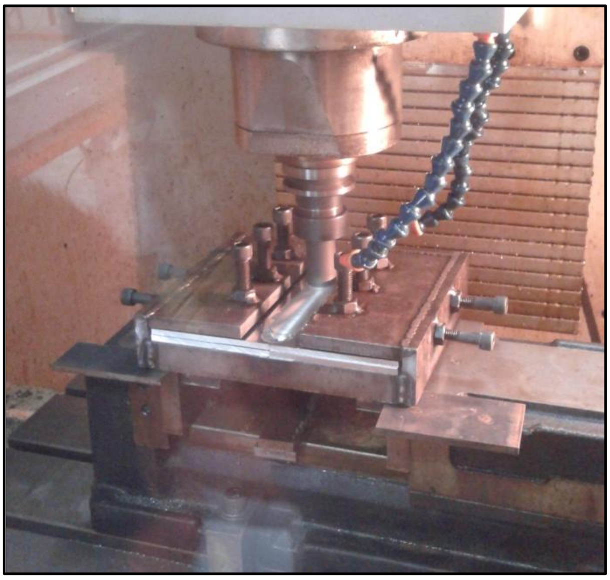


Figure 6: FSP in progress

After the experiment is finish, the sample will be cooled a few minutes before transfer out from the machine and trimmed the excess flashes. The sample and jig have to do the immediate cooling in order to prevent the sample stuck in the jig as the aluminium plates are expand during the process. Figure 7 shows workpiece in cooling process.

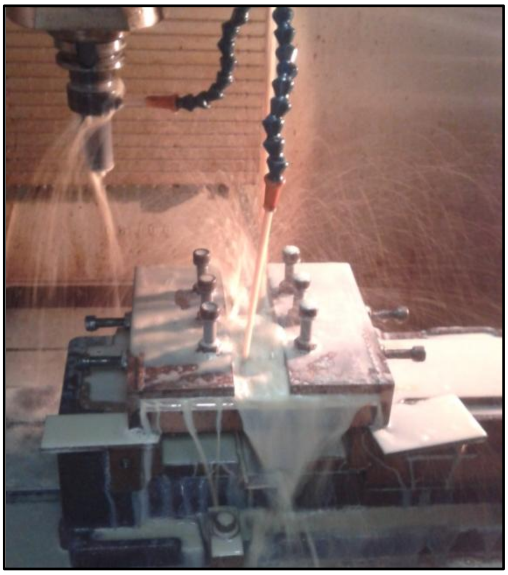


Figure 7: Cooling down process

3.2.2 Prepare the tensile test samples

MMC samples produced by the FSP then cut into the dogbone shape for the tensile test. The EDM Wire-Cut Machine which available at Block 16 is used to prepare the samples of the tensile test according to the American Society for Testing and Materials (ASTM) E8 which specifically used for the FSP samples.

The EDM Wire-Cut Machine is used for preparing the tensile test samples because:

1) The cutting process for the edges and the shape of the samples can be done in high precision.
2) The finishing of the product can be improved as the cutting process is not affect the surrounding area.
3) The cutting process can be done for the hard material and reduced the tolerances of the product.

Figure 8 shows the diagram of the dogbone shape from the workpiece to be cut by the EDM Wire-Cut Machine.

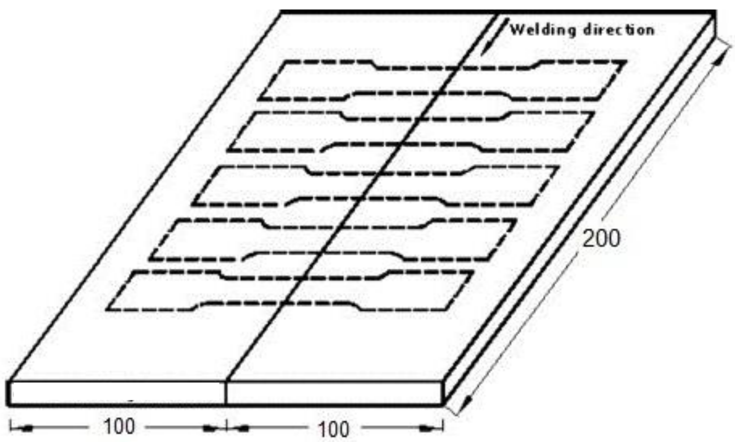


Figure 8: The diagram of the dogbone shape to be cut by EDM Wire-Cut Machine

The FSP samples are cutted into 5 pieces of the flat-type or dogbone shape for the tensile test referring to the ASTM E8 specification. The Welding direction is inversely to the shape of the tensile test samples as the joint to be at the middle of the samples so the cracking can be identify at the joint (stirred region).

Figure 9 shows the dimension of the dogbone shape for tensile test.

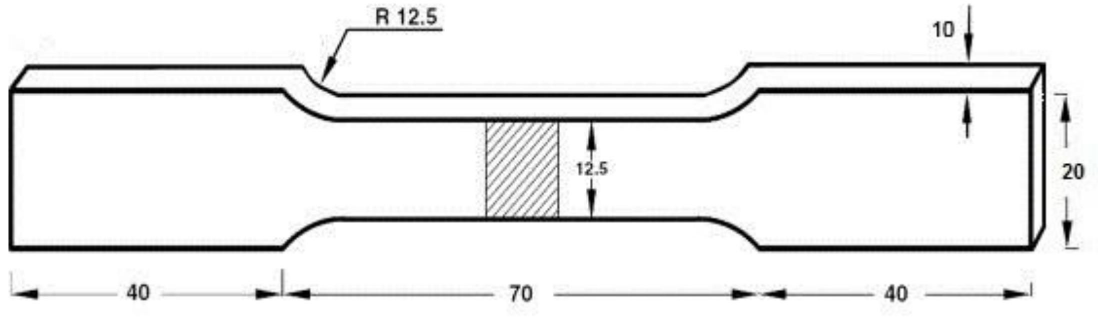


Figure 9: The Flat-type (Dogbone shape) for the tensile test.

The detail of the tensile test samples is cutted from the FSP plate is shown in the Figure 9. The specification of the shape dimension is referring from the ASTM E8 (Matellic Material), the FSP section.

3.2.3 Tensile Test the MMC

Next, tensile test of the FSP samples is conducted by using the UTM Machine (100 kN) which available at the Block 17. The standard method for conducting the Metallic Material especially for the FSP samples need to follow the standard prepared by the American Society of Testing and Material (ASTM) E8.

The detail specification of the samples dimension is shown in the Figure 9. Therefore, the various samples with different parameter is tested to determine its mechanical properties; tensile strength.

The speed of testing when determining the tensile strength in this experiment is 0.05 mm/mm/min. Results obtained from the experiment are Force (N) and Elongation (mm) then convert to the Stress (MPa) and Strain (mm/mm) by using the Excel.

3.3 GANTT CHART OF THE PROJECT

Table 2: Activities/Gantt Chart for the project

NO	DETAIL/WEEK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	Finding Literature Review																									
2	Determine the parameters of FSP																									
3	Procument & detail out the material needed for the FSP Trial																									
4	Trial run the FSP												●													
5	Procument the material for FSP samples																									
6	Gathering the information of tensile test for FSP samples																									
7	Begin the FSP experiment																					●				
8	Preparing the samples for the tensile test (EDM-Wire Cut)																									
9	Begin the tensile test																								●	
10	Analyzing the tensile test result																									

3.4 MILESTONE OF THE PROJECT

	Milestone	Date
1)	Completion of finding the Literature Review	21 June 2013
2)	Completion of procument the material for the FSP	14 June 2013
3)	Completion of trial of FSP on Bridgeport CNC Machine	10 April 2013
4)	Completion of producing MMC samples	2 July 2013
5)	Completion conducting the tensile test of the MMC samples	30 July 2013
6)	Completion of analyzing the result from the tensile test	31 July 2013
7)	Completion of writing the thesis	29 August 2013

3.4 MATERIAL FOR SAMPLE AND TOOLS

There are 2 types of the material to be used as the sample and 1 type of the material as the tool. Table 3 shows the material used for the FSP sample and tool.

Table 3: Material used for sample and tool

No.	Material	Quantity	Purpose
1	Aluminium Plate (Al1100) 	12	Matrix
2	Carbon Nanotubes 	-	Reinforcement
3	Stainless Steel 	1	FSP tool

Aluminium plate (Al1100) is used in this project because it relatively low strength, which good for formability, and weldability. Besides, it also has low chemical composition as shows in the Table 4 which provided by the supplier. Therefore, the Aluminium Al1100 is suitable to use as the matrix or based material in this project. Table 5 shows the mechanical properties of Al1100 provide by the supplier.

Table 4: Chemical composition of the Al1100

Grade	Chemical Composition %										
	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Other		Al
									Each	Total	
1100	0.95 max		0.05-0.2	0.05 max	-	-	0.1 max	-	0.05 max	0.15 max	99.00 min

Table 5: Mechanical properties of Al1100

Grade	Temper Grade	Tensile Test			
1100	H14	Thickness (mm)	Tensile Strength (N/mm²)	Proof Strength (N/mm²)	Elongation %
		0.2 or over, up to and incl. 0.3	120 min 145 max	-	1 min
		Over 0.3, up to and incl. 0.5		-	2 min
		Over 0.5, up to and incl. 0.8		-	3 min
		Over 0.8, up to and incl. 1.3		95 min	4 min
		Over 1.3, up to and incl. 2.9		95 min	5 min
		Over 2.9, up to and incl. 12		95 min	6 min

Size of the Aluminium plate used is 100mm x 200mm x 5mm. Thus, 4 plates are used for 1 FSP sample, in order to achieve the thickness of 10mm.

MWCNT Carbon Nanotube is used in this project as the reinforcement material. The quantity of the Carbon Nanotube used in the experiment is not measured because the project is focusing on the present of the Carbon Nanotube with different parameter of FSP.

The tool used for the FSP tool is from Stainless Steel because it can stand at high temperature and high pressure resistance in order to maintain its shape and transfer the constant torsion and rotation speeds to the Aluminium plate. Other than that, it also large availability in the market, ready to made the spear parts.

3.5 MACHINE AND TOOLS

Machine and tool used to produce and test the sample prepared by the MMC are show in Table 6.

Table 6: Machines and tool

No.	Item	Quantity	Purpose
1	Bridgeport CNC Milling Machine (Block N) 	1	Operate the FSP
2	EDM Wire-Cut Machine (Block 16) 	1	Cut the FSP samples into the flat-type sample for tensile test

Table 6: Machines and tool

No.	Item	Quantity	Purpose
3	Universal Tensile Machine (Block 17) 	1	Test the tensile strength of the samples
3	FSP tools 	1	Supply torsional force to the material

The CNC Bridgeport Machine is used in the project because its capability is suitable to do the FSP. If the workload from the FSP supply to the machine is more than the machine capability, the machine can stop immediately and the damage can occur to the tool's pin. Otherwise, the machine can change the different type of clamping tools with simple way and easy to change the FSP tools used in the experiment.

EDM Wire-Cut Machine functioned to cut the FSP samples into the dogbone shape for the tensile test. Although the machine take long time to process, but the machine can cut the samples in precisely thus not change the samples properties and damage the edges. The precise shape and dimension of the samples for tensile test is important because the internal crack, miscutting and mistolerances can affect the results.

FSP tools are prepared using CNC Lathe Machine available at Block N. Stainless Steel is used for the tools as the material can stand high torsional effect, temperature and wear resistance during operates the FSP, produce the Carbon Nanotube Tensile test.

CHAPTER 4

RESULT AND DISCUSSION

4.1 MMC PRODUCED BY THE FSP

4.1.1 1^{st} Experiment

The 1^{st} experiment has been conducted as for trial in FYP I using the Al-6061. The experiments are carried out with rotational speed of 1200 rpm, and the travelling speed of 30mm/min. Figure 10 shows the sample of the FSP trial experiment using Al-6061.

Figure 10: The sample of the FSP trial (Al-6061)

The sample shows the waving shape around the stirred region as the tools travelled in 2.25 degree. The smooth surface of the stirred region is formed. The sample than has been divided into several sections using the EDM Wire-Cut Machine to produce the precise edges. Figure 11 shows the samples from the trial experiment cutted by the EDM Wire-Cut Machine.

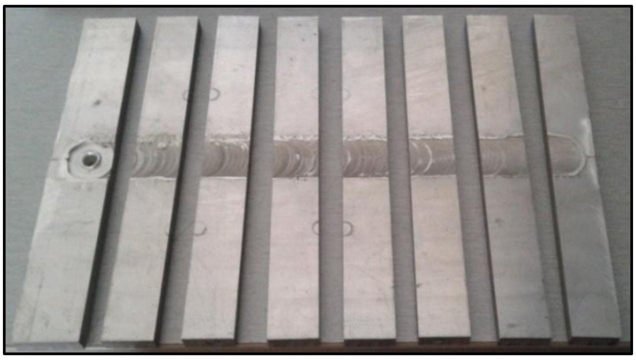


Figure 11: The FSP samples after cut by EDM Wire-Cut

4.1.2 2nd Experiment

The 2nd experiment is conducted by using the Al-1100 as it has low strength but excellent in formability, weldability and corrosion resistance which very much suitable to produce the MMC samples.

The workpiece is 100mm x 200mm x 5mm in dimension, thus the plate is clamped together in the jigs in order to produce the sample in 10mm thickness. The findings from the 2nd experiment are show in Table 7.

Table 7:The findings from the 2nd experiment

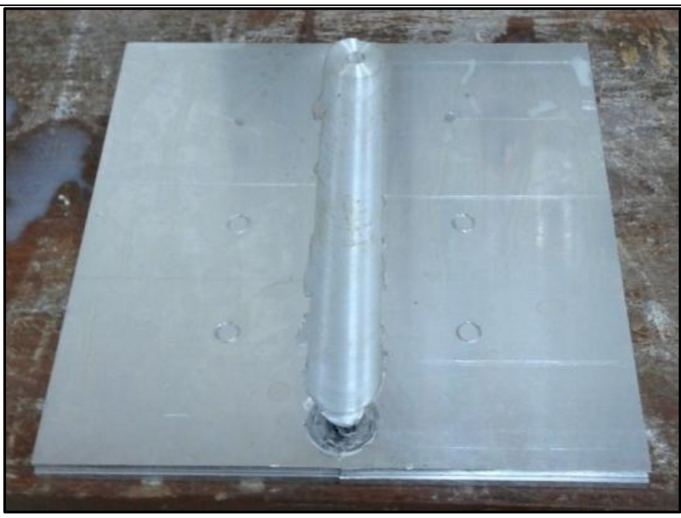
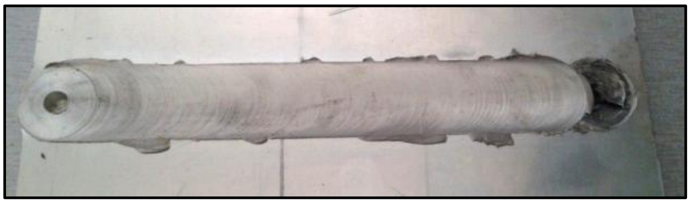
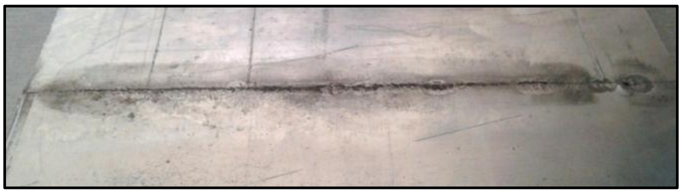
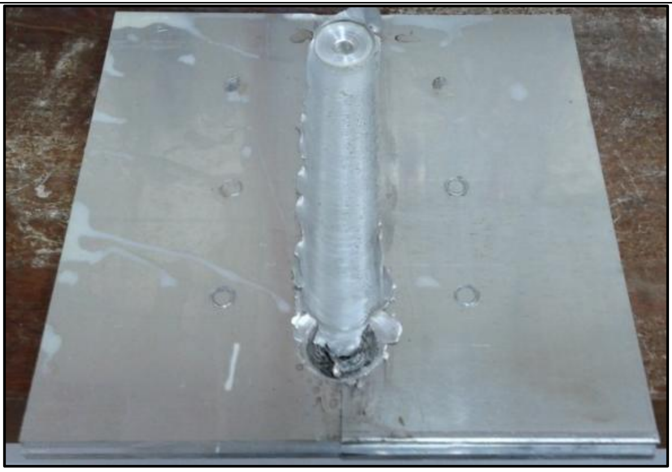
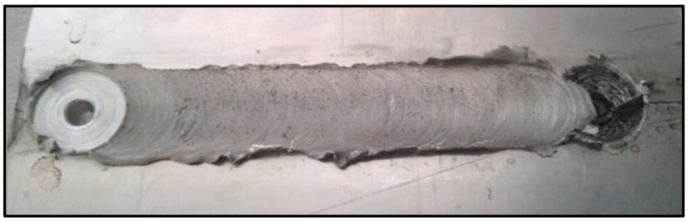
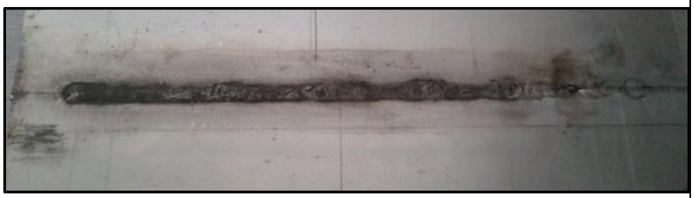
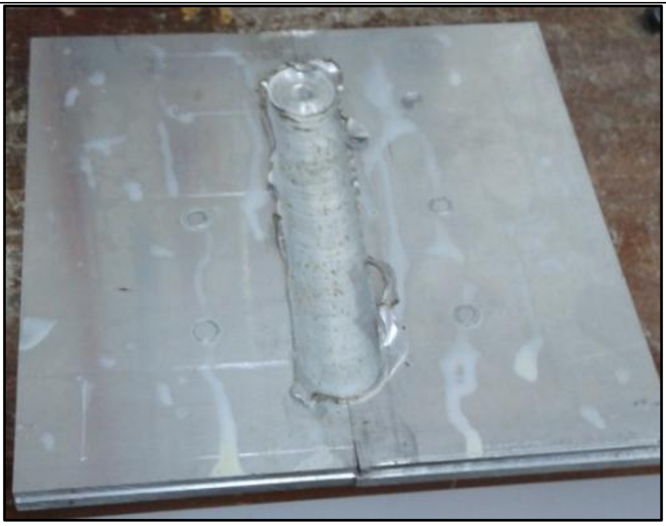
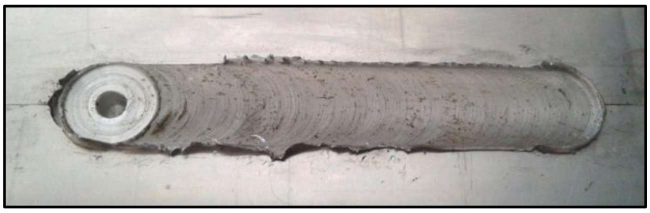
No	Samples	Description
1	 *The overview of 50 mm/min sample*  *The upper side surface of the stirred region*  *The lower side surface of the stirred region*	**Result:** **50 mm/min sample:** Feedrate: 50 mm/min Spindle speed: 1200 rpm **Condition:** -The stirred region in smooth surface -Less chip is produced on the outside layer of the stirred region

Table 7: The findings from 2nd experiment

2	 *The overview of the 75 mm/min sample*  *The upper side surface of the stirred region*  *The lower side surface of the stirred region*	**Result:** **75 mm/min sample:** Feedrate: 75 mm/min Spindle speed: 1400 rpm **Condition:** -Less smooth surface of the stirred region compare to the 50 mm/min sample -More chip developed outer layer of the stirred region

From the table 7, the surface condition of the 75 mm/min sample is rougher than 50 mm/min sample and more chips are developed at the outer layer of the stirred region compared to the 50 mm/min sample. From the observation, it is shown that the increase in the feedrate (in transverse direction) and spindle speed give effect to the surface condition. As the feedrate and the spindle speed increased, the heat produced due to friction between the tool and the workpiece also increased, the workpiece of the 75 mm/min sample melted more at the stirred region compared to the 50 mm/min and thus the surface condition of the 75 mm/min sample rougher than the 50 mm/min sample.

Table 7: The findings from 2nd experiment

3	 *The overview of the 100 min/min sample*  *The upper side surface of the stirred region*  *The lower side surface of the stirred region*	**Result:** **100 mm/min sample:** Feedrate: 100 mm/min Spindle speed: 1400 rpm **Condition:** -Rough surface of the stirred region -More chip developed at the outside layer of the stirred region as compare to the 75 mm/min sample

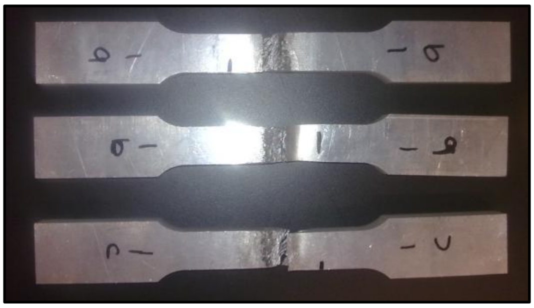
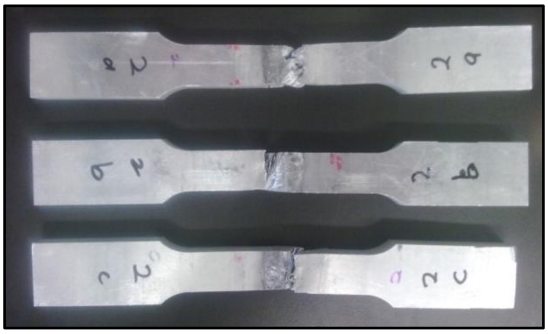
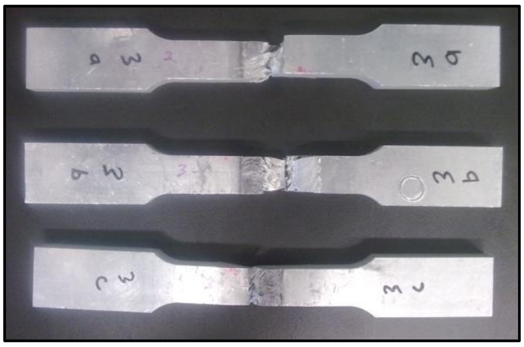
The parameters used in the experiments are based on the literature and the machine capabilities. The spindle speed and the feedrate are different between the samples in order to examine its effect in term of heat produced. Theoretically, the higher spindle speed and the feedrate will yield more heat to the frictioned surface and the microstructure of the samples.

Thus, more chips produced around the stirred region of the 100 mm/min sample and the surface become rough as the frictioned surface uniformly melt along the joint of the plates.

4.2 TENSILE TEST OF THE MMC PRODUCED BY FSP

The dogbone shape of the FSP samples then tested for the tensile strength. There are 5 samples in each plates and the test are carried out by the 3 samples based on the condition stirred region at the joint. The sample labeled 1A,2A,3A are at the initial point of the welding path, 1B,2B,3B re at the middle of the plate and 1C,2C,3C are at the end of the welding path on the respective plates. Table 8 shows the samples and description after tensile test.

Table 8: Samples after tensile test

No	Samples	Description
1	 *The samples from the 50 mm/min sample*	**50 mm/min sample:** Feedrate: 50 mm/min Spindle speed: 1200 rpm -The fracture from the 3 samples are occur at the stirred region
2	 *The samples from the 75 mm/min sample*	**75 mm/min sample:** Feedrate: 75 mm/min Spindle speed: 1400 rpm - For 2a and 2c, the fracture occur at edge of the stirred region
3	 *The samples from the 100 mm/min sample*	**100 mm/min sample:** Feedrate: 100 mm/min Spindle speed: 1400 rpm - For 3c, the fracture occur at edge of the stirred region

The condition of the samples after tensile tested are shown in Table 8. It is shown that the fracture occured at the stirred region for the 1A, 1B, 1C from 50 mm/min sample, 2B from 75 mm/min sample, 3A and 3C from the 100 mm/min sample. Whereas the fracture occured at the edges of the stirred region for 2A, 2C from 75 mm/min sample, and 3C from 100 mm/min sample. Figure 12 shows the fracture occured at one of the sample tested.

Figure 12: Fracture at one of the sample tested

Figure 13 shows the Stress vs Strain curve for various type of the metals [12]. From the graph, the tensile strength of the base material Aluminium (Al1100) is 180 MPa.

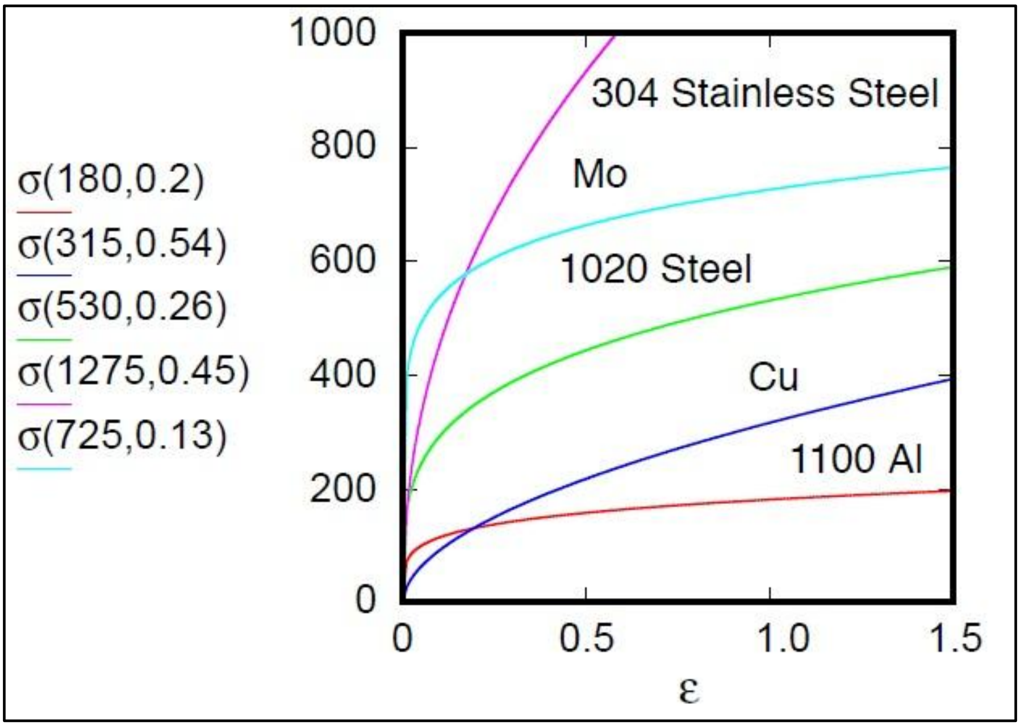
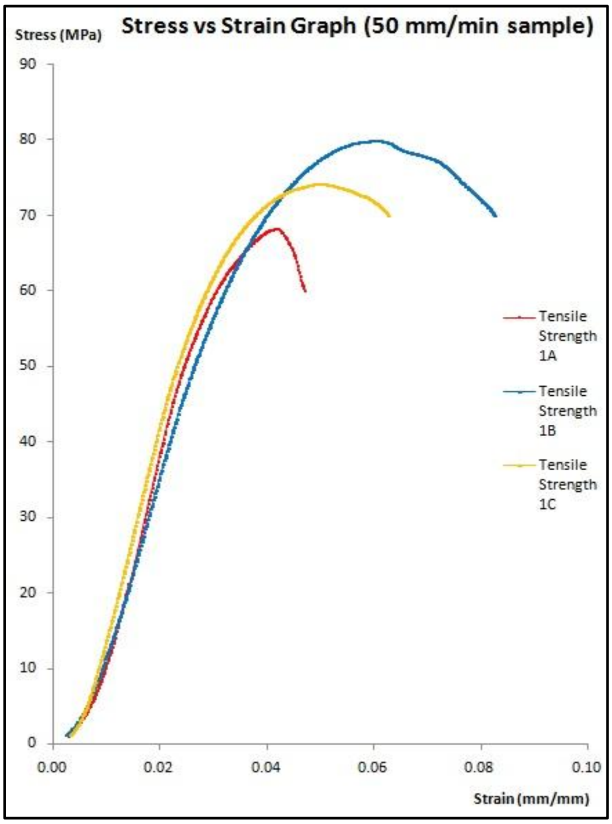


Figure 13: Stress vs Strain curve for different type of metals. [12]

The Figure 14 shows the tensile strength of 1A, 1B & 1C samples from the 50 mm/min sample.



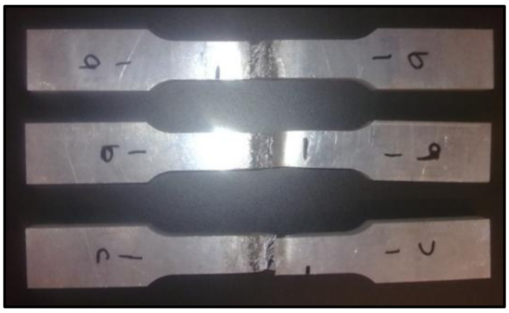
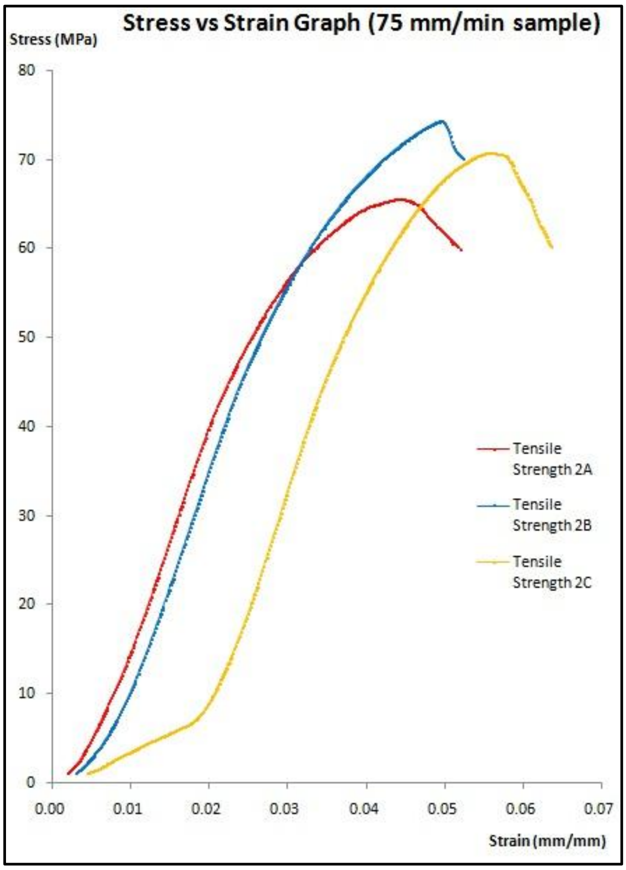


Figure 14: (Left) Stress vs Strain Graph of the 50 mm/min samples, (Right). The 50 mm/min samples.

From the graph, the tensile strength of the 1A, 1B, & 1C are 68.28 MPa, 79.89 MPa, & 74.19 MPa. The 1B sample which situated at the middle of the plate produced the highest tensile strength compare to the 1A & 1C. The average tensile strength of the 50 mm/min sample is 74.12 MPa.

In term of percentage elongation, the sample 1B also produced highest which is 11.9%. The tensile strength of the MMC produced from the 50 mm/min sample is lower than the base material, Al-1100 which 180 MPa. Whereas, in term of the percentage of elongation, the samples show that the MMC produced are higher than the base material which is 2%.

The Figure 15 shows the result of the tensile test for the 2A, 2B & 2C from 75 mm/min sample.



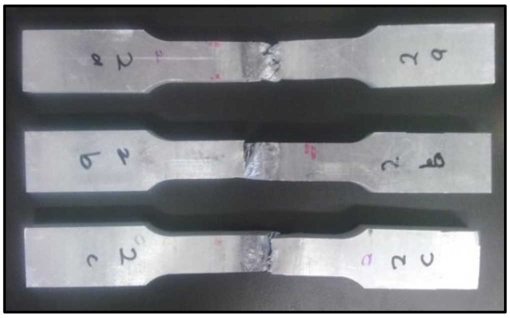
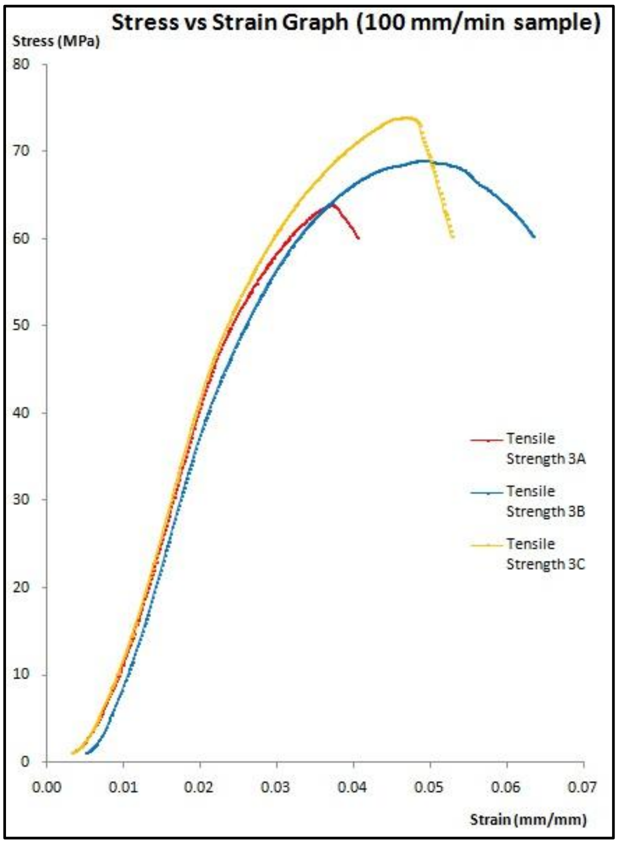


Figure 15: (Left) Stress vs Strain Graph of the 75 mm/min samples, (Right) The 75 mm/min samples

From the graph, the tensile strength of the 2A, 2B, & 2C are 65.20 MPa, 74.37 MPa, & 70.76 MPa. Alike 1B, the 2B sample which situated at the middle of the plate produced the highest tensile strength. In term of percentage elongation, the sample 2C produced highest which is 12.1%.

The tensile strength of the MMC produced from the 75 mm/min sample also lower than the base material but improve in term of the percentage of elongation. The averange tensile strength produced from the samples in the 75 mm/min sample is 70.11 MPa slightly decreased from the 50 mm/min sample. This show that increase in the parametric value; feedrate from 50 mm/min to 75 mm/min and spindle speed from 1200 rpm to 1400 rpm will reduced the tensile strength of the MMC but increased the percentage of elongation.

The Figure 16 shows the result of the tensile test for the 3A, 3B & 3C from 100 mm/min sample.



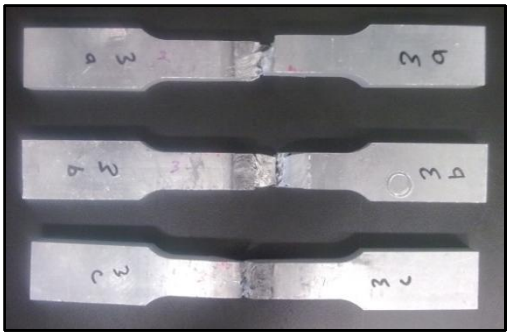


Figure 16:(Left) Stress vs Strain Graph of the 100 mm/min samples, (Right) The 100 mm/min samples

From the graph, the tensile strength of the 3A, 3B, & 3C are 63.92 MPa, 68.94 MPa, & 73.89 MPa. The 3C sample which situated at the end of the plate produced the highest tensile strength. All of the experiment is done in 2.5° gradient and the deepest penetration of the FSP tools is at the end of the welding path. In term of percentage elongation, the sample 3B produced highest which is 16.23%.

The tensile strength of the MMC produced from the 100 mm/min sample also lower than the base material but improve in term of the percentage of elongation. The average tensile strength produced from the samples in the 100 mm/min sample is 68.91 MPa also decreased from the samples of the 50 mm/min and 75 mm/min. This show that increase in; feedrate from 50 mm/min to 100 mm/min but constant spindle speed 1400 rpm will slightly reduced the tensile strength of the MMC but improved the percentage of elongation.

The well mixing of the base material, Aluminium (Al1100) with the reinforcement change the properties of the material in term of mechanical; tensile strength and the percentage of elongation.

Increase of the spindle speed will produced more heat at the surface and the sub layer of the composite thus affect the properties of the microstructure of the base material and results decreased in the tensile strength. The fine composition of the Carbon Nanotube and base material improved the percentage of elongation of the MMC thus the base material become soft and the ductility is increased.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

With the results that have been analysed, it can be concluded that the CNT give effect to the Aluminium Matrix Composite produced by FSP, as it reduced the tensile strength of the composite compare to the base material. The results show that the tensile strength of the 50 mm/min, 75 mm/min, & 100 mm/min sample are 74.12 MPa, 70.11 MPa, & 68.91 MPa lower from the base material, Al-1100 which is 180 MPa. Thus, the Carbon Nanotube is not suitable reinforcement material for the Aluminium Matrix Composite in term of tensile strength.

5.2 RECOMENDATION

For the future study, it is recommendate to do the study on the Carbon Nanotube as the reinforcement for the Aluminium Matrix Composite in term of physical properties as according to the literature, the Carbon Nanotube is good in electrical and thermal conductivity.

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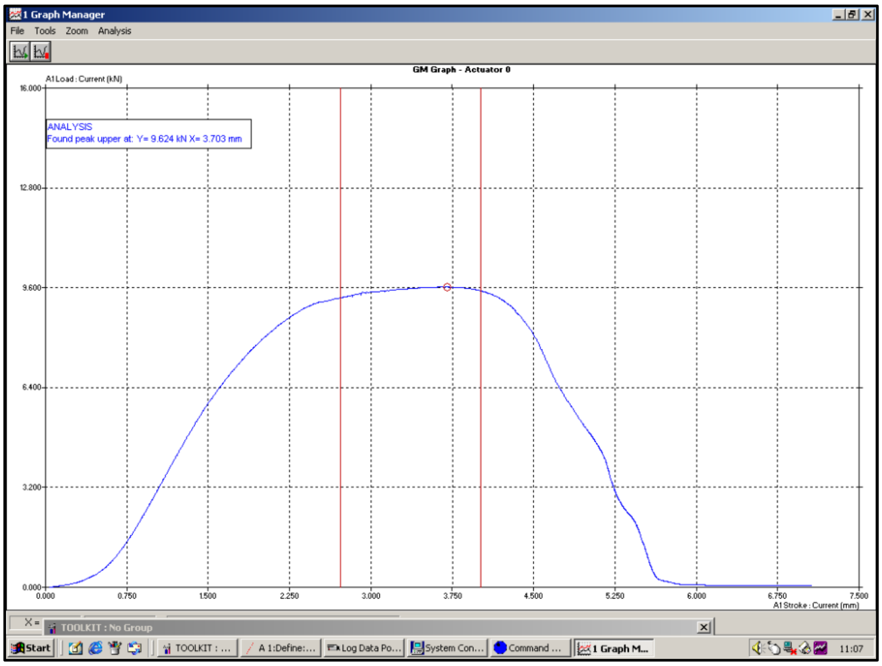
12. Kalpakjian S., Schmid S. R. (2003). *Power Law for Stress/Strain Data.* Manufacturing Processes for Engineering Material, 4^{th} ed. Prentice Hall.

APPENDICES

Appendix 1



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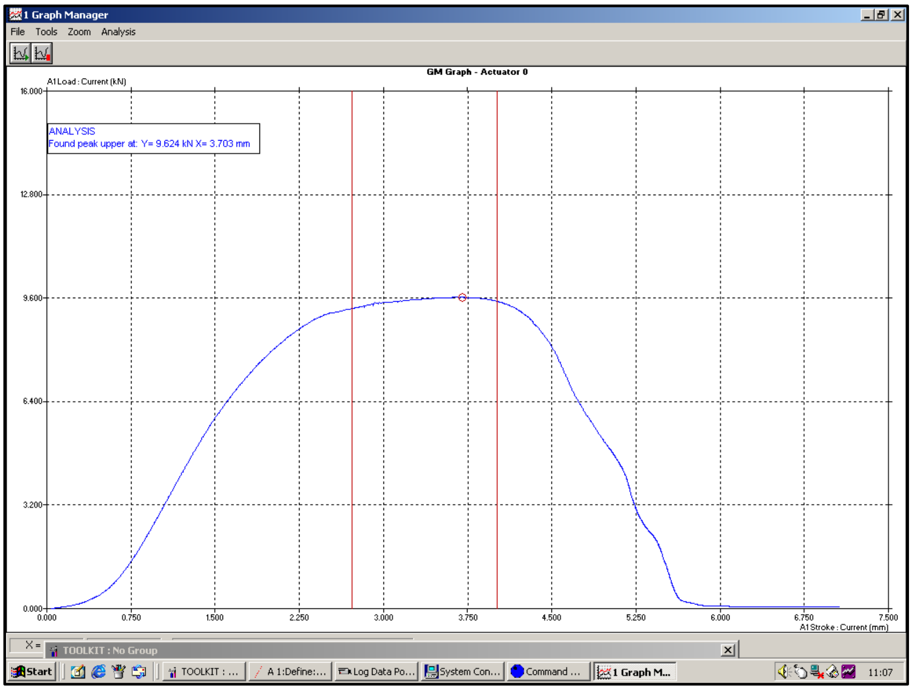
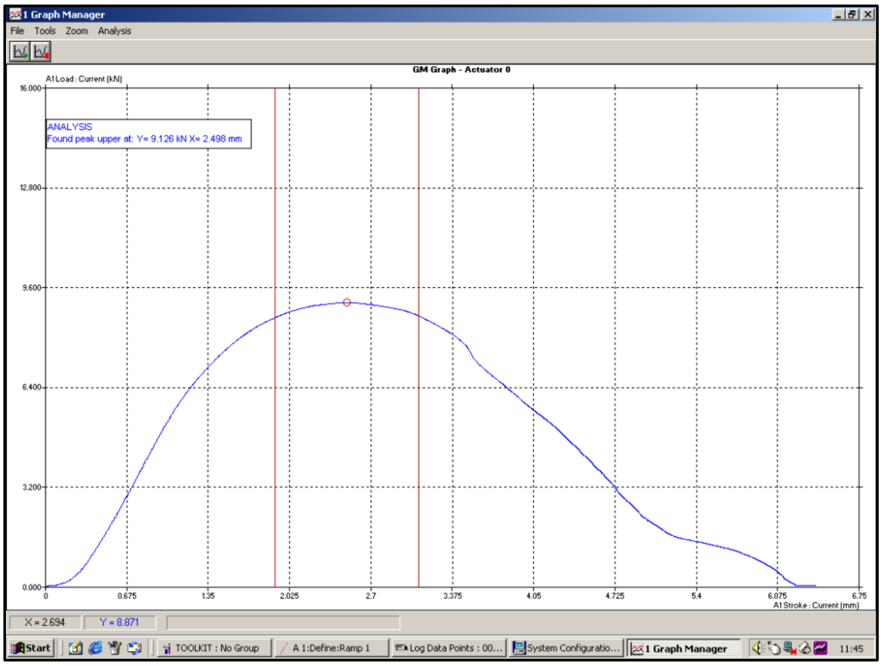


Appendix 3



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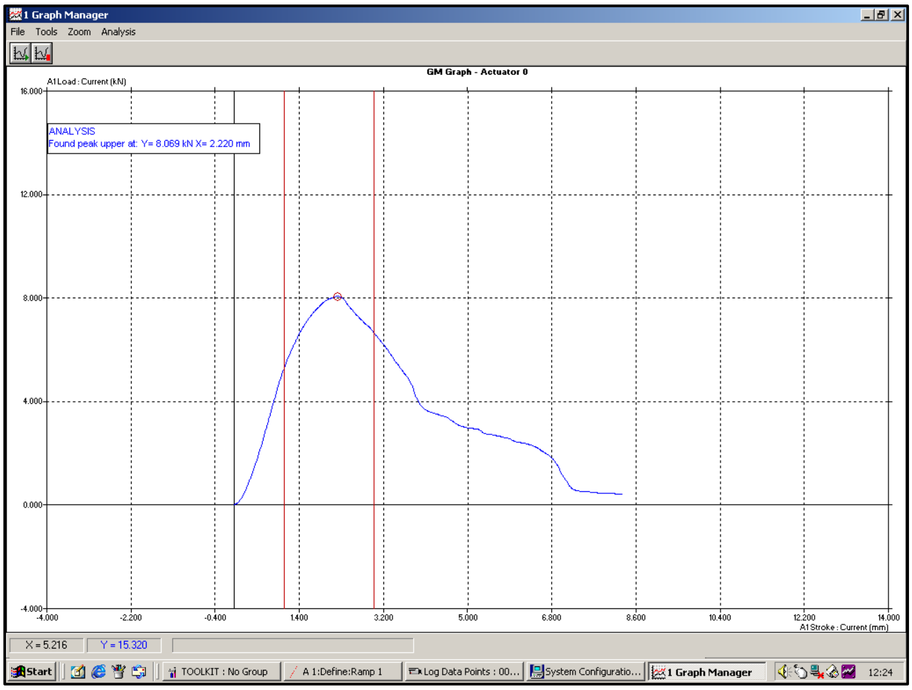

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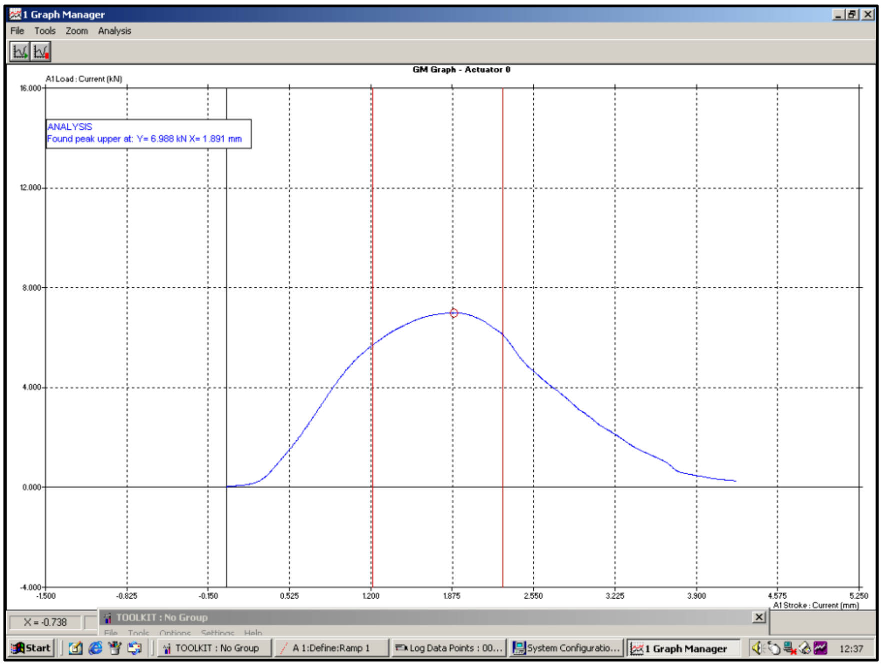
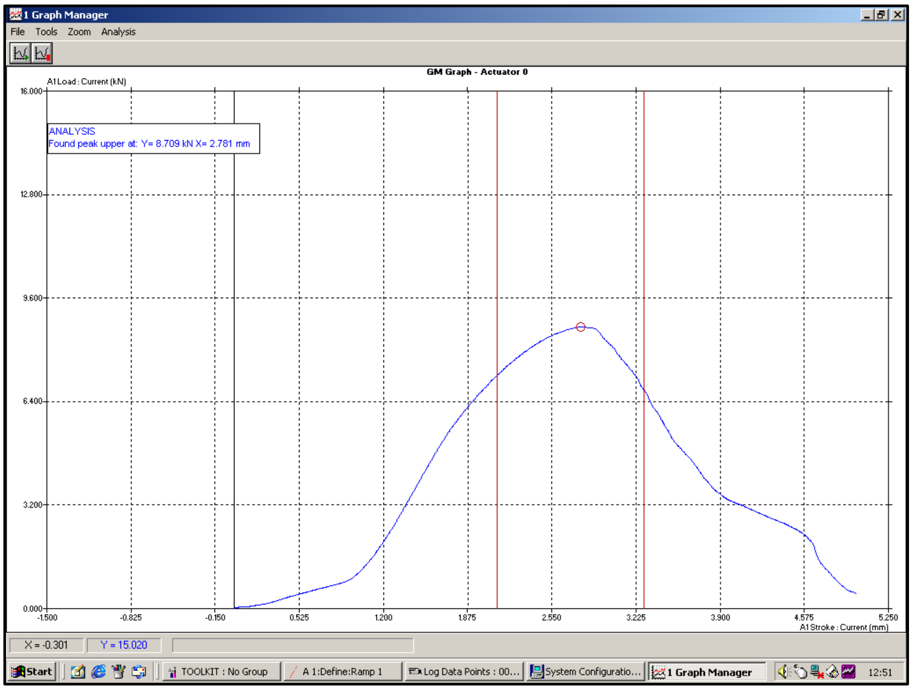
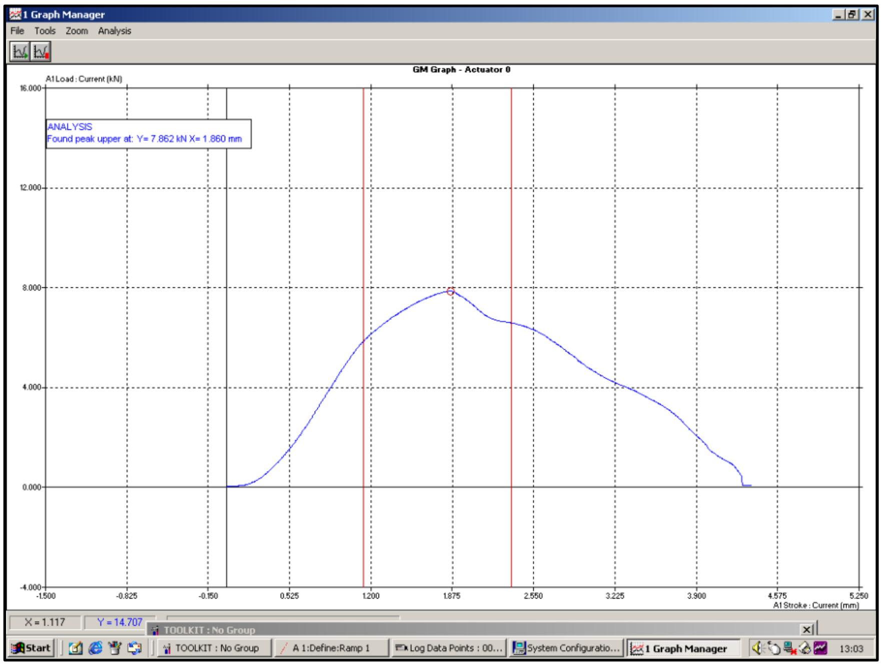


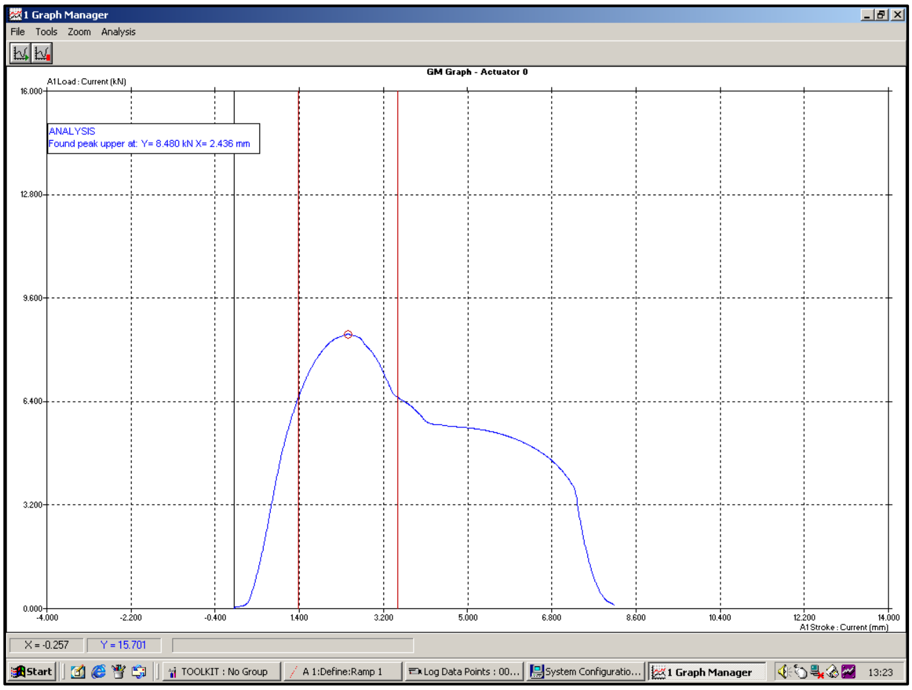
Appendix 6



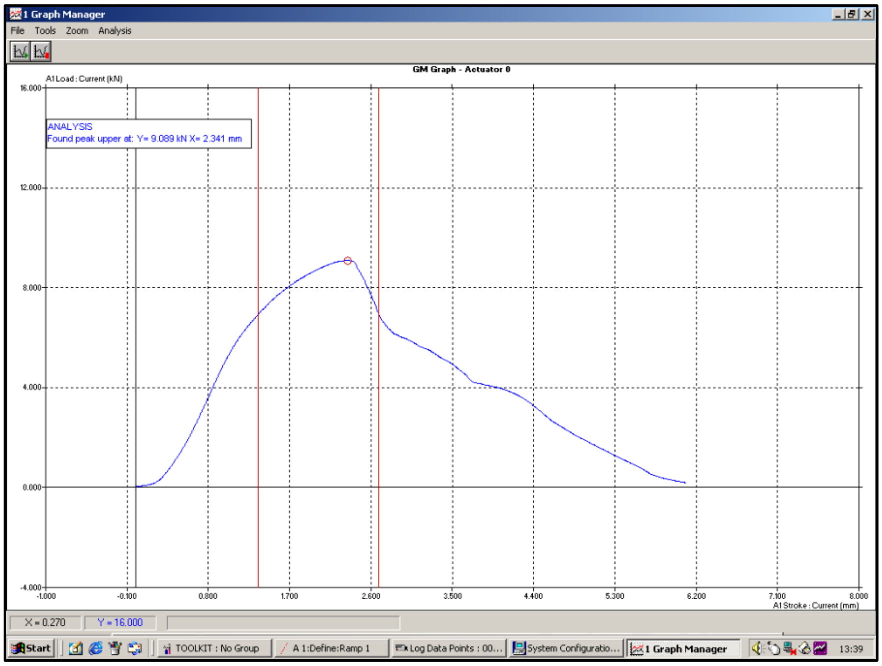
Appendix 7



Appendix 8



Appendix 9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File Tools Zoom Analysis
GM Graph - Actuator 0
A1 Load : Current (kN)
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16.000
12.000
8.000
4.000
0.000
-4.000
-1.000
-0.100
0.800
1.700
2.600
3.500
4.400
5.300
6.200
7.100
8.000
A1 Stroke : Current (mm)
X = 0.270
Y = 16.000
Start
TOOLKIT : No Group
A 1:Define:Ramp 1
Log Data Points : 00...
System Configuratio...
1 Graph Manager
13:39