.

Experimental & Numerical study on sheet metal lateral bending with fixed and pinned ends

NORAZLIANIE BINTI SAZALI

This FINAL Year Project Report is submitted to Faculty of Mechanical Engineering Universiti Malaysia Pahang in Partial fulfilment of Bachelor of Mechanical Engineering with Manufacturing Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

JUNE 2012

SUPERVISOR'S DECLARATION

We hereby declare that we have checked this project report and in our opinion this project is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Manufacturing Engineering.

Signature :
Name of Supervisor : MR ZAIDI BIN SIDIK
Position : SUPERVISOR
Date : 18th JUNE 2012

Signature :
Name of Second Reviewer : DR. AKHTAR RAZUL BIN RAZALI
Position : LECTURER
Date : 18th JUNE 2012

STUDENT'S DECLARATION

I declare that this report entitled Final Year Project report is the result of my own research & learning except as cited in references. The report has not been accepted for any degree is not concurrently submitted in candidature for any other degree.

Signature : ………………………….

Name : NORAZLIANIE BINTI SAZALI

ID Number : ME08069

Date : 18th JUNE 2012

To my beloved parents,

Mr Sazali Bin Kandar

Mrs Soliah Binti Adinan

ACKNOWLEDGEMENT

I am grateful and would likes to express my sincere gratitude to my supervisor Encik Zaidi Bin Sidek for his invaluable guidance and constant support in making the thesis. This Thesis could not been done without him who not only served as my supervisor but also encourage me throughout the process. I also would like to express very special thanks to the panel member who give valuable comment and suggestion during my Final Year Project presentation one and two.

My sincere thanks go to all laboratory assistant from Faculty of Mechanical and Faculty of Manufacturing, Universiti Malaysia Pahang for their teaching and help during the period of my project.

I acknowledge my sincere indebtedness and gratitude to my parents, Encik Sazali Bin Kandar and Puan Soliah Binti Adinan for their love and sacrifice throughout my life. They have always supported my dreams. They did a fine job raising me. Last but not least, for all my friends, who’s supporting and encouraging me to pursue this degree.

ABSTRACT

The main objective of this project is to expose student with many aspect of engineering work, design, fabrication and testing a product. The task follows a common product development activity, where student need to apply all their engineering knowledge and skill to complete this project. In random, student must know some basic knowledge which is buckling definition, software and machine to be used also the finite element method. In the other hand, student must master in conceptual design and complete loose part for an assembly drawing. Not only that, student must know how to solve problem in fabrication work and can develop similar model on Finite Element software. From an engineering standpoint, the finite element method is a method for solving engineering problems such as stress analysis, heat transfer, fluid flow and electromagnetic by computer simulation. The flow of the experiment is to be done from beginning until the testing is conducted to the specimen to determine the output of the buckling test when the combination of the joint are fixed and pinned. These projects explain how the design looks like, how the test rig fabricates also failure and error during the test is going on. From this project, we can prove that the experimental result is same with the simulation result.

ABSTRAK

Objektif utama projek ini adalah untuk mendedahkan pelajar dengan banyak aspek kejuruteraan, reka bentuk, fabrikasi dan menguji sesuatu produk. Tugas ini merangkumi pembangunan aktiviti, di mana pelajar perlu mengaplikasi semua pengetahuan kejuruteraan dan kemahiran mereka untuk menyiapkan projek ini. Secara rawaknya, pelajar mesti tahu beberapa pengetahuan asas seperti maksud kelengkungan, perisian,mesin yang digunakan dan juga kaedah Finite Element. Sebaliknya, pelajar mesti menguasai dalam konsep reka bentuk dan melengkapkan bahagian yang longgar untuk lukisan pemasangan. Bukan itu sahaja, pelajar perlu tahu bagaimana untuk menyelesaikan masalah dalam kerja fabrikasi dan boleh membangunkan model yang sama di perisian Finite Element. Dari sudut pandangan kejuruteraan, kaedah Finite Element adalah satu kaedah untuk menyelesaikan masalah kejuruteraan seperti analisis tegangan, pemindahan haba, aliran bendalir dan elektromagnetik oleh simulasi komputer. Langkah kerja eksperimen dilakukan dari awal sehingga ujian dijalankan ke atas sampel untuk menentukan hasil ujian lengkungan apabila gabungan penyambung adalah tetap dan dipin. Projek ini akan menerangkan bagaimana reka bentuk itu akan kelihatan, bagaimana bahan eksperimen itu bertindak balas, juga kegagalan dan kesilapan semasa eksperimen dijalankan. Daripada projek ini, kita boleh membuktikan bahawa hasil eksperimen adalah sama dengan hasil simulasi.

TABLE OF CONTENTS

.

LIST OF TABLE

LIST OF FIGURES

LIST OF SYMBOLS

ω	Natural frequency
ε	Total strain, Bandwidth parameter
ε_a	Strain amplitude
ε_f	True fracture ductility
ε'_f	Fatigue ductility coefficient
σ	True stress, local stress
$\Delta\sigma$	Stress range
σ_a	Local stress amplitude
σ_m	Local mean stress
σ_{max}	Local maximum stress
σ_f	True tracture strength
S_f	Fatigue strength
S'_f	Fatigue strength coefficient

LIST OF ABBREVIATIONS

AA	Aluminum alloy
A-A	ASTM air to air typical fighter loading
Al	Aluminium
ASTM	American Society for Testing and Materials
CAD	Computer-aided drafting
CAE	Computer-aided engineering
DOF	Degree-of-freedom
DTP	Discretized turning point
FE	Finite element
FFT	Fast Fourier transform
FRF	Frequency response function
IC	Internal combustion
LG	Linear generator
MBD	Multibody dynamics
PDF	Probability density function
PSD	Power spectral density
SAE	Society of Automotive Engineers

CHAPTER 1

INTRODUCTION

1.0 INTRODUCTION

When a structure (subjected usually to compression) undergoes visibly large displacements transverse to the load then it is said to buckle. Buckling may be demonstrated by pressing the opposite edges of a flat sheet of cardboard towards one another. For small loads the process is elastic since buckling displacements disappear when the load is removed. Local buckling of plates or shells is indicated by the growth of bulges, waves or ripples, and is commonly encountered in the component plates of thin structural members. Buckling proceeds in manner which may be either:

i. stable - in which case displacements increase in a controlled fashion as loads are increased, the structure's ability to sustain loads is maintained, or

ii. unstable - In which case deformations increase instantaneously, the load carrying capacity nose- dives and the structure collapses catastrophically.

Neutral equilibrium is also a theoretical possibility during buckling. This is characterized by deformation increase without change in load. Buckling and bending are similar in that they both involve bending moments. In bending these moments are substantially independent of the resulting deflections, whereas in buckling the moments and deflections are mutually inter-dependent so moments, deflections and stresses are not proportional to loads. If buckling deflections become too large then the structure fails. This is a geometric consideration, completely divorced from any material strength consideration. If a component or part thereof is prone to buckling then its design must satisfy both strength and buckling safety constraints, which is why we now examine the subject of buckling.

All relevant buckling problems can be demonstrated with any possible test stand. Buckling, as opposed to simple strength problems such as drawing, pressure, bending and shearing, is primarily a stability problem. Buckling plays an important role in almost every field of technology. The strength of a column may therefore be increased by distributing the material so as to increase the moment of inertia. This can be done without increasing the weight of the column by distributing the material as far from the principal axis of the cross section as possible, while keeping the material thick enough to prevent local buckling. This bears out the well-known fact that a tubular section is much more efficient than a solid section for column service.

1.1 BUCKLING TEST

Another bit of information that may be gleaned from buckling test is the effect of displacement on critical load. For a given size column, doubling the unsupported displacement quarters the allowable load. The restraint offered by the end connections of a column also affects the critical load. If the connections are perfectly rigid, the critical load will be four times that for a similar column where there is no resistance to rotation (hinged at the ends). Examples of this are:

i. Columns and supports in construction and steel engineering
ii. Stop rods for valve actuation and connecting rods in motor construction
iii. Piston rods for hydraulic cylinders and
iv. Lifting spindles in lifting gear

1.1.1 Applying the Buckling Theory

If a rod is subjected to longitudinal forces, as implied in the sketch, it can fail in two ways. On the one hand, it can be plasticized and flattened if its admissible compressive strain is exceeded .On the other hand, it is possible that it will suddenly shift to one side and buckle before attaining the admissible compressive strain. This effect is called buckling. The shape of the rod is the factor determines which of the two cases of failure will occur. A rod with articulated mounting at both ends according to Euler case is slowly subjected to an axial force. Above a certain load it will buckle laterally. In this case the buckling (deformation) of the rod specimen will be measured in the middle of the rod and recorded in a table along with the accompanying force. Force/deformation graphs will be developed using these measured values. The results of the test should be compared with the buckling theory values. A slender, thin rod is more likely to buckle than a thick, stout rod. Figure 1.1 shows a slender, thin rod is more likely to buckle than a thick, stout rod under compressive force.

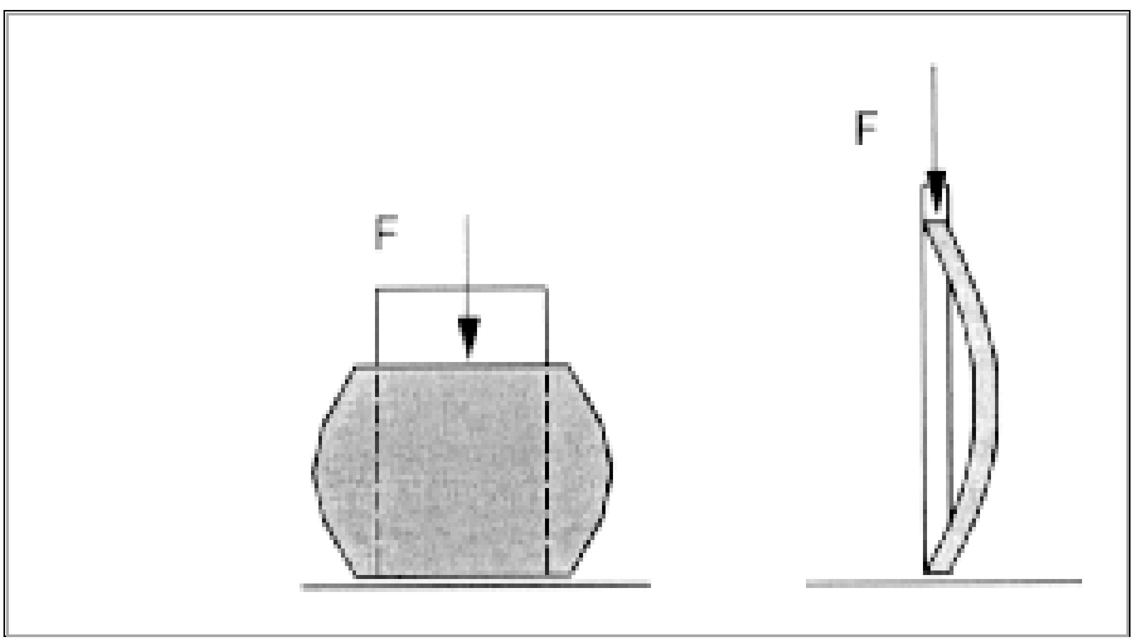


Figure 1.1: Stout and slender rod under compressive force

1.1.2 Euler Formula

Buckling occurs suddenly and without warning when a certain limit load is attained. It is therefore an extremely dangerous type of failure, which must be avoided by all means. As soon as a rod begins to buckle, it will become deformed to the point of total destruction. This is typical unstable behaviour. Since structural columns are commonly of intermediate length, and it is impossible to obtain an ideal column, the Euler formula on its own has little practical application for ordinary design. Issues that cause deviation from the pure Euler strut behaviour include imperfections in geometry in combination with plasticity/non-linear stress strain behaviour of the column's material. Consequently, a number of empirical column formulae have been developed to agree with test data, all of which embody the slenderness ratio. For design, appropriate safety factors are introduced into these formulae. Buckling is a stability problem. The critical limit load above which buckling can occur is dependent on both the slenderness of the rod, which is influence of length and diameter, and the material used. In order to define slenderness the slenderness ratio l will be introduced here. In this case $l\ k$ is the characteristic length of the rod. It takes both the actual length of the rod and the mounting conditions into consideration.

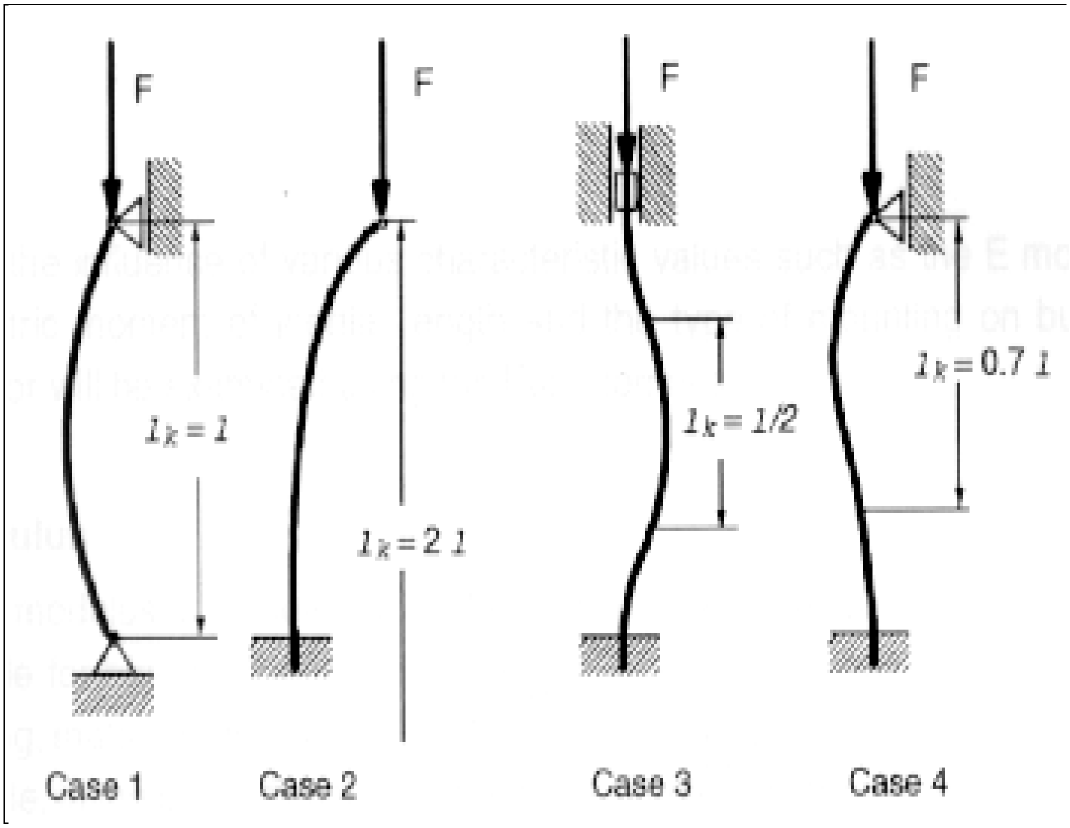


Figure 1.2: Example on buckling tests

Figure 1.2 shows the example on buckling test. For clamping, the ends of the odds cause rigidity. The buckling length decisive for slenderness is shorter than the actual length of the rod. Altogether, a differentiation is made between four types of mountings, each having a different buckling length. The influence of diameter in the slenderness ratio is expressed by the inertia radius i. It is calculated using the minimum geometrical moment of inertia *ly* and the cross-sectional area, A.

1.2 DESIGNS FOR MANUFACTURE AND ASSEMBLY (DFMA)

Design for manufacture or 'Manufacturability' concerns the cost and difficulty of making the product. At a simple level manufacturability, design for manufacture (DFM) at a part level, involves detail such as ensuring that where a pin is to be assembled into a hole that is only slightly larger in diameter, then it is much easier if the end of the pin or the entry to the hole (or both) are chamfered or finished with a radius. This applies whether the assembly is carried out manually or automatically. This is a fine tuning process carried out once the product form has been decided. Indeed automatic assembly would be very difficult and expensive if neither component of a close fitting pair was chamfered. At a more complex level, product DFM tackles the more fundamental problem of deciding on the product structure and form. Design for assembly (DFA) is an important part of this. Some 'manufacturability' software is available, relating both to manufacture and to assembly. This section starts with some simple but important principles of manufacturability.

DFMA is an abbreviation for "Design for Manufacturing and Assembly" or "Design for Manufacturability and Assembly. It a system comprised of various principles that, when used properly, will improve the ability for a design to be easily manufactured and assembled. It is most beneficial to consider these principles during the design phase of new product development. This system can be divided into three major sections. The first is the raw material. Choosing the right material is the foundation of a good design. Second are the machines and processes used to work the raw material .The right process is essential for creating finished parts that will meet your design requirements. Third is the assembly of the product. It is during the assembly of the finished product that provides the greatest opportunity to apply DFMA principles. The proper use of DFMA principles will allow one to design a high quality product.

Choosing the best raw material for the design is the first step in using DFMA to design a world class product. There are many factors that need to be considered when choosing the best material for a design. First the material must have the correct mechanical and chemical properties to meet the design criteria. Second when possible one should choose a standard material that is readily available. Using special materials may increase purchase price and lengthen deliveries. Third use nearly net parts whenever possible. The raw material's profile should be as close to finished parts as possible to reduce processing.

Choosing the appropriate machine and processes can drastically reduce the time and further increase the quality of the parts. When determining the best machine for the job, there are many things to consider. First and foremost is the material for being processed. Some materials may require coolant and others may require special fixturing or tooling. Second is to apply as liberal tolerances as the design will allow. It typically takes longer and is more costly to hold tighter tolerances. Third are the machines capabilities. Pick a machine and process that can provide desired finish, hold tolerances required, and be repeatable. Next is the tooling. You will need to pick tooling with the best combination of finish, performance, life and cost. Another consideration is fixturing. Proper fixturing is necessary for quality while fixturing that is user friendly can reduce the amount of labour time in the manufacturing process.

Assemblies are the area with the most potential in applying DFMA principles. First, reduce the parts count in an assembly. It can be reduce parts by eliminating or combining multiple parts. Second by making parts symmetrical when the design allows. Having asymmetrical parts require more attention in the positioning of the parts at assembly. Third is simplicity of design. Typically the simpler the design the less opportunity for mistakes. Next is self fixturing. The usage of the part itself is to help position or align itself with a mating part. Whenever possible try to avoid using parts in the design that are easily tangled. Tangled parts take time to untangle that may be spent doing productive work. It will also have to think about accessibility. If a part is hard to get to it may take more time to position and assemble it. Last but surely not least is poka yoke or mistake proofing. The goal of poka yoke is to make it impossible to make a mistake.

1.2.1 Traditional design paradigm

In order to survive and develop in the market, the enterprises have to present their new product to the public rapidly and continuously. Meanwhile, they must keep their products with the low price and high quality. So, developing the new product to satisfy the costumes requirements and make them appear in the market as soon as possible becomes the key to share more part of the cake of the market. The tradition manufacturing method follows the developing cycle shown as figure that follow the conceptual sketches of the parts completed on the CAD workstation, the design engineers create the detail drawing and assembly engineer create the assembly plan. The workshop makes the prototype and gives the feedback, which accords to the sample test, to the design engineers and assembly engineers who will redesign the product, the assembly and the manufacturing process. The same cycle repeats again and again until arriving at competitive design. This kind of process makes the design and manufacturing been performed independently. The design engineer and the manufacturing engineer works individually and what results is that the final products have many disadvantages such as poor characteristics in manufacturing, assembly, maintenance; long developing period; high cost; and unguaranteed quality. Figure 1.3 below shows the traditional manufacturing process.

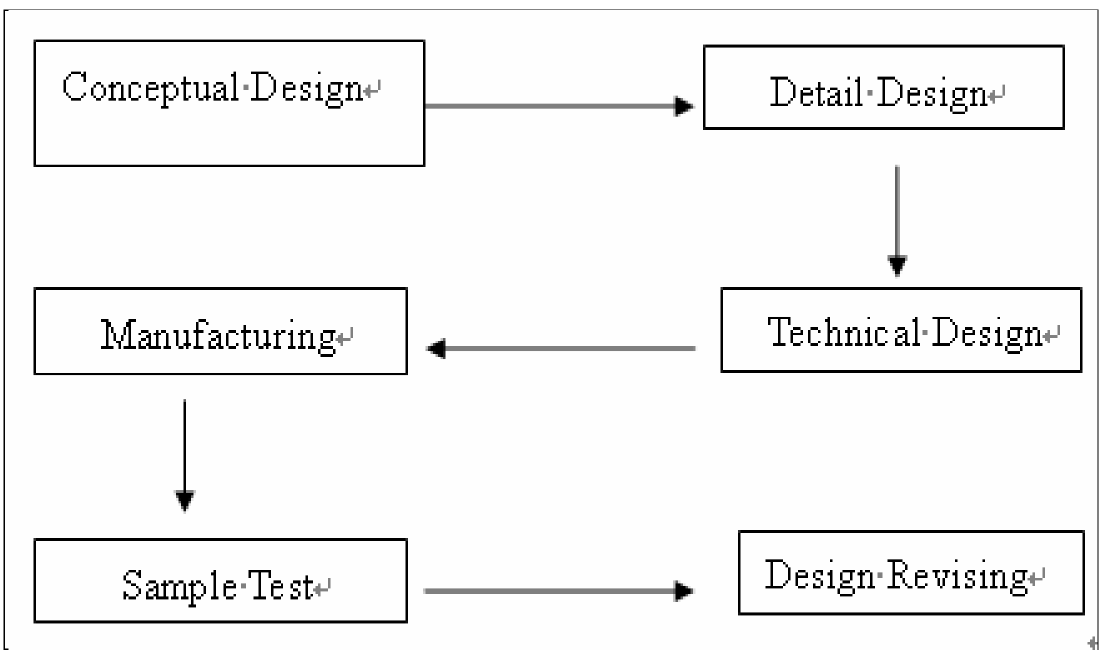


Figure 1.3: Traditional Manufacturing Process

1.2.2 Objective of DFMA

The basic concept of it is that the design engineers apply the DFMA paradigm or software to analyze the manufacturing and assembly problems at the early design stage. By this means, all of considerations about the factors that affect the final outputs occur as early as possible in the design cycle. The extra time spent in the early design stage is much less the time that will be spent in the repeatedly redesign. And meanwhile, the cost will be reduced. DFM is that by considering the limitations related to the manufacturing at the early stage of the design; the design engineer can make selection among the deferent materials, different technologies, estimate the manufacturing time the product cost quantitatively and rapidly among the different schemes. They compare all kinds of the design plans and technology plans, and then the design team will make revises as soon as possible at the early stage of the design period according this feedback information and determine the most satisfied design and technology plan.

There are three goals in DFM:

i. Increase the quality of new produces during the developing period, including design, technology, manufacturing, service and so on.
ii. Decrease the cost, including the cost of design, technology, manufacturing, delivery, technical support, discarding and so on.
iii. Shorten the developing cycle time, including the time of design, manufacturing preparing, and repeatedly calculation.

1.3 FINITE ELEMENT METHOD (FEM)

The basic idea behind the FE method is to divide the body or region into a finite number of finite elements, connected by nodes, and obtain an approximate solution in terms of the temperatures at these nodes. These elements may be one, two or three dimensional. A popular two-dimensional element is the triangular element. When a two dimensional region is divided into non-overlapping triangles, we can see that essentially any planar geometry can be easily represented by a union (in the language of mathematical sets) of these elements. Instead of determining the temperature at every point in the plate, let us consider determining the temperature at only a finite number of points, the vertices (or nodes) of the triangles. The finite element method provides a systematic methodology whereby the temperatures at the nodes (nodal temperatures) can be determined. Interpolation can then be used to obtain the temperature throughout the problem domain.

For linear problems, we will need to solve a system of linear equations with the number of unknowns (nodal temperatures) equal to the number of nodes. To obtain a reasonably accurate solution, thousands of nodes are usually needed, so computers are essential in solving these equations. Generally, the accuracy of the solution improves as the number of elements (nodes) increases, but the computer time, and hence the cost, also increases. The computer program determines the temperature at each node and the heat flow through each element. The results are usually presented as computer visualizations, such as contour plots, although selected results are often printed. This information is then used in the engineering design process. Although we have just presented the concept in the context of heat transfer, the same basic concept is applicable in other areas. In stress analysis, the field variables are the displacements, in chemical systems the variables are material concentrations, and in electromagnetic, the potential field.

The preponderance of finite element analyses in engineering design is today still linear FEM. In heat conduction, linearity requires that the conductance be independent of temperature. In 6 stress analyses, linear FEM is only applicable if the material behaviour is linear elastic and the displacements are small. Additional discussions of the assumptions underlying linear analysis are given later.

1.4 PROJECT BACKGROUND

The main idea of this project is to expose student with many aspect of engineering work; design, fabrication and testing a product. The task follows a common product development activity, where student need to apply all their engineering knowledge and skill to complete this project. In random, student must know some basic knowledge which is Buckling definition, software and machine to be used also the finite element method. In the other hand, student must master in conceptual design and complete loose part for an assembly drawing. Not only that, student must know how to solve problem in fabrication work and can develop similar model on FEM software.

1.5 PROBLEM STATEMENT

In recent years, study of the buckling test has become significant. All these study are aimed to design and fabricate of a lateral bending(buckling) test equipment .The first problem statement is to study how the bending(buckling) test equipment looks like when then combination of the joint are fixed and pinned .Secondly, for current teaching practices which is prefer hands-on or practical. It is easy and fast to understand the related engineering problem. For example, Finite Element course need better teaching technique to make student easily understand their application in solving engineering problem. Thirdly, for simple engineering problem that can be investigated (by experimental) in laboratory. For example, buckling test is a simple engineering problem. Lastly, for teaching purpose, a buckling problem can be tested in laboratory and finite element software can be used to develop similar model.

1.6 SCOPE OF THE PROJECT

The scope of this project is to expose student with many aspect of engineering work; design, fabrication and testing a product. The task follows a common product development activity, where student need to apply all their engineering knowledge and skill to complete this project.

In random, student must know some basic knowledge which is Buckling definition, software and machine to be used also the finite element method. In the other hand, student must master in conceptual design and complete loose part for an assembly drawing. Not only that, student must know how to solve problem in fabrication work and can develop similar model on Finite Element software. There are three objectives of this project. First, to fabricate the laboratory test equipment for sheet metal lateral bending (buckling) condition where the ends joint are fixed and pinned. Secondly, to establish the buckling tests under fixed-pinned setting. Thirdly, to compare between the experiment results and the stimulation results by using Finite Element software.

CHAPTER 2

LITERATURE REVIEW

2.0 INTRODUCTION

Buckling occurs when the compressive load in a tubular exceeds a critical value, beyond which the tubular is no longer stable and deforms into a sinusoidal or helical shape. The sinusoidal buckling (first mode of buckling) corresponds to a tube that snaps into a sinusoidal shape. This first mode of buckling is sometimes called lateral buckling, snaking or two-dimensional buckling. The helical buckling (second mode of buckling) corresponds to a tube that snaps into a helical shape (spiral shape).For analysis on finite element; many physical phenomena in engineering and science can be described in terms of partial differential equations. In general, solving these equations by classical analytical methods for arbitrary shapes is almost impossible. The finite element method is a numerical approach by which these partial differential equations can be solved approximately. From an engineering standpoint, the finite element method is a method for solving engineering problems such as stress analysis, heat transfer, fluid flow and electromagnetic by computer simulation.

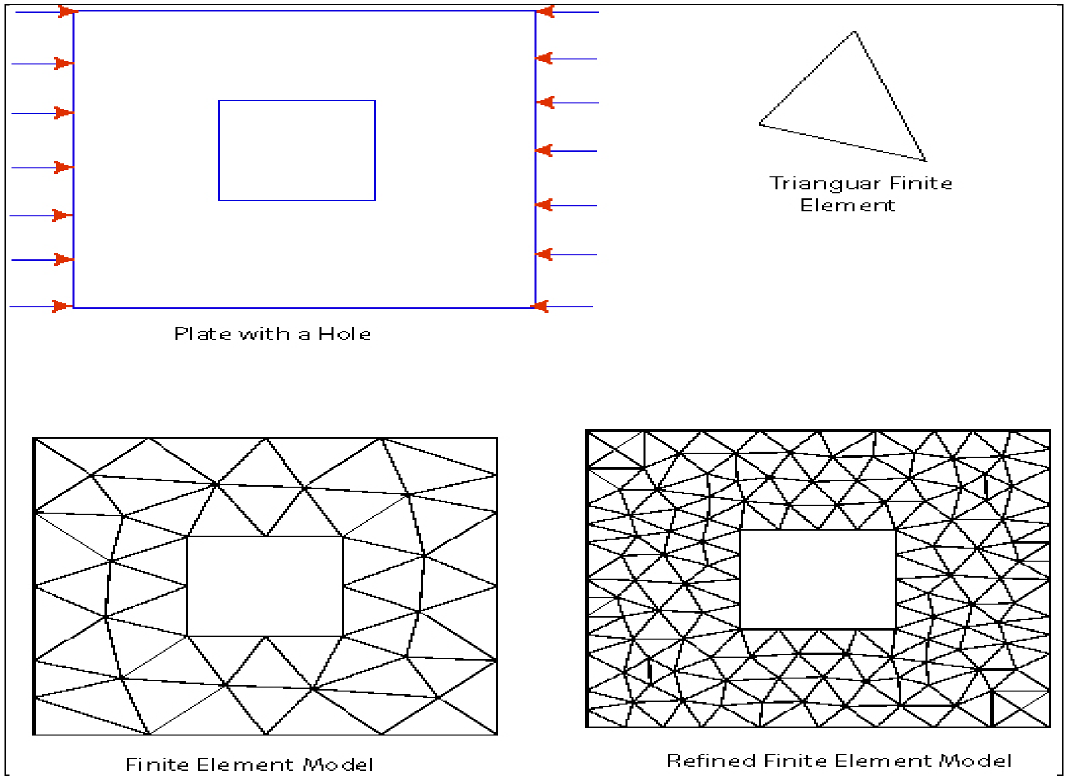


Figure 2.1: Geometry, loads and finite element meshes

The purpose of Finite Element is to predict the behaviour of structural, mechanical, thermal, electrical and chemical systems in both design and performance analysis. Its popularity can be gleaned by the fact that over 1 billion is spent annually in the United States on FEM software and computer time. More than 250 books and over 20,000 articles have been published on this subject. In principle, it is possible to write a heat balance equation at each point in the plate. However, the solution of the partial differential equations that governs energy balance for a complicated geometry such as an engine block becomes almost impossible by classical methods like separation of variables. Numerical methods such as finite difference methods also are quite awkward for arbitrary shapes; software developers have not marketed finite difference programs that can deal with the arbitrary geometries that are commonplace in engineering. Similarly, in stress analysis problems, equilibrium is governed by complex partial differential equations that are very difficult to solve except for very simple geometries, like rectangles, and engineering problems seldom have such simple shapes.

2.1 BUCKLING HISTORY

The buckled beam is a simple 1D example of a bistable structure, and negative stiffness behaviour is implicit to constrained bistable elements of any configuration (Prasad, 2006; Qiu, 2004). This behaviour has been confirmed by experimental studies of buckled tubes and carbon nano tubes which found decreased force with increasing strain response and higher damping levels for buckled tubes relative to unbuckled tubes under sinusoidal forcing (Lakes, 2000; Yap, 2007). These findings confirm that buckled beams are negative stiffness elements under specific conditions and that they can therefore be used for damping purposes. However, it is difficult iteratively design and tune negative stiffness elements with conventionally manufacturing methods.

The major players were Boeing and Bell Aerospace (long vanished) in the U.S. and Rolls Royce in the U.K. M. J. Turner, R. W. Clough, H. C. Martin, and L. J. Topp published one of first papers that laid out the major ideas in 1956. It established the procedures of element matrix assembly and element formulations that you will learn in this course, but did not use the term “finite elements.” The second author in this paper, Ray Clough, was a professor at Berkeley, who was at Boeing for a summer job. Subsequently he wrote a paper that first used the name finite elements, and he is given much credit as one of the founders of the method. He only worked in finite elements for a few more years, and then turned to experimental methods, but his work instigated a tremendous effort at Berkeley, led by the younger professors, primarily E. Wilson and R.L. Taylor and graduate students such as T.J.R. Hughes, C. Felippa, and K.J. Bathe. These established Berkeley as the center of linear finite element research for many years. Their working coincided with the rapid growth of computer power, and the method quickly became widely used in the nuclear power, defence, automotive and aeronautics industries.

Much of the academic community first viewed finite element methods very sceptically, and some journals refused to publish papers on FEM-the typical resistance of mankind (and particularly academic communities) to the new. Nevertheless, several capable researchers early recognized its potential, most notably O.C. Zienkiewicz (then at Northwestern) and R.H. Gallagher (at Cornell). O.C. Zienkiwiecz built a renowned group at Swansea in Wales that included B. Iron, R. Owen and many others who pioneered concepts like the isoperimetric element and nonlinear analysis methods. Other important early contributors were J.H. Argyris and J.T. Oden. Subsequently mathematicians discovered a 1943 paper by R. Courant, in which he used triangular elements with variation principles to solve vibration problems.

Consequently, many mathematicians have claimed that this was the original discovery of the method (though it is somewhat reminiscent of the claim that the Vikings discovered America instead of Columbus). It is interesting that for many years the finite element method lacked a theoretical basis, i.e. any logical underpinning that finite element solutions gave the right answer, and this original work of Courant's was duplicated by the engineering community to provide a mathematical justification for the method. In the late 1960's, the field became of great interest to many mathematicians, who showed that for linear problems, such as we will deal with in this course, finite element solutions converge to the correct solution of the partial differential equation (provided that certain aspects of the problem are sufficiently smooth). In other words, it has been shown that as the number of elements is increased the solutions will improve and tend in the limit to the exact solution of the partial differential equations.

The improvements in personal computers since the 1980's have had a major impact on the finite element applications, and hence engineering. Until about the early 1990's, personal computers were too feeble to handle the many equations needed for practical finite element analysis. However, around 1990, personal computers crossed that threshold, and it's rapidly became capable of treating finite element analyses of linear problems required in engineering practice. The software that is most widely used by engineers in stress analysis, such as NASTRAN, ANSYS, ABAQUS, and LSDYNA, were adapted to personal computer.

2.2 CLASSIFICATION OF DESIGN FOR MANUFACTURING ANALYSIS

To match those, and using the example from the buckling and automotive industries, the DFMA and the Manufacturing Engineering show themselves as powerful alternatives to the running design management methods, bringing together some interesting advantages. About those, BOOTHROYD (2001) has affirmed that a winning project can only be developed when the product responsible is prepared to get in to the process and understand the way the manufacturing works and behaves – something close to what HUANG (1996) stated about the good developer, who “must know the manufacturing to prevent unrealizable products due lack of intimacy with the productive process”. Agreeing and complementing, according to DEWHURST (2005) project must involve any single part and respect all opinions; else, the lack of participation of one or more groups can mitigate the success of the product and finally, increase unexpected costs and problems.

All them are showing a project must be accepted and discussed with all responsible: the design area, which is the conceiver of the product, then the project engineering, which will transform the sketched concept into a proposal; after the process engineering that will prepare the factory for the project; forwardly the manufacturing which will release the concept into a tangible product, the quality people that approve the developed parts and processes and so on. Over that, this paper intends to show a successful product developed under this synergy and also explains how DFMA and Manufacturing Engineering have helped students to reach the target of develop a new part more affordable, with quality improvements, reduced time to assembly and with a short time to enter the market.

According to ARAÚJO (2000) apud CANCIGLIERI (2005) communication and information share is important to all design definition and execution phases, but mainly in the conceptual phase. That viewpoint can be defended when is considered the aggregated cost caused by any late change needed by misinformation, an unexpected redesign or reprocess or either a necessity that was neglected due lack of a strong team participation – ANDERSON (1990) apud CANCIGLIERI (2005) evidenced this by affirming that the design determinates the product manufacturability and a significant part of the resources investment (80%) - once these resources have been allocated, it will be very difficult and expensive to make any changes.

Designers do not enter a new design situation as newcomers or novices. Through education and practice they have acquired a vast repertoire of design solutions, which they will carry over the design task at hand (PASMAN, 2003). These experiences are the result of several situations of mistake, improvement opportunities or just real good new ideas acquired due to development and research on design area. How to acquire a “high manufacturability level product” experience? HUANG (1996) affirmed that reasons like increasing complexity level of the bundled technologies in the product, stress caused by short time to deliver some output to the market, the pernicious philosophy adopted by some designers of “we design, you assemble” or “we do sketches, you do products”, the complexity of some industrial processes (and sometimes even the distances) invalidate the implemented idea of the development people caring about the manufacturing reality.

A good development designer or engineer must know the factory in a sufficient detail level that can permit an assembly to be done and an injected part to be extracted and also must know his job to ensure the assembled parts to be there and the injected material to be in the correct geometry. These means two different and in a first view conflicting conditions: that the designer cannot stay in his area ignoring what is happening around and the designer must know his tasks perfectly to justify his work position. The question remains: is it possible to be in simultaneously in the factory and in the design office? FERREIRA and TOLEDO (2002) say so and suggested how: using the technique of Design for Manufacture and Assembly is possible to “hear the voice of the production line” and been virtually near to the information. BUSS et al. (2001) agreed with this point of view, saying that the DFMA allows bring to the project area the considerations related to the assembly and manufacturability of the product.

Finally FAGADE and KAZMER (1998) defended that the most significant advantage of DFMA is the encouragement of the teamwork between project and production, improving the reliability of the final product and generating the possibility of cost/time to deliver reductions due decreasing in the parts number and/or more productive parts that can accelerate processes. Now the perspective is clearer: is understood why use a Production Oriented Design and how implement this using the DFMA.

2.3 ANALYSIS ON FINITE ELEMENT

The Finite Element Method is one of most important in developments computation methods. Within few decades, this technique has involved from applications in structural engineering to most of computational approach for science and technology areas. For many purpose computations, class of finite elements are researched and developed into finite analysis program. The formulations, element stiffness and mass matrices of finite beam elements which are based on Euler or Timoshenko beam theory are presented on the most text books about finite element method. Other the finite element which is frequently in used in structural, architectural and mechanical engineering - thin shell element. Despite the fact that for over year, intense interest has been focused on the development of shell finite element, there is still some dissatisfaction with available methodology. Currently, a number of research efforts are directed at depending and understanding of and improving shell finite element capabilities. Many different approaches have been developed in finite element shell analysis.

In 1979 W.K Nukulchai have been suggested the Bilinear Degenerated Shell (BDS) element. This element is developed based on a degeneration concept, in which the displacement and rotation of the shell mid-surface are independent variables. Bilinear functions are employed in conjunction with a reduced integration of transverse shear energy. The advantages of BDS element are simple, efficient and versatile; it is used in much finite element software.

K.J Bathe, E. Onate proposes a triangular element for thick and thin plate and shell analysis. It is base on Reissner-Mindin theory and has standard linear deflection field and incompatible linear rotation field expressed in term of the mid-side rotation. Numerical examples are presented for range of plate and shell problems are good performance. For the analysis of large structural system, the methods subtracting and reductions have been developed. The system (or structure) is divided into number of parts, each called a substructure. The global matrices of structure are assembled from matrices of each substructure. Main advantages of these methods are the number of these equations much be less compared to the total number of unknowns viz. computing cost and accumulative error of the system will be reduced.

Until now, much available powerful Finite Element Analysis software can carry out analysis a very complex structure and widely used to solve a class of structural problems in engineering areas such as SAMCEF, ANSIS, SAP90 etc., The structure can be constructed from various kind of elements, complex boundary and loading,. In the practical design steel frame, a number of studies (Goverdan, 1984; Nethercot, 1985; Chen and Kishi, 1986) indicate simple connection posses no negligible stiffness and ultimate moment capacity are semi-rigid. Furthermore, these connections may in general undergo large rotation enabling the member to achieve the ultimate limit state. In many instances joint behavior involves a sufficient degree of continuity to affect significantly the internal stress state and the deformation of the frame (Anderson).

CHAPTER 3

METHODOLOGY

3.0 INTRODUCTION

Project methodology is one of the most important parts in this project. The objective of project methodology is to draft the flow of experiment to be done from beginning until the testing is conducted to the specimen to determine the output of the buckling test when the combination of the joint are fixed and pinned. In this project, the materials that have been chosen are hollow iron or steel, aluminium bar, and galvanic iron. There are few steps in designing and fabricate of a lateral bending (buckling) test equipment. First, cut the rectangular hollow iron or steel with disc cutter. Make sure the measurement are 40cm each, for 8 pieces and the dimensions are 1.5' x 1.5'. Second, combine the rectangular hollow steel by using welding to make it in square. Do it twice for top and bottom. Third, by using grinding machine, the surface of the rectangular hollow iron will be smoother. Fourth, measured 4 pieces of L shaped iron steel; 8cm height and dimensions are 1.0' x 1.0'.Then, start welding it again to build the structure. After that, cut 4 pieces of sheet metal; 80cm x 40 cm measurements, then continue with welding it to the structure. Next steps, by using milling machine, design aluminium so that the solid aluminium can go through into it. Then, by using 8cm x 4 pieces of 0.5 Aluminium plat test the buckle weather it will produce an output or not when load is applied on it. The output produced will be compared to the stimulation result. The conclusion will be made at the end of the experiment weather this project was success or failed. Figure 3.1 shows the Process flow of Final Year Project.

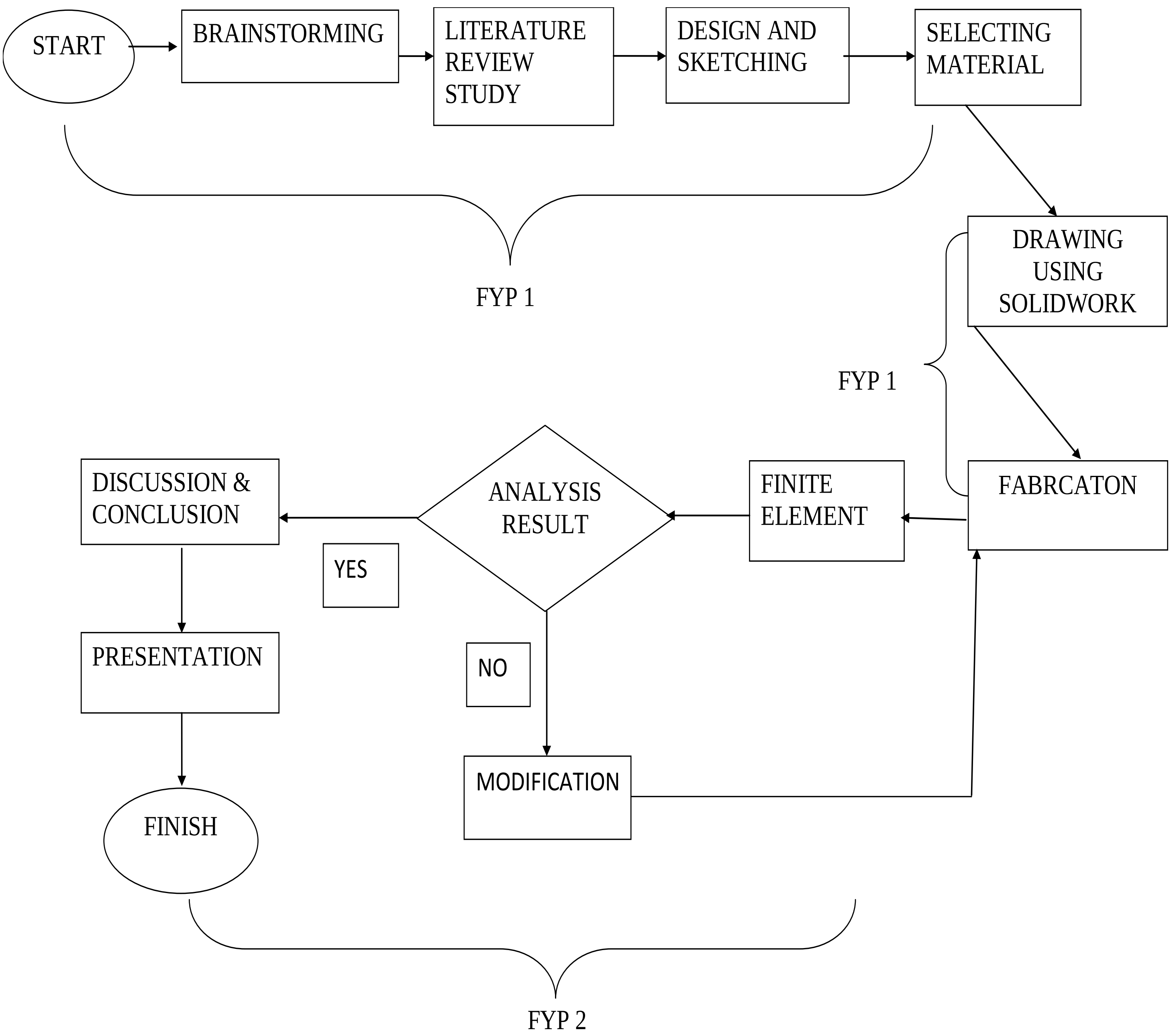


Figure 3.1 Process flow of Final Year Project

3.1 MATERIAL PREPARATION

For material preparation, there consists three parts. Firstly, select the best raw material for the project. Secondly, arrange an appropriate activity so that this project can be completely done before the due date. Thirdly, choose the right machine for the right method.

3.1.1 Hollow Iron or Steel

A hollow structural section (HSS) is a type of metal profile with a hollow tubular cross section. In some countries they are referred to instead as a structural hollow section (SHS).Most HSS are of circular or rectangular section, although other shapes are available, such as elliptical. HSS is only composed of structural steel per code. HSS is sometimes mistakenly referenced as hollow structural steel. Rectangular HSS are also called tube steel or structural tubing. Circular HSS are sometimes mistakenly called steel pipe though true steel pipe is actually dimensioned and classed differently than HSS. The corners of HSS are heavily rounded, or chamfered, at radii approximately twice the wall thickness.

The wall thickness is uniform around the section. HSS, especially rectangular sections, are commonly used in welded steel frames where members experience loading in multiple directions. Square and circular HSS have very efficient shapes for this multiple-axis loading as they have uniform geometric and thus uniform strength characteristics along two or more cross-sectional axes; this makes them good choices for columns. They also have excellent resistance to torsion. HSS can also be used as beams, although wide flange or I-beam shapes are in many cases a more efficient structural shape for this application. However, the HSS has superior resistance to lateral torsion buckling. The flat square surfaces of rectangular HSS can ease construction, and they are sometimes preferred for architectural aesthetics in exposed structures, although elliptical HSS are becoming more popular in exposed structures for the same aesthetic reasons. HSS is commonly available in mild steel, such as A500 grade B. Figure 3.2 shows the **e**xample on hollow iron/steel.

Figure 3.2: Example on hollow iron/steel

The rectangular hollow iron/steel will be cut with disc cutter. The measurement are 40cm each, for 8 pieces and the dimensions are 1.5' x 1.5'. Figure 3.3 shows the example on hollow iron/steel after been welding while Figure 3.4 above shows example on welding process on hollow iron/steel.

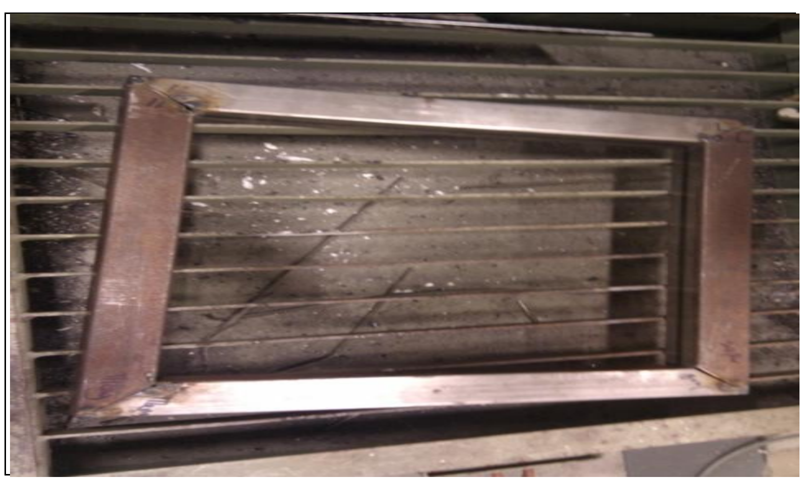


Figure 3.3: Example on hollow iron/steel after been welding

The table below showed the dimensions and properties of rectangular hollow bar sections.

Table 3.1: Dimensions and properties of rectangular hollow bar sections.

Sr. No.	Size (MM)	Wall Thickness (MM)
1.	25 x 15	0.80 MM to 1.20 MM
2.	35 x 15	0.80 MM to 1.20 MM
3.	40 x 20	0.80 MM to 3.00 MM
4.	40 x 25	1.00 MM to 3.00 MM
5.	40 x 30	1.20 MM to 3.00 MM
6.	50 x 15	1.20MM to 3.00 MM
7.	50 x 25	1.50 MM to 3.00 MM
8.	60 x 40	1.50 MM to 3.00 MM
9.	62 x 32	1.50 MM to 3.00 MM
10.	80 x 40	2.00 MM to 5.00 MM
11.	125 x 75	4.00 MM to 6.00 MM
12.	150 x 50	4.00 MM to 6.00 MM

Figure 3.4: Example on welding process on hollow iron/steel

3.1.2 L Shaped Iron Steel

The L shaped iron steel will be measured 8cm height and dimensions are 1.0’ x 1.0’and cut for 4 pieces. The iron steel ability are very good strength, rust resistance, made of galvanized sheet, cauterization resistance, ceiling T-bar and ceiling suspension the L shaped iron steel is widely used in steel purlins, wall beams which can be combined into its own light weight roof trusses, brackets, and other building components. In addition, light manufacturing machine can be used in the columns, beams and arms and so on. L shaped iron steel is formed by pressing the high strength steel plate, so the specification and size is adjustable. After cold bending process, compressive strength is big, the size of cross section is dexterous, so that it conforms to the purlin stressed characteristic to enable the steel products mechanics potency to be fully displayed. It is possible to reduce the roof weight of constructions and, reduces the project to use the amount of steel. Figure 3.5 shows the example of L shaped iron steel

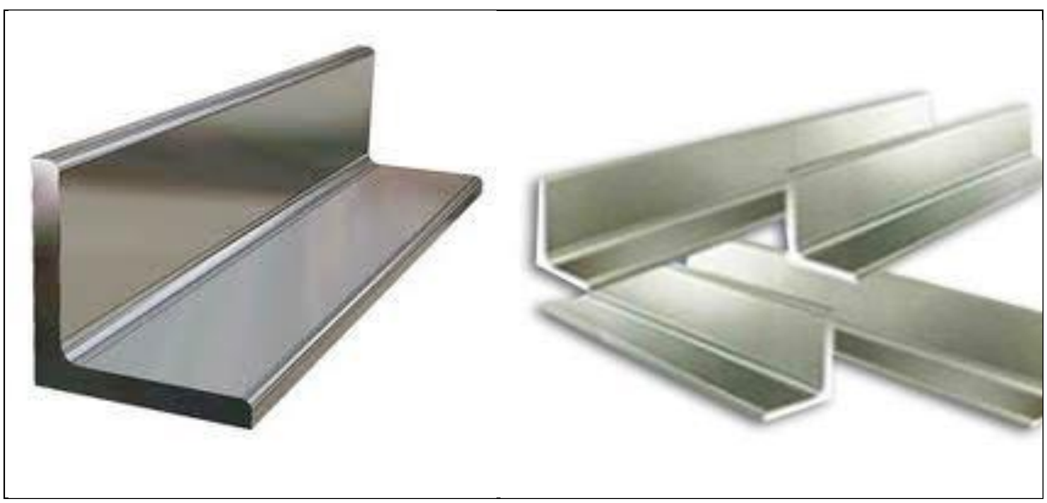


Figure 3.5: Example of L shaped iron steel

Structural steel is steel construction material, a profile, formed with a specific shape or cross section and certain standards of chemical composition and mechanical properties. Structural steel shape, size, composition, strength, storage, etc., is regulated in most industrialized countries. Structural steel members, such as I-beams, have high second moments of area, which allow them to be very stiff in respect to their cross-sectional area.

3.1.3 Sheet Metal

Sheet metal is simply metal formed into thin and flat pieces. It is one of the fundamental forms used in metalworking, and can be cut and bent into a variety of different shapes. Countless everyday objects are constructed of the material. Thicknesses can vary significantly, although extremely thin thicknesses are considered foil or leaf, and pieces thicker than 6 mm (0.25 in) are considered plate. The sheet metal must been cut into 4 pieces where the measurement are 80cm x 40cm. Sheet metal is available in flat pieces or as a coiled strip. The coils are formed by running a continuous sheet of metal through a slitter. The thickness of the sheet metal is called its gauge. The gauge of sheet metal ranges from 30 gauge to about 8 gauge. The larger the gauge number, the thinner the metal. There are many different metals that can be made into sheet metal, such as aluminum, brass, copper, steel, tin, nickel and titanium. For decorative uses, important sheet metals include silver, gold, and platinum (platinum sheet metal is also utilized as a catalyst.)

Sheet metal has applications in car bodies, airplane wings, medical tables, roofs for buildings and many other things. Sheet metal of iron and other materials with high magnetic permeability, also known as laminated steel cores, has applications in transformers and electric machines. Historically, an important use of sheet metal was in plate armor worn by cavalry, and sheet metal continues to have many decorative uses, including in horse tack. Figure 3.6 shows the example on sheet metal.

Figure 3.6: Example on sheet metal

3.1.4 Aluminium

The four most common aluminium grades available as sheet metal are 1100-H14, 3003-H14, 5052-H32, and 6061-T6. Grade 1100-H14 is commercially pure aluminium, so it is highly chemical and weather resistant. It is ductile enough for deep drawing and weld able, but low strength. It is commonly used in chemical processing equipment, light reflectors, and jewelry.

Grade 3003-H14 is stronger than 1100, while maintaining the same formability and low cost. It is corrosion resistant and weld able. It is often used in stampings, spun and drawn parts, mail, cabinets, tanks, and fan blades. Grade 5052-H32 is much stronger than 3003 while still maintaining good formability. It maintains high corrosion resistance and weld ability. Common applications include electronic chassis, tanks, and pressure vessels. Grade 6061-T6 is a common heat-treated structural aluminium alloy. It is weld able, corrosion resistant, and stronger than 5052, but not as formable. Note that it loses some of its strength when welded. The used of Grade 3003-H14 is to make solid aluminium holder. The design of solid aluminium holder will be made by milling process. Then, it will be pinned to the structure. The solid aluminium is being cut by band saw.

Aluminium is a silvery white member of the boron group of chemical elements. It has the symbol Al, and its atomic is 13. It is not soluble in water under normal circumstances. Aluminium is the third most abundant element (after oxygen and silicon), and the most abundant metal, in the Earth's crust. It makes up about 8% by weight of the Earth's solid surface. Aluminium metal is too reactive chemically to occur natively. Instead, it is found combined in over 270 different minerals. The chief ore of aluminium is bauxite. Aluminium is remarkable for the metal's low density and for its ability to resist corrosion due to the phenomenon of passivation. Structural components made from aluminium and its alloys are vital to the aerospace industry and are important in other areas of transportation and structural materials. The most useful compounds of aluminium, at least on a weight basis, are the oxides and sulfates.

Despite its prevalence in the environment, aluminium salts are not known to be used by any form of life. In keeping with its pervasiveness, it is well tolerated by plants and animals. Because of their prevalence, potential beneficial (or otherwise) biological roles of aluminium compounds are of continuing interest. Figure 3.7 shows the example of aluminium materials.

Figure 3.7: Example of aluminium

3.2 EQUIPMENT PREPARATION

For the equipment preparation, the material needed must be prepared well so that there is no mistake while the experiment being conducted.

3.2.1 Disc Cutter

The rectangular hollow iron/steel will be cut with disc cutter. The disc cutter models used are HITACHI CC 14SP. Figure 3.8 shows example of cutting disk while Figure 3.9 shows the example of using cutting disk.

Figure 3.8: Examples of cutting disk (Model HITACHI SS 14SF)

The HITACHI SS14SF cutting disks are example of speed-cut off machine. The weights of these models are around 19kg and its manufacture by HITAQCHI Company. The cutting disk specifications:

<u>Features</u>:

i. Powerful Hitachi motor 2000W/230V
ii. Soft Grip D-Handle for easy operation
iii. Quick locking vise for easy clamping
iv. Trigger switch with lock-off button and spark-chute (diversion-guard) for operators safety
v. Spindle lock for easy wheel replacement
vi. Double Insulation

Specifications:

Wheel Diameter: 355mm (14") Reinforced resinoid cut-off wheel

Wheel Arbor: 25.4mm (1")

Capacity: Bar Dia. 65mm (2-9/16")

Pipe Dia. 120mm (4-47/64")

Shape Steel (W x H) 130mm x 115mm (5-1/8" x 4-1/2")

235mm x 70mm (9-1/4" x 2-49/64")

Power Input: 2,000W / AC 230V

No-Load Speed: 3,800 /min.

Dimensions: (L x W x H) 603 x 318 x 603 mm (23-47/64" x 11-7/32" x 23-47/64")

Standard Accessories: 1 Cut-Off Wheel; 1 Hex. Bar Wrench

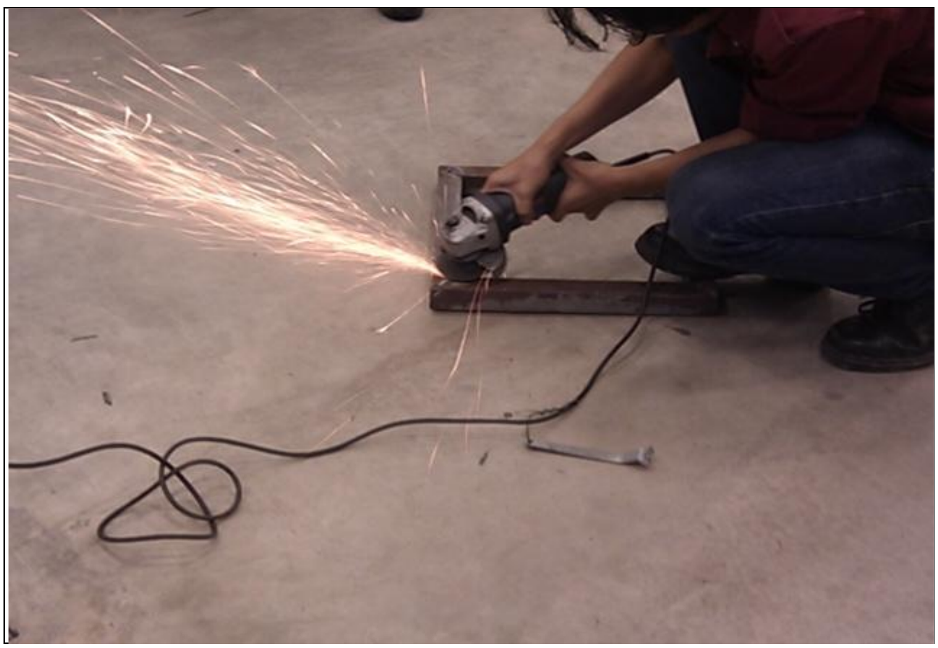


Figure 3.9: Example of using cutting disk (Model HITACHI SS 14SF)

3.2.2 Band saw

A band saw for cutting off slices from a work piece includes a saw band which circulates over a system of pulleys and has a band back and a cutting edge, which is situated opposite to the band back and is provided with a cutting surface. There is also a feed system, which effects a relative movement between the work piece and the cutting edge, so that the saw band penetrates into the work piece, thus forming a cutting gap. The band saw has a support plate, which supports the band back and is held by a holding device. There is also a process for cutting off slices from a work piece using this band saw. A part of the support plate, which part adjoins the band back, also penetrates into the cutting gap during the cutting of the work piece.

The present invention is also directed to a process for cutting off slices from a work piece using a band saw with a circulating saw band and said saw band having a band back and having a cutting edge with a cutting surface comprising the steps of using said band saw for circulating said saw band for causing said cutting edge to penetrate into said work piece for cutting a cutting gap within said work piece; supporting the circulating saw band back by a support plate; and having a part of the support plate which part is supporting the band back, also penetrating into the cutting gap.

The support plate, which also penetrates at least partially into the cutting gap, stabilizes the saw band. Thus, it is possible to use even saw bands with a small cross-sectional thickness; and thus the waste material produced can be kept to a minimum amount. The support plate furthermore makes it possible to hold the saw band in the planned cutting plane, so that a cutting path which is as planar as possible is achieved. The support plate moreover makes it possible to operate at high feed rates which further improve the economic efficiency of the process.

3.3 SAMPLE PREPARATION

For sample preparation part, each material must be prepaid early so that the process can be done on schedule and avoid unwanted error.

3.3.1 Preparation of sheet metal process

The raw material obtained is in sheet metal. The material is cut into 80cm x 40 cm x 4 pieces. This can be done by using MSV-C shear cutting machine shown in Figure 3.10.

Figure 3.10: MVS-C shear cutting machine

Parameters for shearing cutting machine that used to cut the materials are:

i. Blade clearance – 25 mm
ii. Rake angle - 1°

Sheet metal is simply metal formed into thin and flat pieces. It is one of the fundamental forms used in metalworking, and can be cut and bent into a variety of different shapes. Countless everyday objects are constructed of the material. Thicknesses can vary significantly, although extremely thin thicknesses are considered foil or leaf, and pieces thicker than 6 mm (0.25 in) are considered plate.

3.3.1 (a) Sheet metal processing

The raw material for sheet metal manufacturing processes is the output of the rolling process. Typically, sheets of metal are sold as flat, rectangular sheets of standard size. If the sheets are thin and very long, they may be in the form of rolls. Therefore the first step in any sheet metal process is to cut the correct shape and sized 'blank' from larger sheet.

3.3.1 (b) Sheet metal forming processes

Sheet metal processes can be broken down into two major classifications and one minor classification:

(i) Shearing processes -- processes which apply shearing forces to cut, fracture, or separate the material.

(ii) Forming processes -- processes which cause the metal to undergo desired shape changes without failure, excessive thinning, or cracking. This includes bending and stretching.

(iii) Finishing processes -- processes which are used to improve the final surface characteristics.

Figure 3.11 shows shearing operations which is punching, blanking and perforating and Figure 3.12 shows common die-bending operations.

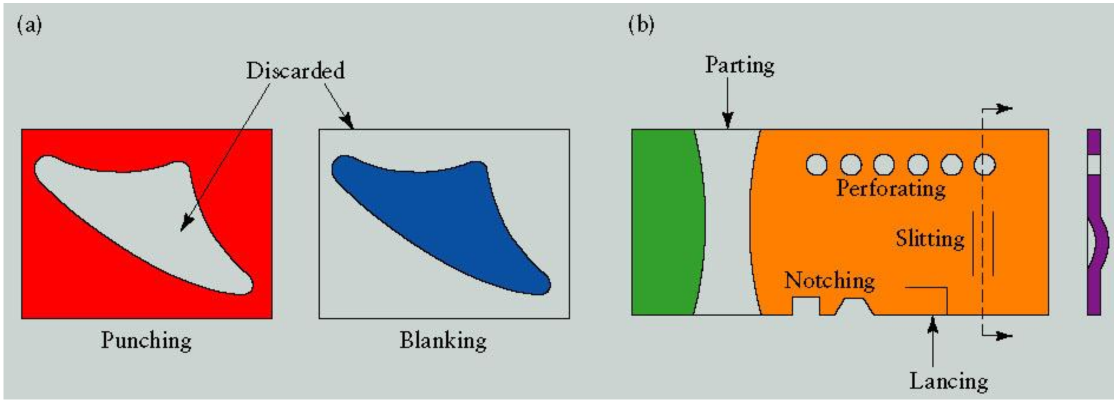


Figure 3.11: Shearing Operations: Punching, Blanking and Perforating

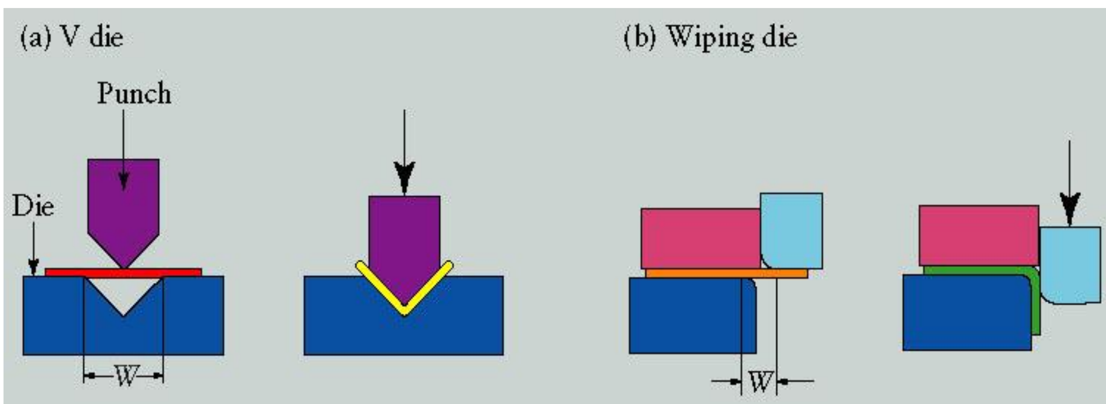


Figure 3.12: Common Die-Bending Operations

3.3.1 (c) Finishing process

Material properties, geometry of the starting material, and the geometry of the desired final product play important roles in determining the best process that involved.

3.3.2 Preparation of welding process

A weld occurs when pieces of metal are joined by causing the interface to melt and blend prior to solidifying as a uniform metal joint. This process may be caused by heat, pressure or a combination of both. When heat alone is used the process is called fusion welding. Pressure welding usually involves heating the surfaces to a plastic state and then forcing the metal together. The heating can be by electric current of by friction resulting from moving one surface relative to the other. The methods and equipment used for welding metal are also associated with cutting metal. There are a large number of welding and allied processes. The Table 3.2 provides a short introduction to some of the welding process.

Table 3.2: Welding process

Welding Processes						
Soldering	Brazing	Gas Welding	Arc Welding	Resistance Welding	Solid State Welding	Other Welding

Table 3.3: Allied process

Allied processes						
Adhesive Bonding	Thermal Spraying	Oxygen Cutting	Thermal Cutting	Arc Cutting	Electron Beam Cutting	Laser Cutting

The Table 3.3 provides a short introduction to some of the allied process. From the experiment, the low carbon steel is most suitable for spot welding. Higher carbon content or alloy steels tend to form hard welds that are brittle and could crack. This tendency can be reduced by tempering. Austenitic Stainless steels in the 300 series can be spot welded as also the Ferritic stainless steels. Martensitic stainless steels are not suitable since they are very hard. Aluminums can be welded using high power and very clean oxide free surfaces.

Cleaning the surface to be oxide-free, adds extra costs (that can be avoided with low carbon steel).

Dissimilar materials cannot be spot welded due to different melt properties and thermal conductivities. Plated steel welding takes on the characteristics of the coating. Nickel and chrome plated steels are relatively easy to spot weld, whereas aluminum, tin and zinc need special preparation inherent to the coating metals.

Figure 3.13: Welding area and machine

Figure 3.13 shows a welding area and machine involved. In this project, welding is used to joint two dissimilar materials which are aluminum and iron steel as shown in Figure 3.4.2(c). This welding machine is limited to 6A~350A of its current, and 20.2V~35V of voltage. All the parameters of welding that involved have shown in Table A and Table B. The arc current and welding voltage are the variable parameters, while welding speed and welding gun angle are the fix parameters.

In all welding joint processes heat is applied to or produced at the joint and heated surfaces are brought into close contact, as result the joint surfaces to grow together into single body. Now we will see what happen during this growing up together process. It is we all known that the matter is made of molecules which in turn into atom. The atoms of molecules are become active when the temperature of material reaches absolute zero (-2730C). At that time the molecules are moves with vibratory motion. In the higher temperature the vibratory motions of atoms is greater. During welding temperature it is sufficient to allow the atoms to make a bridge for the closely contacting surfaces. Thus there is an exchange of atoms among the molecules of the surfaces to be joined. Through this exchange of molecules of one surface interlock with adjacent other surface and this process that have been joined. Figure 3.16 shows sheet metal after welding processand 3.17 shows welding road.

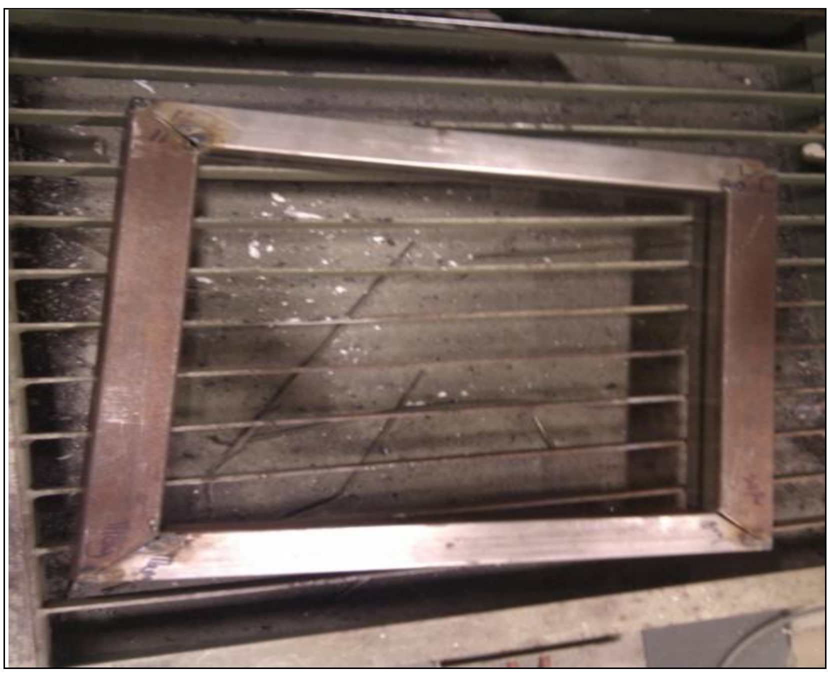


Figure 3.14: After welding process

Figure 3.15: Welding rod

3.3.3 Preparation of grinding process

For material removal, the method used in grinding is called abrasion. In other words, in grinding, an abrasive material rubs against the metal part and clears or removes tiny pieces of material. The process implies that instead of cutting like a lathe bit, the material is slowly and steadily worn away. This is because compared to the material being ground, the abrasive is harder. The grinding wheel actually acts like many hundreds of very small lathe bit, each cutting off some metal. The abrasive must be strong enough to bear any kind of forces acting upon it while grinding. Usually some sort of impact shock occurs when the abrasive comes in contact with the material. Grinding abrades material in a way similar to sanding. The grinding operation is performed on a several machines like the lathe and the mill, with the appropriate add-on accessories, the most important of which is the spindle.

Grinding is necessary because the material is too hard to be machined economically. If the surface is adequately supported, grinding can produce flatness tolerances of less than ±0.0001 in. (±0.0025 mm) on a 5 x 5 in. (127 x 127 mm) steel surface. Machining removes excessive material. Grinding should be used when size tolerance specifications are beyond the capability of turning. It is also applied if the requirements of surface finish are too tight for hard turning.

Grinding can be of various types, Surface grinding, Centred grinding, Centred less grinding and Contour grinding this is perhaps the most fundamental of operations. Surface grinding is the process of providing precision ground surfaces either to a critical size or for the surface finish. In other words, it accurately processes or grounds a surface. Parts require surface grinding for various reasons such as to produce a flat surface, for specifying accurate tolerance thickness, A very smooth surface roughness is required and for sharpening of cutting tool. Figure 3.18 shows grinding machine process.

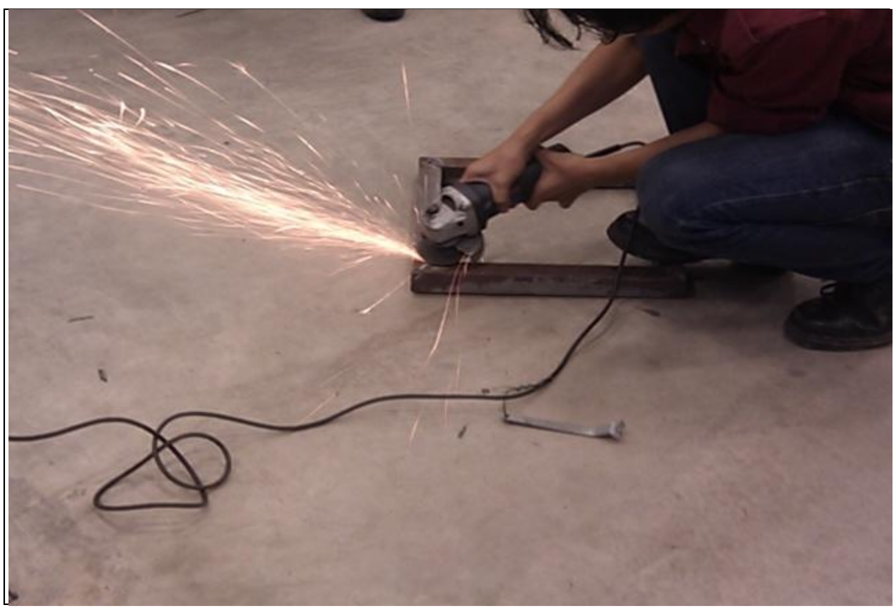


Figure 3.16: Grinding machine process

3.3.4 Preparation of Milling Process

Milling is the most common form of machining, a material removal process, which can create a variety of features on a part by cutting away the unwanted material. The milling process requires a milling machine, work piece, fixture, and cutter. The work piece is a piece of pre-shaped material that is secured to the fixture, which itself is attached to a platform inside the milling machine. The cutter is a cutting tool with sharp teeth that is also secured in the milling machine and rotates at high speeds. By feeding the work piece into the rotating cutter, material is cut away from this work piece in the form of small chips to create the desired shape. For this project, the aluminium bar must be designed so that it will become holder that can be pinned to the structure. Then, solid aluminium can get through on it when the load applied. Figure 3.17 shows example of aluminium milling process.

Figure 3.17: Example of aluminium milling process

Milling is typically used to produce parts that are not axially symmetric and have many features, such as holes, slots, pockets, and even three dimensional surface contours. Parts that are fabricated completely through milling often include components that are used in limited quantities, perhaps for prototypes, such as custom designed fasteners or brackets. Another application of milling is the fabrication of tooling for other processes. For example, three-dimensional molds are typically milled. Milling is also commonly used as a secondary process to add or refine features on parts that were manufactured using a different process. Due to the high tolerances and surface finishes that milling can offer, it is ideal for adding precision features to a part whose basic shape has already been formed.

Figure 3.20 shows example of milling machine and figure 3.21 shows Milling machine model (VMM 3917 PARTNER).

Figure 3.18: Example of milling machine

Figure 3.19: Milling machine model (VMM 3917 PARTNER

CHAPTER 4

DESIGN AND FABRICATION

4.0 INTRODUCTION

This chapter presents the design, fabrication and testing a product on buckling test. The result and discussion of the test will be shown in chapter 6, which is analysis and discussion chapter. My case is to study how the bending (buckling) test equipment looks like when the combination of the joint are fixed and pinned. This chapter explain how the design looks like, how the test rig fabricates also failure and error during the test is going on. If a rod is subjected to longitudinal forces, as implied in the sketch, it can fail in two ways. On the one hand, it can be plasticized and flattened if its admissible compressive strain is exceeded .Plus, it is possible that it will suddenly shift to one side and buckle before attaining the admissible compressive strain. This effect is called buckling. The shape of the rod is the factor determines which of the two cases of failure will occur. The different case must be applied to the test rig so that the entire factor can be determined. The displacement of the aluminium buckling also will be measured. Figure 4.1 shows condition on the test rig which is combination of fixed and pinned condition.

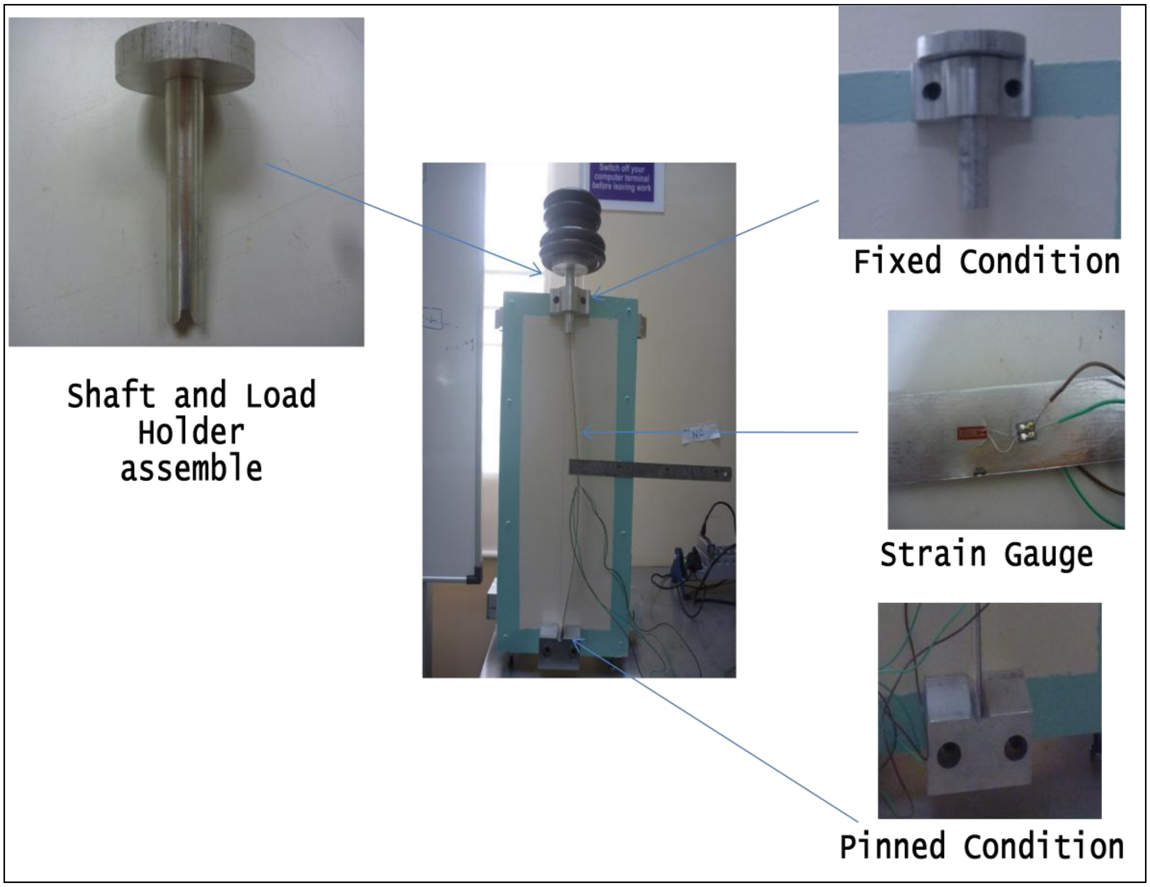


Figure 4.1: Condition on the test rig which is combination of fixed and pinned condition.

4.1 MATERIAL DESIGNS

The designs of the test rig are as shown above. There are several materials needed for combination part such as upper hub, load holder, base and top, shaft, pillar, stand and wall. From the material designs analysis, the material composition, parameters and the strength of the material must be analysis first. The best materials must be choosing so that there are no problems and difficulties occurred while this experiment is done. On the other hand, all the material are said to be easy to get and fabricate. The first step of the investigation was to choose the lengths of the specimens to be tested. These lengths were decided on the basis of results of linear buckling analyses performed by means of the Finite Element Method. The finite element models included the perforations of the members and the boundary conditions of the experimental tests. It should be pointed out that the tests were performed with two different end supports.

Firstly, all sections were tested with pinned member ends. In this case, the specimens were pinned with respect to the flexural modes of buckling, and pinned with respect to torsion and distortional buckling (from now on these specimens will be called pinned specimens). Table 4.1 shows quantity and measurement for each part.

Table 4.1: Quantity and measurement for each part

Part	Material	No part	Length (mm)	High (mm)	Width (mm)	Thickness (mm)
Top	Hollow bar	4	400	38.1	38.1	5
Base	Hollow bar	4	400.0	50.8	50.8	5
Wall	Sheet metal	1	400.0	800.0	5.0	
Pillar	L-shape	4	25.4	800.0	25.4	3
Upper hub	Aluminium	4	150.0	38.1	40.0	
Stand	Hollow bar	4	400.0	50.8	38.1	
Shaft	Aluminium	4	Diameter 15mm x high 8 mm			
Load holder	Aluminium	4	Diameter 50 mm x high 15 mm			

4.2 PART FABRICATION

For part fabrication, each material must be fabricated clearly so that the assembly part can be done. Each part consist its own measurement and quantity involved.

4.2.1 Upper hub

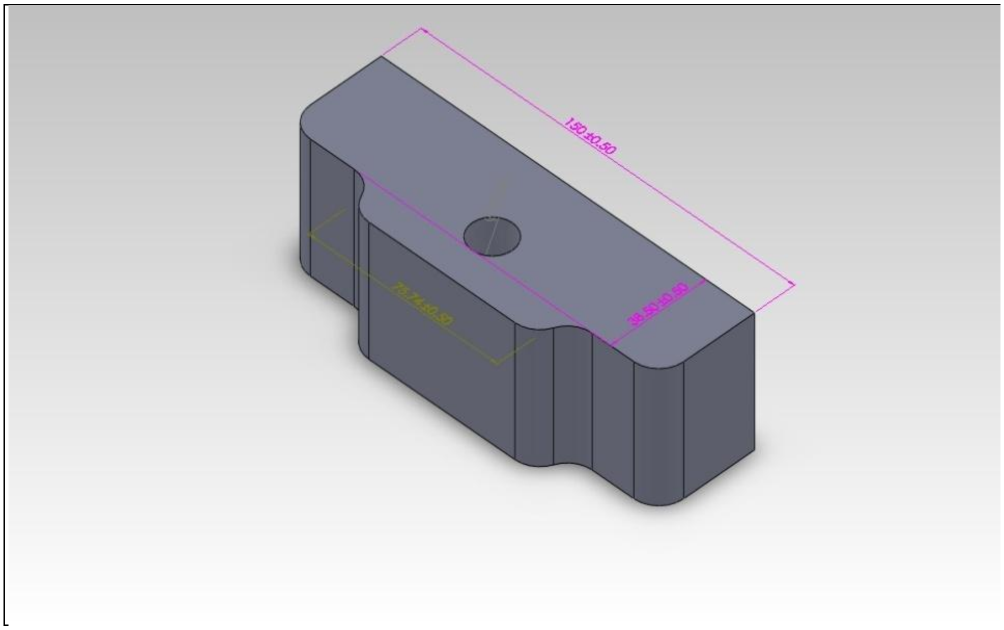


Figure 4.2: Upper hub part

Figure 4.2 shows the upper hub part. For the upper hub part, the material made is from aluminium. The designs of this part are by using CNC machine and Milling machine. For the hollow part, Milling machine and Drilling machine will take part. The design on shape takes a bit longer time because the centre of the shape must be hole first so that it can easily drill the hole later. If it is not centre yet, it will effect on the design, do shaping on CNC machine again and it wasting time. For finishing part, the Grinding machine must take part. The dimension of the upper hub is 150 mm x 38.1 mm x 40 mm. The upper hub must been create four pieces because each case need upper hub.

4.2.2 Load holder

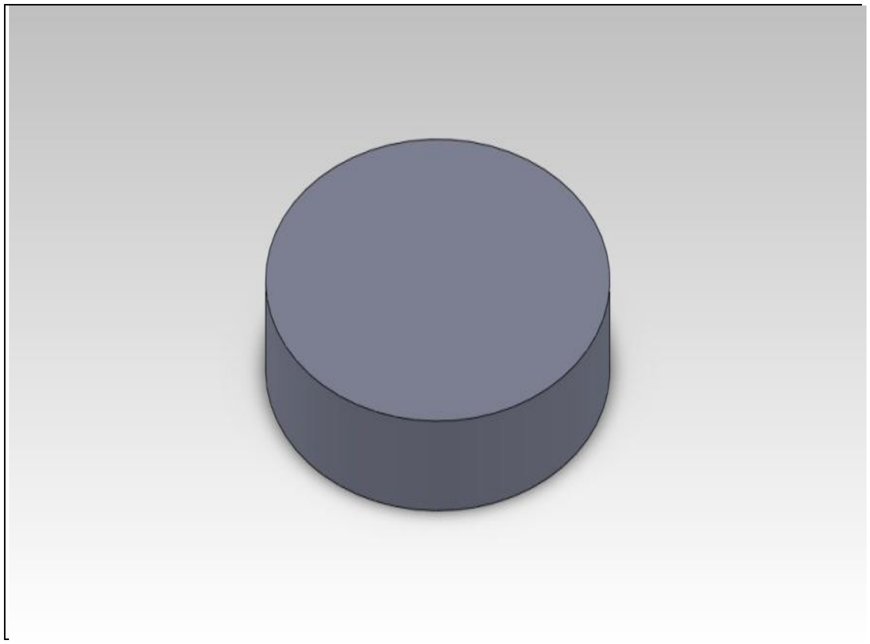


Figure 4.3: Load Holder part

Figure shows load holder part .For the load holder part, the material made is also from aluminium. It will be design by using Turning machine and Milling machine. For finishing part, the Grinding machine must take part. The dimension of the load holder is 50 mm x 15mm. The load holder part must be done on four pieces because each case need load holder.

4.2.3 Base and Top

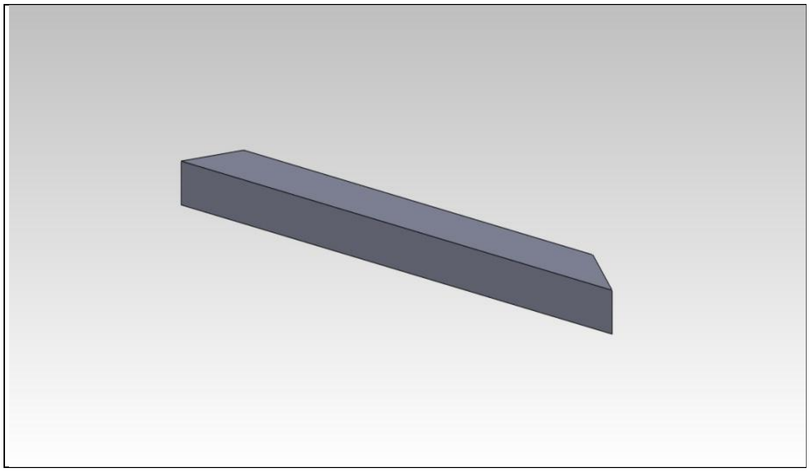


Figure 4.4: Base part

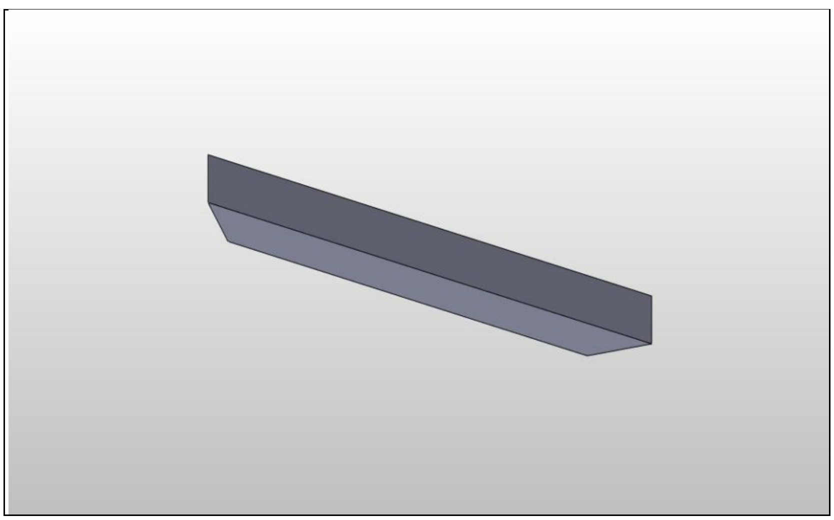


Figure 4.5: Top part

Figure 4.4 shows base part while figure 4.5 shows top part. For figure 4.6, its shows combination of base part while for figure 4.7, its shows combination of tops part.

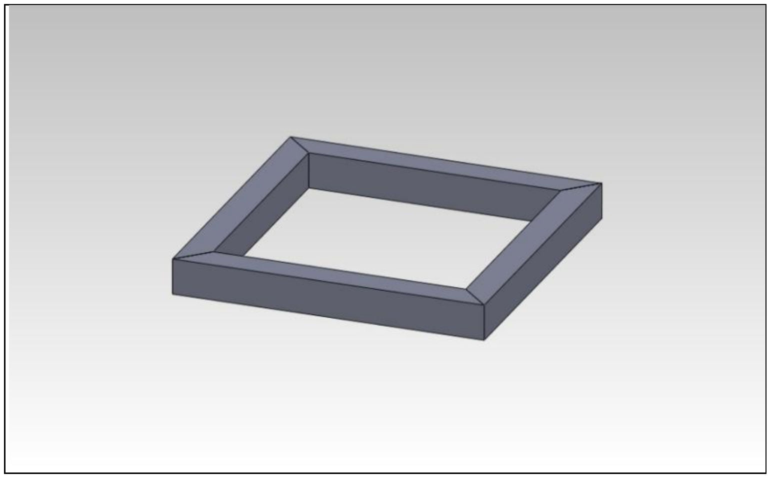


Figure 4.6: Combination of base parts

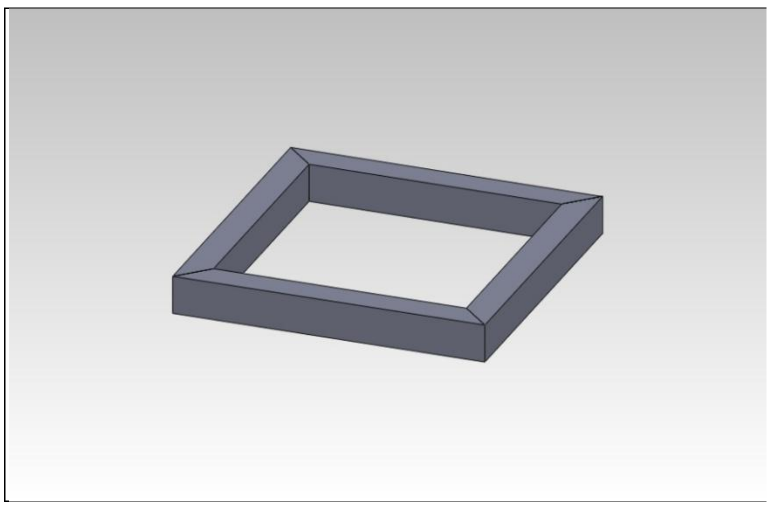


Figure 4.7: Combination of top parts

For the base and top part, the material made is from hollow bar. It will be designed by using disc cutter machine and bend saw. For finishing part, the Grinding machine must take part. The dimension of the base part is 400 mm x 50.8mm x 50.8 mm while for top part 400 mm x 38.1 mm x 38.1 mm. Both of base and top parts have 5 mm thickness. For base and top part, each part must be build four pieces because each case needs both base and top. Make sure base part bigger than top part in order to make sure the design tougher and not easily to collapse.

4.2.4 Shaft

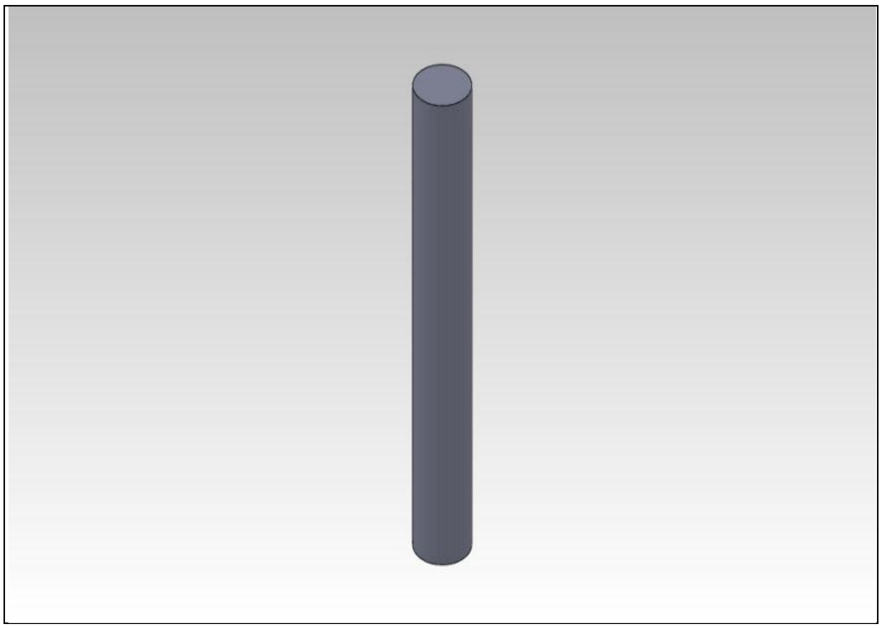


Figure 4.8: Shaft part

Figure 4.8 shows shaft part. For the shaft part, the material made is also from aluminium. It will be designed by using Turning machine and Milling machine. For finishing part, the turning machine also must take part. The dimension of the shaft is 15 mm x 8mm and must be build four parts because each case need shaft.

4.2.5 Pillar

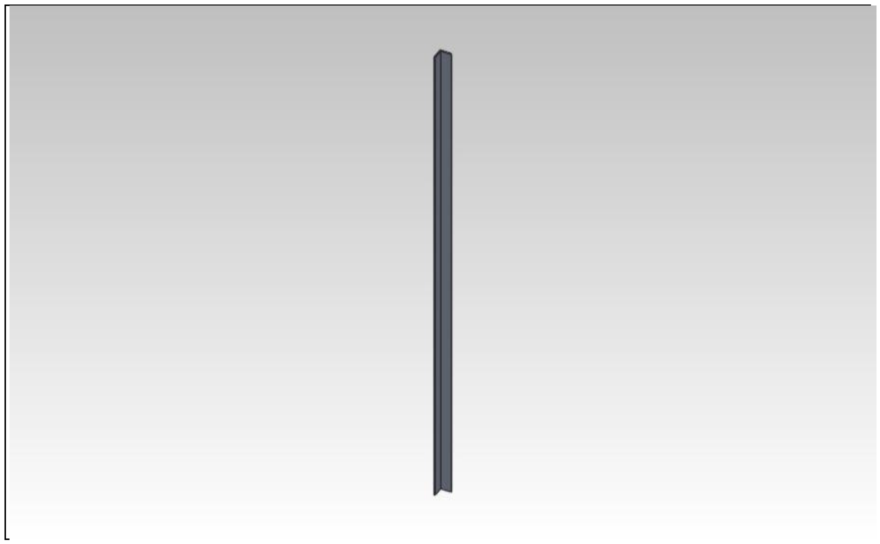


Figure 4.9: Pillar part

Figure 4.9 shows pillar part. For the pillar part, the material made is from L-shape. The design of the pillar is by disc cutter machine and bend saw. For finishing part, the Grinding machine must take part. The dimension of the pillar is 25.4mm x 800 mm x 25.4mm. The thickness of the pillar is 3mm. The pillar must be build four pieces because each case need pillar.

4.2.6 Wall

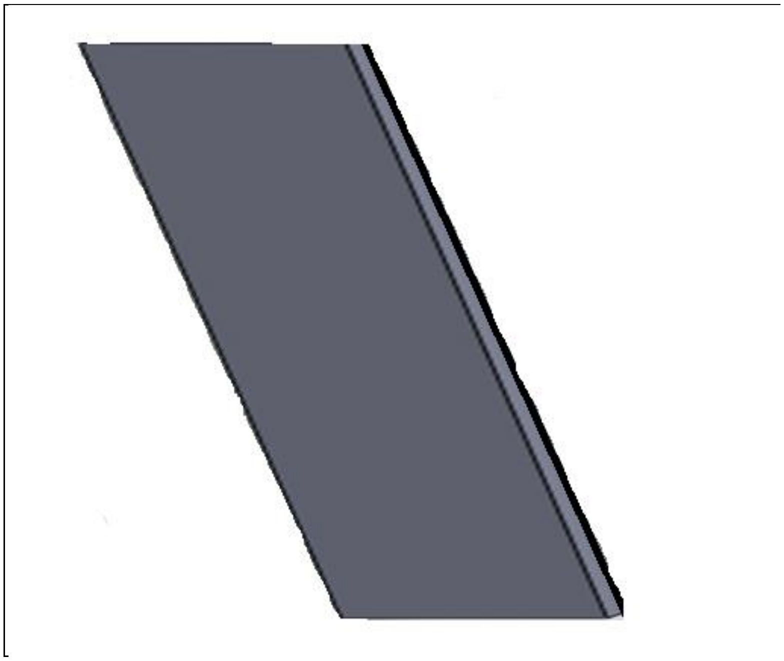


Figure 4.10: Wall part

Figure 4.10 shows wall part. For the wall part, the material made is from sheet metal. The design for the wall is using shearing machine and disc cutter. For finishing part, the Grinding machine must take part. The dimension of the wall is 400 mm x 800 mm x 5 mm. The wall also must be done four pieces because each case need wall.

4.2.7 Stand

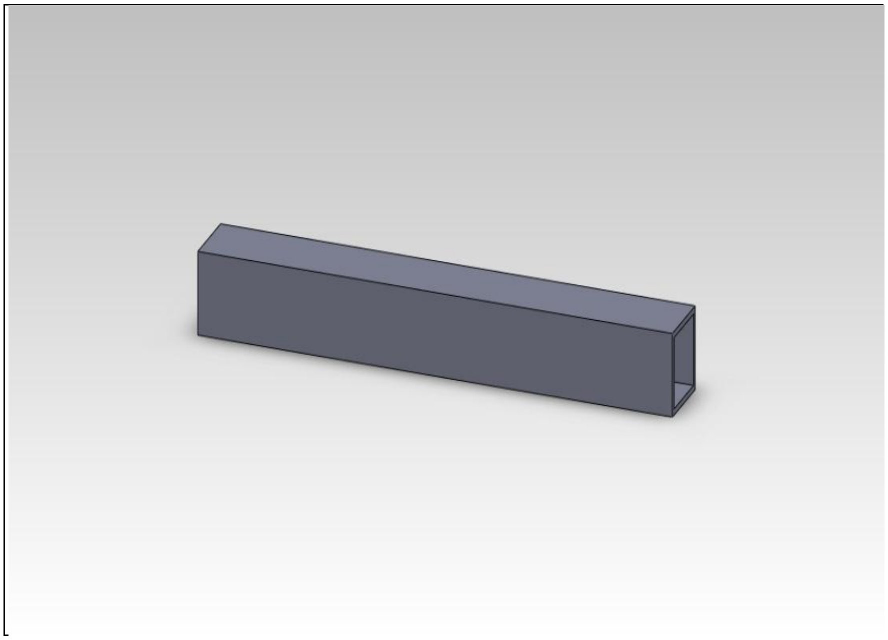


Figure 4.11: Stand part

Figure 4.11 shows stand part. For the stand part, the material made is from aluminium. The design for this part is by using Milling machine and disc cutter. For finishing part, the Grinding machine must take part. The dimension of the stand is 400 mm x 50.8 mm x 38.1 mm. The stand parts must be done four pieces as well as each case need stand.

4.3 PART ASSEMBLY

For part assembly, this part must be finish properly and follow the order so that the final design on perfect test rig will be on schedule.

4.3.1 Base and top

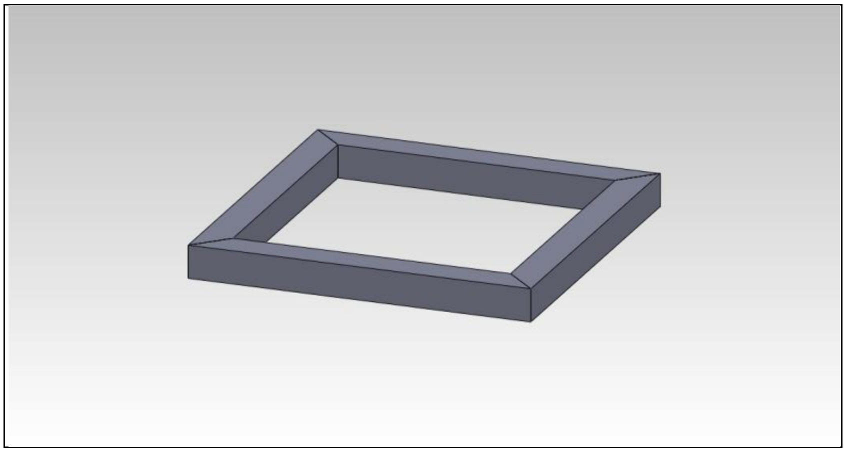


Figure 4.12: Combination on base parts

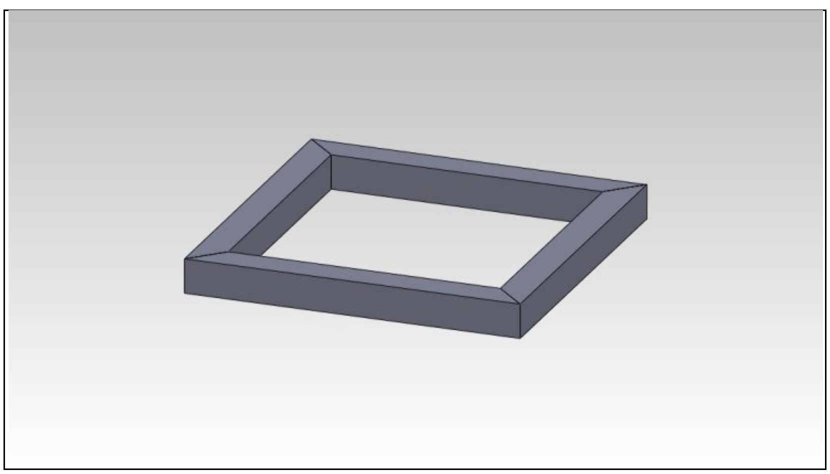


Figure 4.13: Combination on top parts

For figure 4.12, its shows combination on base parts while figure 4.13, it shows combination on top parts. By using welding machine, each part of base and top must be combined so that it can be square shape. Make sure that base part is bigger than top part. Went joining each part of base and top, make sure there is no sand or unneeded things inside the hollow bar.

4.3.2 Shaft and load holder

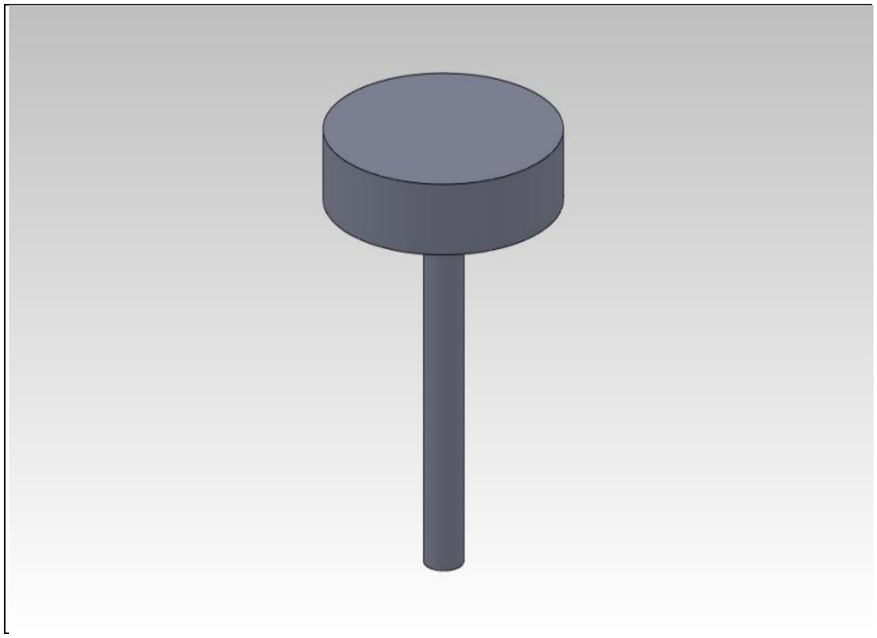


Figure 4.14: Combination of shaft and load holder

Figure 4.14 shows the combination of shaft and load holder. The load holder and shaft can be joining by using screw. Small hole must be created before joint the screw together with around 2mm thickness on the load holder so that the screw can sink inside it. (This is to prevent the screw head from sticking out). Do it for four pieces because each case need this combination of shaft and load holder.

4.3.3 Combination of base and top, with L-shape and wall

Figure 4.15: Combination of base with L-shape

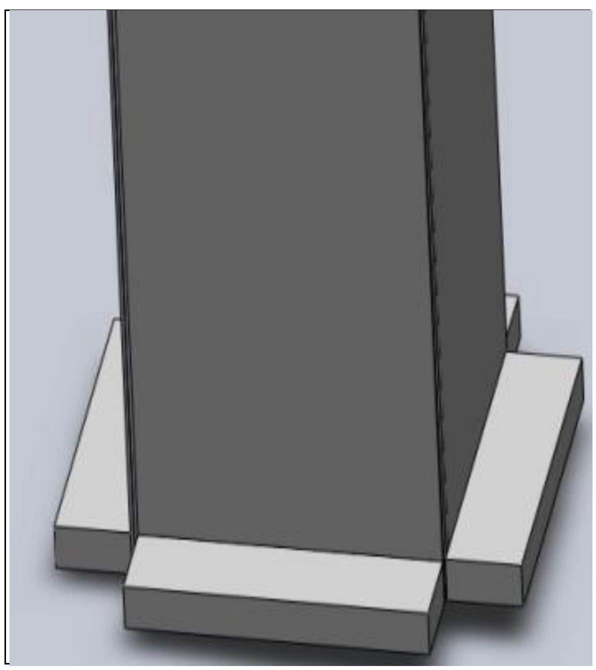


Figure 4.16: Combination of base, L-shape and wall

Figure 4.15 shows the Combination of base with L-shape. When the base and top are already welding, the L-shape also must be weld together with the base and top. After that, screw the wall which is sheet metal to the previous structure in each side of the square shape. Make sure all the screw have been band tightly so that the structure not collapses. Figure 4.16 shows the combination of base, L-shape and wall.

4.3.4 Combination of Top with Shaft and load holder

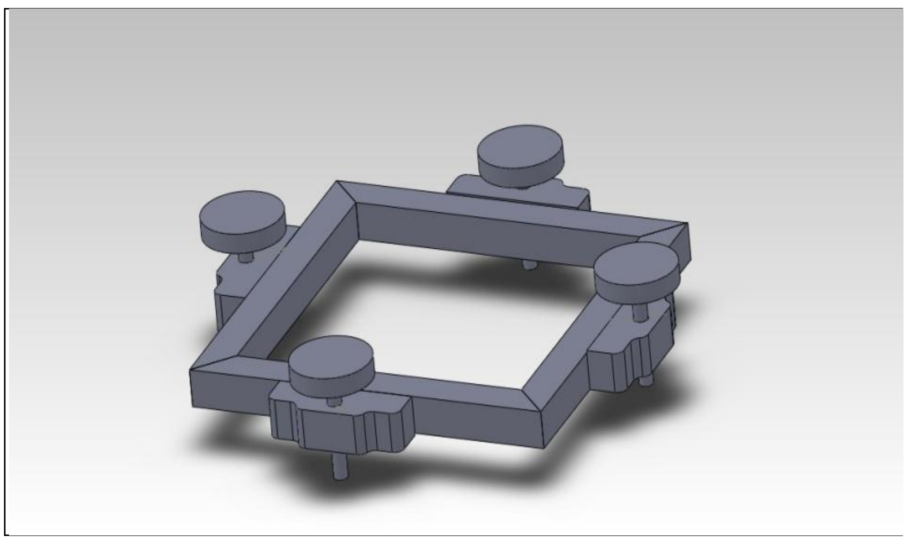


Figure 4.17: Combination of top with shaft and load holder

Figure 4.17 shows the combination of top with shaft and load holder. The load holder and shaft can be joining to the top by using 8mm screw. Make sure before join it, the small hole with must been created around 2mm thickness on the each side of the upper hub so that the screw can sink inside it. (This is to be done because to prevent the screw head from sticking out). Do it for four pieces because each case need this combination of shaft and load holder. For my case, the top part is in fixed condition while the base is in pinned condition.

4.3.5 Complete Design

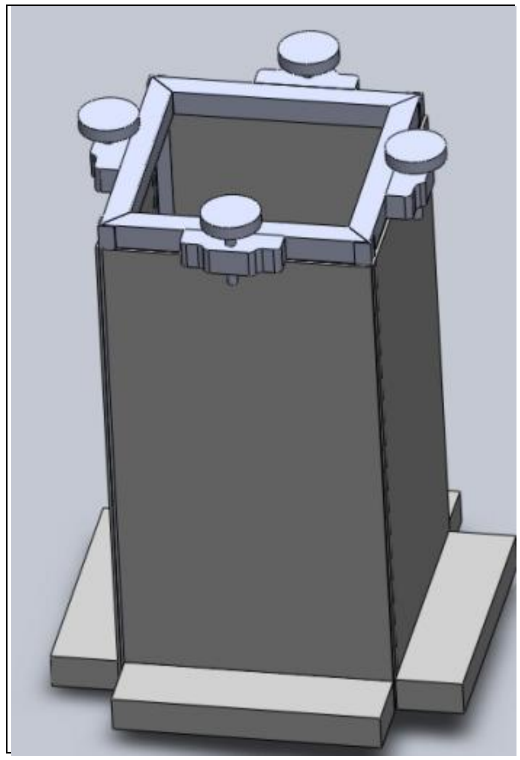


Figure 4.18: Complete design for buckling test

Figure 4.18 shows the complete design for buckling test. With combination of all part, the complete design can be build which also can be known as test rig. Each side of test rig contain different case. For case A, the design is combination of both fix. For case B, combination of both pinned. For case C, combination of fixed and pinned and for case D, combination of fixed and free design. Each case may produce different output which can be produce by Abaqus Software (finite element test). In chapter 5, it discuss on comparison between finite element method (using Abaqus software) and Dasy Lab software (using strain gauge).

4.3.6 Holder Design for Pinned Case

For my case, the holder design in the base part is pinned. The pinned holder design is shows in figure 4.19. Each case consists of different ending.

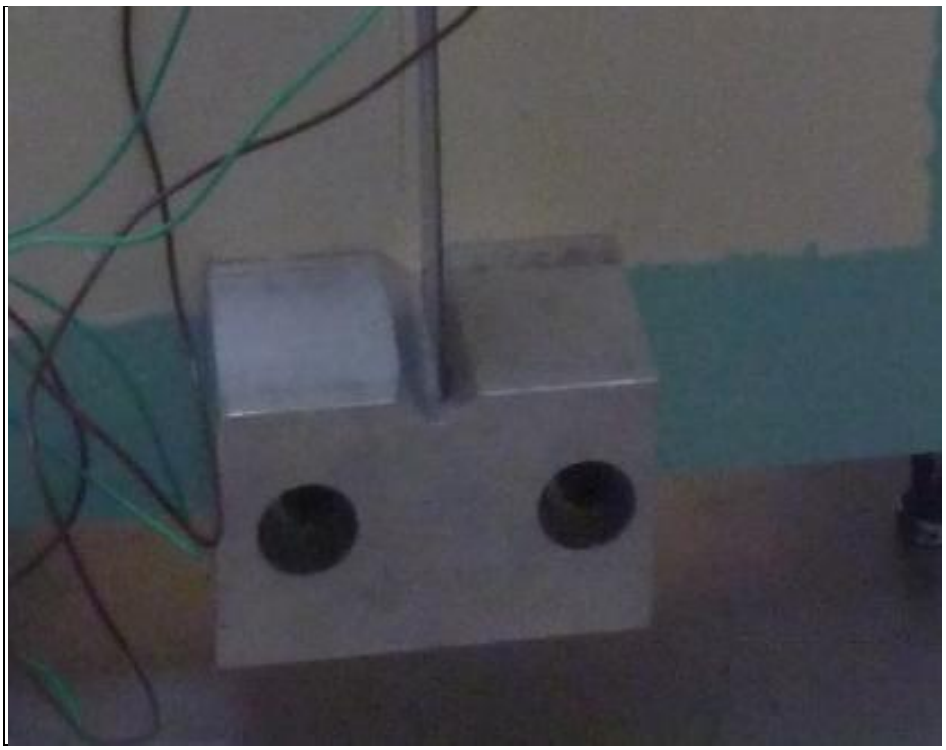


Figure 4.19: Holder design for pinned case

4.4 MACHINES INVOLVED

There are several machines that involve in this experiment. For example, turning machine, shearing machine and milling machine. This entire machine must be conducted properly to avoid unnecessary incident.

4.4.1 CNC Milling Machine

Computer Numerical Control (CNC) Milling is the most common form of CNC. CNC mills can perform the functions of drilling and often turning. CNC Mills are classified according to the number of axes that they possess. Axes are labeled as x and y for horizontal movement, and z for vertical movement, as shown in this view of a manual mill table. A standard manual assumed to have four axes:

i. Table x.
ii. Table y.
iii. Table z.
iv. Milling Head z.

The number of axes of a milling machine is a common subject is often interpreted in varying ways. It presents here what it has seen typically presented by manufacturers. A five-axis CNC milling machine has an extra axis in the form of a horizontal pivot for the milling head, as shown below. This allows extra flexibility for machining with the end mill at an angle with respect to the table. A six-axis CNC milling machine would have another horizontal pivot for the milling head, this time perpendicular to the fifth axis. CNC milling machines are traditionally programmed using a set of commands known as G-codes. G-codes represent specific CNC functions in alphanumeric format. Figure 4.20 shows CNC milling machine.

Figure 4.20: CNC milling machine

4.4.2 Milling machine

Milling is the process of machining flat, curved, or irregular surfaces by feeding the work piece against a rotating cutter containing a number of cutting edges. The usual Mill consists basically of a motor driven spindle, which mounts and revolves the milling cutter, and a reciprocating adjustable worktable, which mounts and feeds the work piece. Milling machines are basically classified as vertical or horizontal. These machines are also classified as knee-type, ram-type, manufacturing or bed type, and planer-type. Most milling machines have self-contained electric drive motors, coolant systems, variable spindle speeds, and power-operated table feeds. The cutter head containing the milling machine spindle is attached to the ram. The cutter head can be swiveled from a vertical spindle position to a horizontal spindle position or can be fixed at any desired angular position between vertical and horizontal. The saddle and knee are hand driven for vertical and cross feed adjustment while the worktable can be either hand or power driven at the operator's choice.

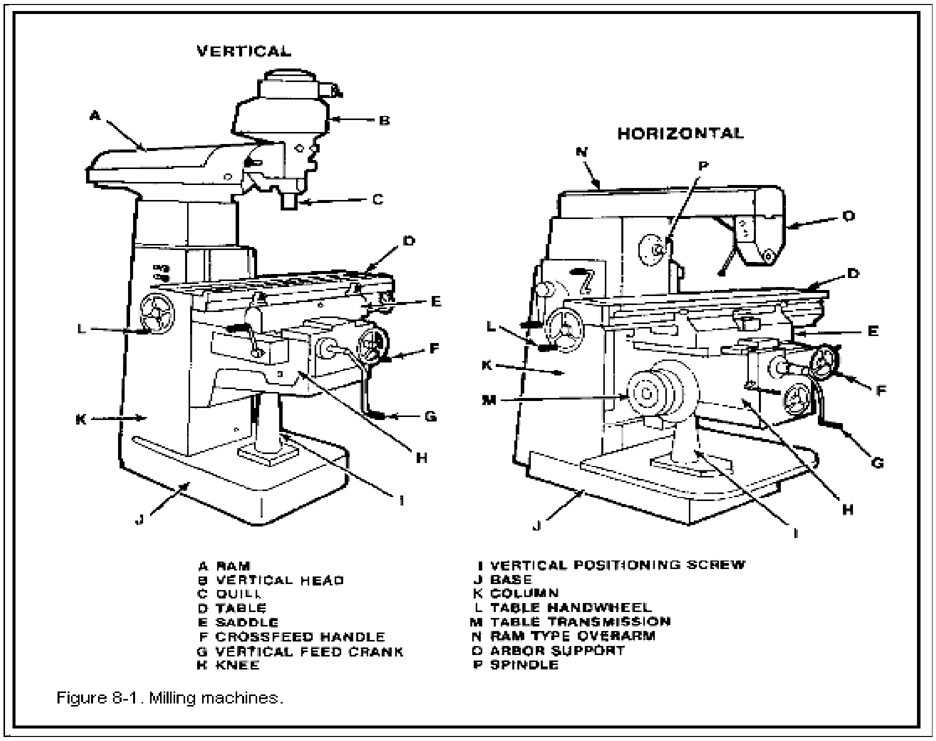


Figure 8-1. Milling machines.

Figure 4.21: Illustration on milling machine

Figure 4.21 shows an illustration on milling machine .An efficient and positive method of holding work pieces to the milling machine table is important if the machine tool is to be used to its fullest advantage. The most common methods of holding are clamping a work piece to the table, clamping a work piece to the angle plate, clamping the work piece in fixtures, holding a work piece between centers, holding the work piece in a chuck, and holding the work piece in a vise. Regardless of the method used in holding, there are certain factors that should be observed in every case. The work piece must not be sprung in clamping, it must be secured to prevent it from springing or moving away from the cutter, and it must be so aligned that it may be correctly machined T-slots. Milling machine worktables are provided with several T-slots which are used either for clamping and locating the work piece itself or for mounting the various holding devices and attachments. These T-slots extend the length of the table and are parallel to its line of travel. Most milling machine attachments, such as vises and index fixtures, have keys or tongues on the underside of their bases so that they may be located correctly in relation to the T-slots.

4.4.3 Speed Computation

The formula for calculating spindle speed in revolutions per minute is as follows:

$$RPM = \frac{CS \times 4}{D} \quad (1)$$

Where **RPM** = Spindle speed (in revolutions per minute).

CS = cutting speed of milling cutter (in SFPM)

D = diameter of milling cutter (in inches)

For example, the spindle speeds for machining a piece of steel at a speed of 35 SFPM with a cutter 2 inches in diameter is calculated as follows:

$$RPM = \frac{CS \times 4}{D} = \frac{35 \times 4}{2} = \frac{140}{2} = 70 \text{ RPM}$$

Therefore, the milling machine spindle would be set for as near 70 RPM as possible. The rate of feed, or the speed at which the work piece passes the cutter, determines the time required for cutting a job. In selecting the feed, there are several factors which should be considered. Forces are exerted against the work piece, the cutter, and their holding devices during the cutting process. The force exerted varies directly with the amount of feed and depth of cut, and in turn are dependent upon the rigidity and power of the machine. Milling machines are limited by the power they can develop to turn the cutter and the amount of vibration they can resist when using coarse feeds and deep cuts. The feed and depth of the cut also depend upon the type of milling cutter being used. For example, deep cuts or coarse feeds should not be attempted when using a small diameter end milling cutter. Coarse cutters with strong cutting teeth can be fed at a faster rate because the chips may be washed out more easily by the cutting oil. Coarse feeds and deep cuts should not be used on a frail work piece if the piece is mounted in such a way that its holding device is not able to prevent springing or bending.

Experience and judgment are extremely valuable in selecting the correct milling feeds. Even though suggested rate tables are given. Remember that these are suggestions only. Feeds are governed by many variable factors, such as the degree of finish required. Using a coarse feed, the metal is removed more rapidly but the appearance and accuracy of the surface produced may not reach the standard desired for the finished product. Because of this fact, finer feeds and increased speeds are used for finer, more accurate finishes, while for roughing, to use a comparatively low speed and heavy feed.

More mistakes are made on over speeding and underfeeding than on under speeding and overfeeding. Over speeding may be detected by the occurrence of a squeaking, scraping sound. If vibration (referred to as chattering) occurs in the milling machine during the cutting process, the speed should be reduced and the feed increased. Too much cutter clearance, a poorly supported work piece, or badly worn machine gears are common causes of chattering. The feed of the milling machine may be designated in inches per minute or millimeters per minute the milling feed is determined by multiplying the chip size (chip per tooth) desired the number of teeth on the cutter, d the revolutions per minute of the cutter.

Example: the formula used to find the work feed in inches per minute.

IPM = CPT x N x RPM

(2)

IPM = Feed rate in inches per minute.

CPT = Chip per t

N = Number of teeth per minute of the milling cutter.

The first step is to calculate the spindle speed before the feed rate can be calculated.

$$\text{RPM} = \frac{\text{CSD } 4}{\text{D}} = \frac{300 \times 4}{1/2} = \frac{1{,}200}{0.5} = 2{,}400$$

The second step is to calculate the feed rate.

IPM=CPT x N x RPM

=0.005 x 2 x 2,400

=24

Therefore, the RPM for an l/2-inch-diameter end mill machining aluminum revolves at 2,400 RPM and the feed rate should be 24 inches per minute. The formula used to find work feed in millimeters per minute is the same as the formula used to find the feed in IPM, except that mm/min is substituted for IPM. Figure 4.22 shows how the milling machine looks like.

Figure 4.22: Milling machine

4.4.4 Shearing Machine

Sheet metal processing is an important process for many industries, which are one of the largest manufacturers of products such as home appliances (fridge, washer, dryer, vacuum cleaners etc.), electronics (DVD- and CD-players, stereos, radios, amplifiers etc.), toys and PC’s. Most of these products have metal casings that are made by cutting and bending sheet metal. We look at some the basic sheet metal cutting and forming processes. Cutting processes are those in which a piece of sheet metal is separated by applying a great enough force to cause the material to fail. The most common cutting processes are performed by applying a shearing force, and are therefore sometimes referred to as shearing processes. When a great enough shearing force is applied, the shear stress in the material will exceed the ultimate shear strength and the material will fail and separate at the cut location.

This shearing force is applied by two tools, one above and one below the sheet. Whether these tools are a punch and die or upper and lower blades, the tool above the sheet delivers a quick downward blow to the sheet metal that rests over the lower tool. A small clearance is present between the edges of the upper and lower tools, which facilitates the fracture of the material. The size of this clearance is typically 2-10% of the material thickness and depends upon several factors, such as the specific shearing process, material, and sheet thickness.

The effects of shearing on the material change as the cut progresses and are visible on the edge of the sheared material. When the punch or blade impacts the sheet, the clearance between the tools allows the sheet to plastically deform and "rollover" the edge. As the tool penetrates, the sheets further the shearing results in a vertical burnished zone of material. Finally, the shear stress is too great and the material fractures at an angle with a small burr formed at the edge. The height of each of these portions of the cut depends on several factors, including the sharpness of the tools and the clearance between the tools. Figure 4.23 shows the example on sheared edge.

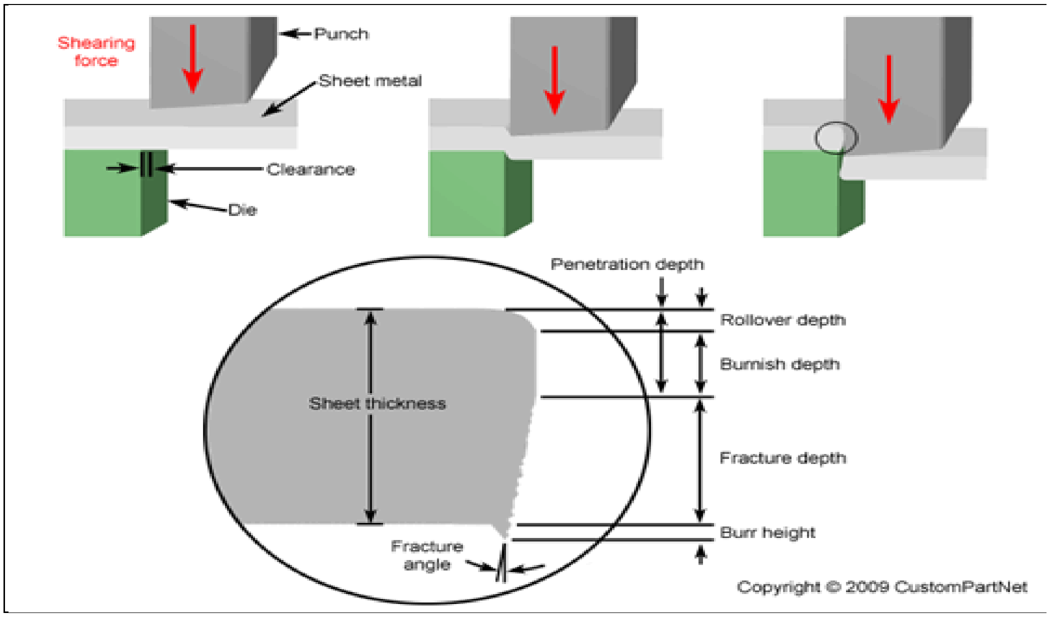


Figure 4.23: Sheared edge

A variety of cutting processes that utilize shearing forces exist to separate or remove material from a piece of sheet stock in different ways. Each process is capable of forming a specific type of cut, some with an open path to separate a portion of material and some with a closed path to cutout and remove that material. By using many of these processes together, sheet metal parts can be fabricated with cutouts and profiles of any 2D geometry.

Figure 4.24: Shearing machine

Figure 4.24 shows the shearing machine. The shearing process is performed on a shear machine, often called a squaring shear or power shear, that can be operated manually (by hand or foot) or by hydraulic, pneumatic, or electric power. A typical shear machine includes a table with support arms to hold the sheet, stops or guides to secure the sheet, upper and lower straight-edge blades, and a gauging device to precisely position the sheet. The sheet is placed between the upper and lower blade, which are then forced together against the sheet, cutting the material. In most devices, the lower blade remains stationary while the upper blade is forced downward. The upper blade is slightly offset from the lower blade, approximately 5-10% of the sheet thickness. Also, the upper blade is usually angled so that the cut progresses from one end to the other, thus reducing the required force. The blades used in these machines typically have a square edge rather than a knife-edge and are available in different materials, such as low alloy steel and high-carbon steel.

4.4.5 Welding Machine

There are many kinds of welding machines on the modern market, some of which are designed for heavy-duty commercial use and others which are suitable for home handymen as well as professional users. A welding machine is a device that allows the user to fuse two or more pieces of metal together into a single, solid continuum, giving the whole piece more strength and durability than would be the case were it simply bolted together. Welding allows the combination of several pieces of metal into a single, continuous complex shape that could not otherwise be molded or machined, and used. Many of the most effective welding machines are arc welders, which make use of a combination of electricity, an inert gas shield, and often, some kind of filler metal to fuse pieces of metal together into a whole. Manual metal arc welding (MMA), metal inert gas welding (MIG), and tungsten inert gas welding (TIG) are all examples of arc welding types that are offered by various welding machines.

Welding machines vary in size, including fixed installations in factories, large wheeled models that are too heavy to be practically carried and must be used at places where they can be wheeled to, and smaller compact models that are man-portable with a shoulder strap and can be carried to any place that a human can walk, climb, or crawl. Even the smallest modern models offer many features and settings, such as digital controls to maintain a stable arc, wide volt ranges so that they can be used effectively on different projects and materials, and a large array of safety features. Manual metal arc welding machines, otherwise known as stick welding, are welding machines that operate by using a consumable metal rod, or “stick,” as the electrode – hence the name “stick welding.” The electrode therefore steadily heats and melts and its own tip with the electric arc, and is consumed as it works. The principle bears some resemblance to a hot glue gun, where a stick of hard glue is inserted into the gun and slowly moved forward by trigger pulls as a heated nozzle melts it at the front. MMA welding is slow because unless the job is very small, the rod must be replaced many times before the job is completed.

Figure 4.25: Welding machine

Figure 4.25 shows the welding machine. Arc welding is a process in which an electric arc is created between an electrode and the base material using a constant power supply. This electric arc melts the metal at the welding point. The power supply can be either Alternating Current (A.C.) or Direct Current (D.C.). Sometimes an inert or semi-inert gas, know as shielding gas is used to protect the welding region. A filler material may also be used in place of the shielding gas.

4.4.6 Turning Machine

A Turning machine is a device that manipulates symbols on a strip of tape according to a table of rules. Despite its simplicity, a Turing machine can be adapted to simulate the logic of any computer algorithm, and is particularly useful in explaining the functions of a CPU inside a computer. Turning is the process whereby a single point cutting tool is parallel to the surface. It can be done manually, in a traditional form of lathe, which frequently requires continuous supervision by the operator, or by using a computer controlled and automated lathe which does not. This type of machine tool is referred to as having computer numerical control, better known as CNC. It is commonly used with many other types of machine tool besides the lathe. When turning, a piece of material (wood, metal, plastic, or stone) is rotated and a cutting tool is traversed along 2 axes of motion to produce precise diameters and depths. Turning can be either on the outside of the cylinder or on the inside (also known as boring) to produce tubular components to various geometries. Although now quite rare, early lathes could even be used to produce complex geometric figures, even the platonic solids; although until the advent of CNC it had become unusual to use one for this purpose for the last three quarters of the twentieth century. It is said that the lathe is the only machine tool that can reproduce itself. Figure 4.26 shows picture of turning machine.

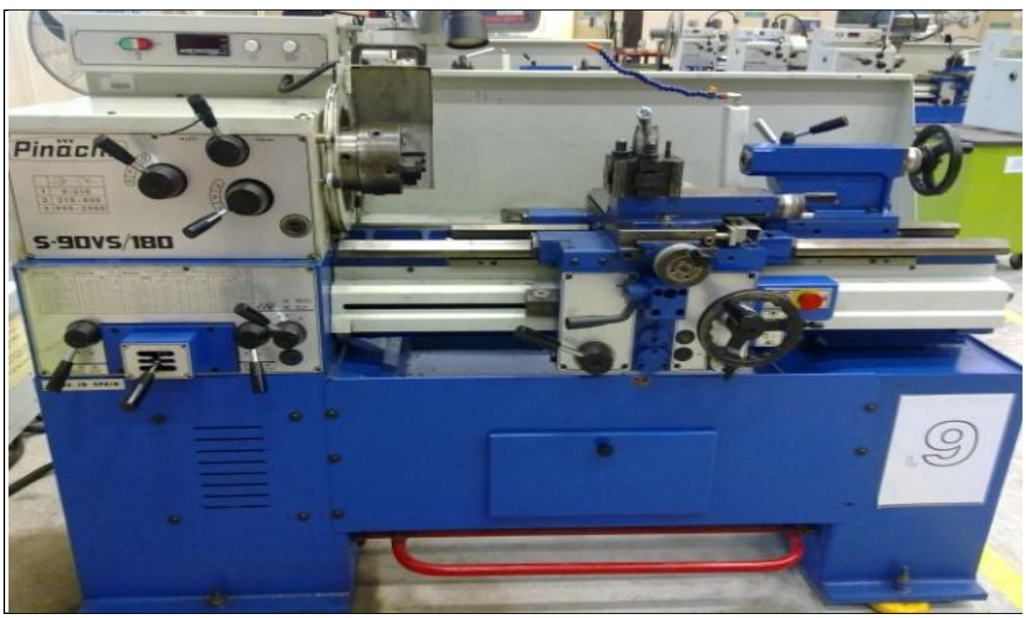


Figure 4.26: Turning machine

The turning processes are typically carried out on a lathe, considered to be the oldest machine tools, and can be of four different types such as straight turning, taper turning, profiling or external grooving. Those types of turning processes can produce various shapes of materials such as straight, conical, curved, or grooved work piece. In general, turning uses simple single-point cutting tools. Each group of work piece materials has an optimum set of tools angles which have been developed through the years. Figure 4.27 shows the roughing turning step, figure 4.28 shows parting aluminium step while figure 4.29 shows finish turning step.

Figure 4.27: roughing or rough turning step

Figure 4.28: Parting aluminium step

Figure 4.29: Finish turning step

4.4.7 Disc Cutter Machine

Figure 4.30: Disc cutter machine

Figure 4.30 shows the disc cutter machine. These cutting machines are intended to cut steel. Cutting is done with a disc (1800 rpm). ·The precision twin cutter tools and a quick drum to rotor changeover to help increase your service capability. It Infinitely variable spindle and cross feed speed settings allow for quick rough and precision finish cuts. It also a convenient top storage tray means you can easy to take your favorite adapters and tools. Other than that, the variety of adapters lets you machine all standard and composite rotors for foreign and domestic cars and light trucks. Furthermore, positive rake cutter tip angle provides for a one pass finish virtually every time, allowing you to complete your work fast.

CHAPTER 5

COMPARISON BETWEEN FINETE ELEMENT METHODS (ABAQUS SOFWARE) WITH STRAIN GAUGE (DASY LAB SOFWARE)

5.0 INTRODUCTION

This chapter presents the output produce when the different method has been applied through the test rig. For simulation part, the Finite element methods will be used by applied ABAQUS software while for experimental part, the strain gauges will be used by applied DASYLab software. The ABAQUS suite of software for finite element analysis (FEA) is known for its high performance, quality and ability to solve more kinds of challenging simulations than any other software. The ABAQUS suite consists of three core products: ABAQUS/Standard, ABAQUS/Explicit and ABAQUS/CAE. Each of these packages offers additional optional modules that address specialized capabilities some customers may need. Experience has shown that ABAQUS is the easiest FEA software package to learn which is very good online documentation and small learning curve that we can model much faster. DASY Lab is a graphical programming software package that serves the data acquisition user who requires customized applications but doesn't have the time, training, or inclination to write code. With DASY Lab, it is quickly develop data acquisition and control applications simply by creating a flowchart in which functions are connected by wires. Available in four different versions (Lite, Basic, Full and Pro) and includes hardware drivers for Measurement Computing DAQ Devices. DASY Lab software also gain data acquisition software program designed for users who want to get started right away without any programming effort. Combined with DGH modules the data acquisition software can perform visualization, open and closed loop control. With DASY Lab it can perform all these tasks interactively on the screen. For this experiment, the DASY Lab software will be done through strain gauge reading.

5.1 ANALYSIS ON EXPERIMENTAL RESULT WITH STRAIN GAUGE (DASY LAB)

Figure 5.1 shows the strain gauge testing by using DASYLab software.

Figure 5.1: Strain gauge test using DASY Lab software

5.1.1 Specimen preparation

There are several steps for specimen preparation. Firstly, weld the Data Logger wire to the strain gauge, and then glue it widely to the aluminium plate. Make sure the grind process have been done early through the aluminium surface in order to get better result. Figure 5.2 shows the Strain gauges that have been glue to the Specimen test.

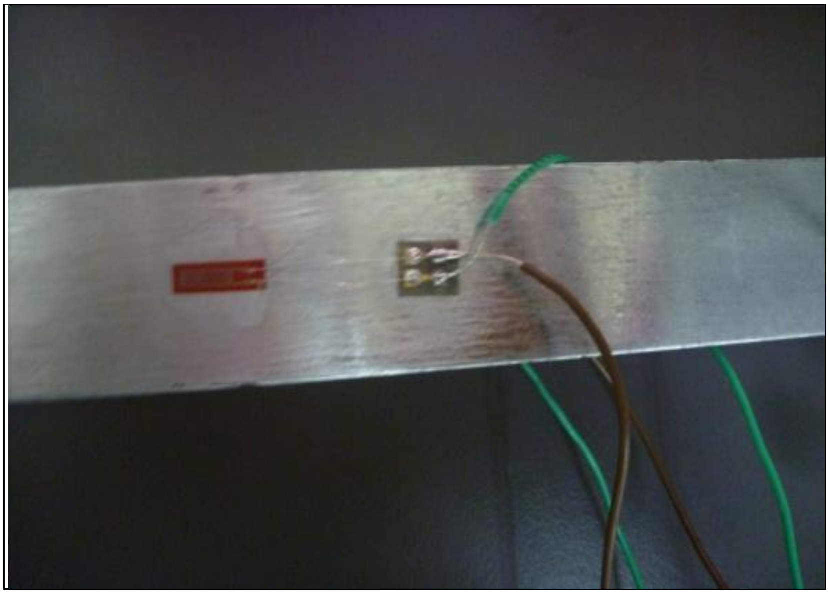


Figure 5.2: Strain gauge have been glue to the Specimen test

Secondly, connect the strain gauge to the data logger tightly. Figure 5.3 shows how the strain gauges that have been connect with Data Logger.

Figure 5.3: How Strain Gauge connects with Data Logger

Thirdly, connect the Data Logger to the Laptop and Test Rig. Figure 5.4 shows the connection of Data Logger while figure 5.5 shows the connection of Data Logger to the laptop and test rig.

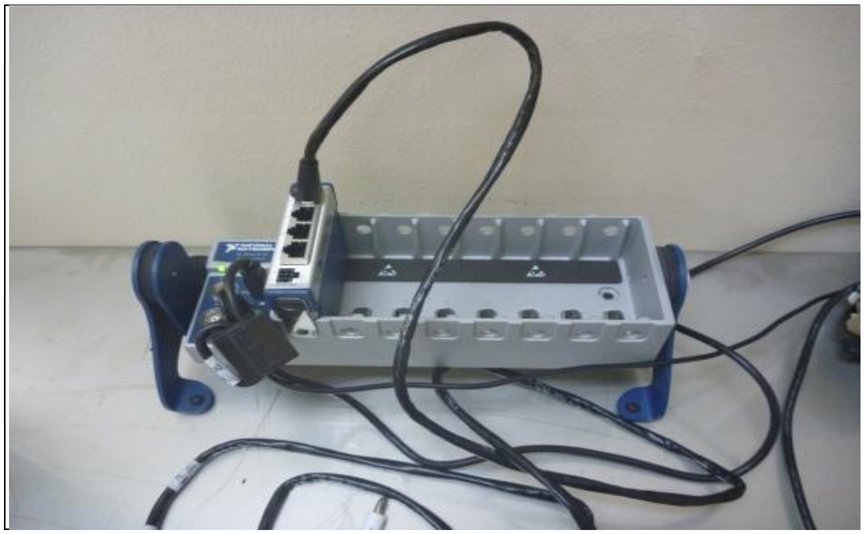


Figure 5.4: The connection of Data Logger

Figure 5.5: The connection of Data Logger to the laptop and test rig

5.1.2 Test procedure

For the test procedure**,** put the load one by ones on the load holder from 10N until 80 N. The entire figure below shows how the load will effect to the buckling readings. Each test must be done by three times to get the average reading.

10 N

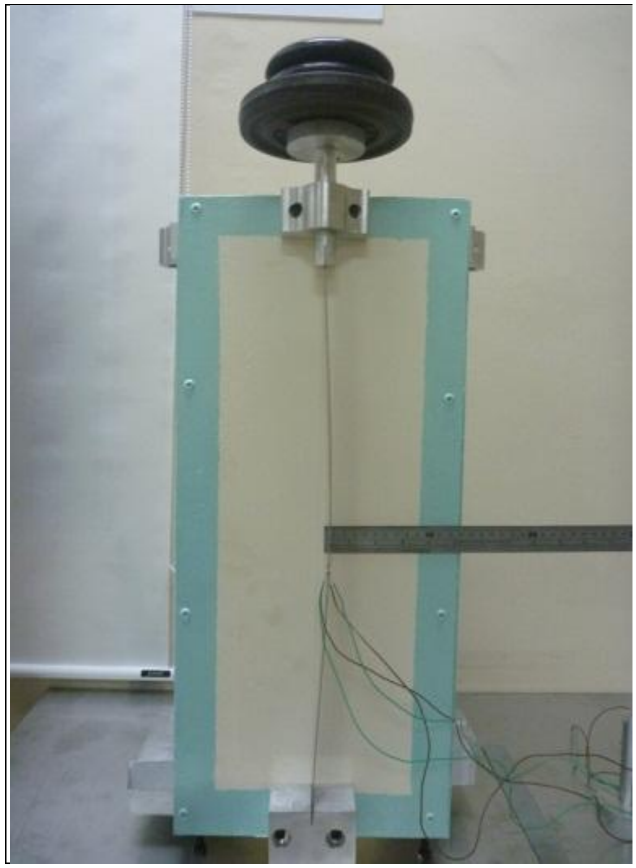
Figure 5.6: 10N loads applied on test rig

Figure 5.6 shows when 10N loads applied on the test rig, strain readings occurred and the displacement was measured.

20 N

Figure 5.7: 20N loads applied on test rig

Figure 5.7 shows when 20N loads applied on the test rig, strain readings occurred and the displacement was measured.



30 N

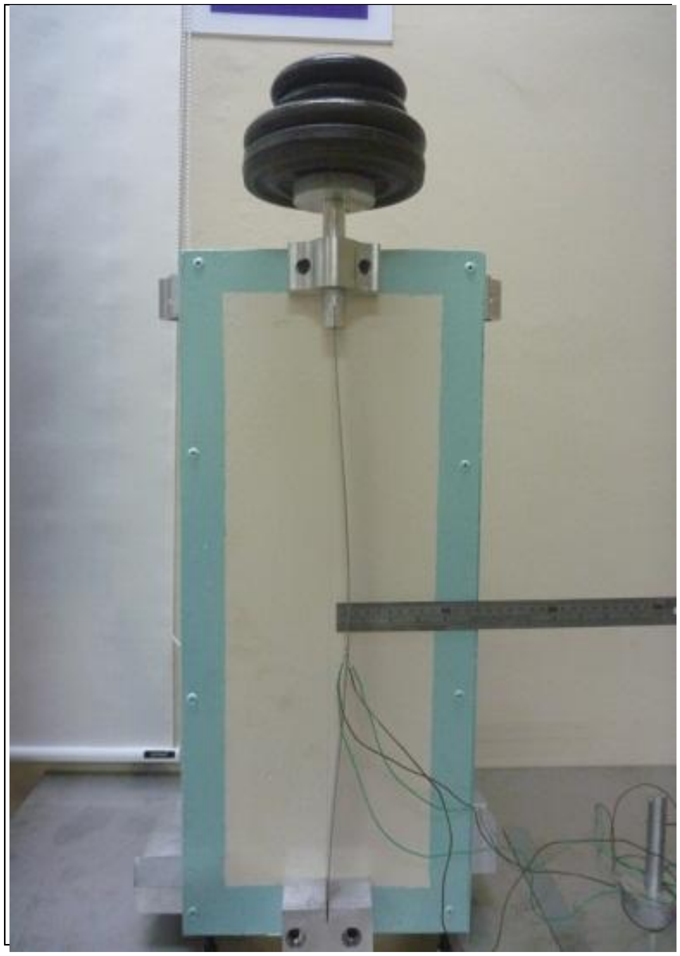
Figure 5.8: 30N loads applied on test rig

Figure 5.8 shows when 30N loads applied on the test rig, strain readings occurred and the displacement was measured.

40 N

Figure 5.9: 40N loads applied on test rig

Figure 5.9 shows when 40N loads applied on the test rig, strain readings occurred and the displacement was measured.



50 N

Figure 5.10: 50N loads applied on test rig

Figure 5.10 shows when 50N loads applied on the test rig, strain readings occurred and the displacement was measured.

60 N

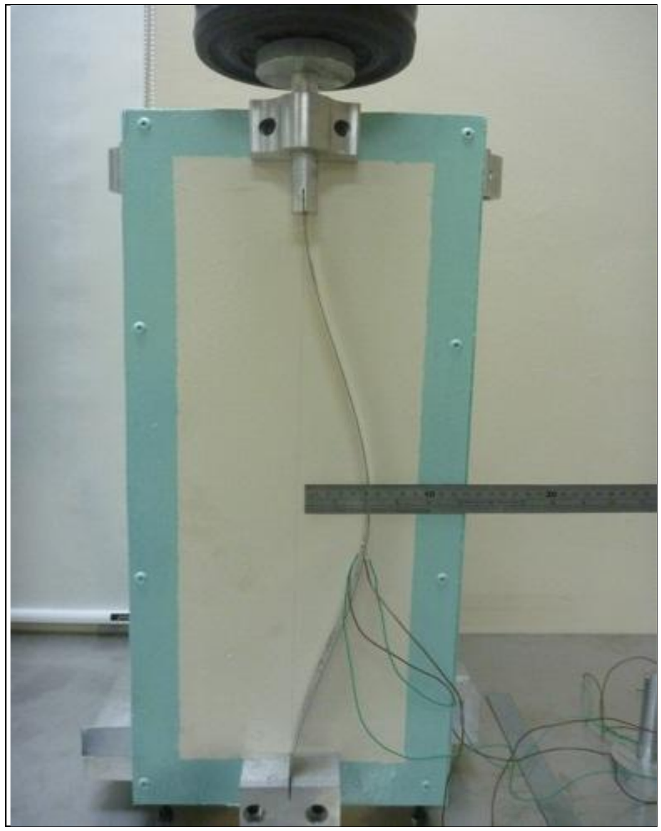
Figure 5.11: 60N loads applied on test rig

Figure 5.11 shows when 60N loads applied on the test rig, strain readings occurred and the displacement was measured.

70 N

Figure 5.12: 70N loads applied on test rig

Figure 5.12 shows when 70N loads applied on the test rig, strain readings occurred and the displacement was measured.



80 N

Figure 5.13: 80N loads applied on test rig

Figure 5.13 shows when 80N loads applied on the test rig, strain readings occurred and the displacement was measured. Next, the aluminium plat is buckle once the loads had been placed. Then, data logger also take the reading from the strain gauge with attach to the aluminium plat. Then, take the displacement was measured. Repeat the reading 3 times for average reading so that we can get the same answers with the theory. Sketch the graph and discuss the answer to compare between result and simulation.

5.2 ANALYSIS ON SIMULATION RESULT WITH FINETE ELEMENT (ABAQUS SOFTWARE)

After getting the experimental result from the Data Logger, the result will be compared to be simulation result which is finite element. The ABAQUS suite of software for finite element analysis (FEA) is known for its high performance, quality and ability to solve more kinds of challenging simulations than any other software. The ABAQUS suite consists of three core products which are ABAQUS/Standard, ABAQUS/Explicit and ABAQUS/CAE. Each of these packages offers additional optional modules that address specialized capabilities some customers may need. ABAQUS/Standard provides ABAQUS analysis technology to solve traditional implicit finite element analyses, such as static, dynamics, thermal, all powered with the widest range of contact and nonlinear material options. ABAQUS/Standard also has optional add-on and interface products with address design sensitivity analysis, offshore engineering, and integration with third party software, e.g., plastic injection molding analysis. ABAQUS/Explicit provides ABAQUS analysis technology focused on transient dynamics and quasi-static analyses using an explicit approach appropriate in many applications such as drop test, crushing and many manufacturing processes. ABAQUS/CAE provides a complete modeling and visualization environment for ABAQUS analysis products. With direct access to CAD models, advanced meshing and visualization, and with an exclusive view towards ABAQUS analysis products, ABAQUS/CAE is the modeling environment of choice for many ABAQUS users.

For this experiment, the ABAQUS software used was version 6.7. The packages of this software are including CAE model and Implicit which is Run calculation. The element type is meshing type which is C4PE continuum. For model with continuum elements, the model most 3D structures that are bending Continuum or brick elements are the best. Each element requires any nodes. Models can be made by hand rather than CAE but can take much longer. Further result of finite element will be discussed in chapter 6, which is result and discussion part. Figure 5.14 shows the example of continuum model.

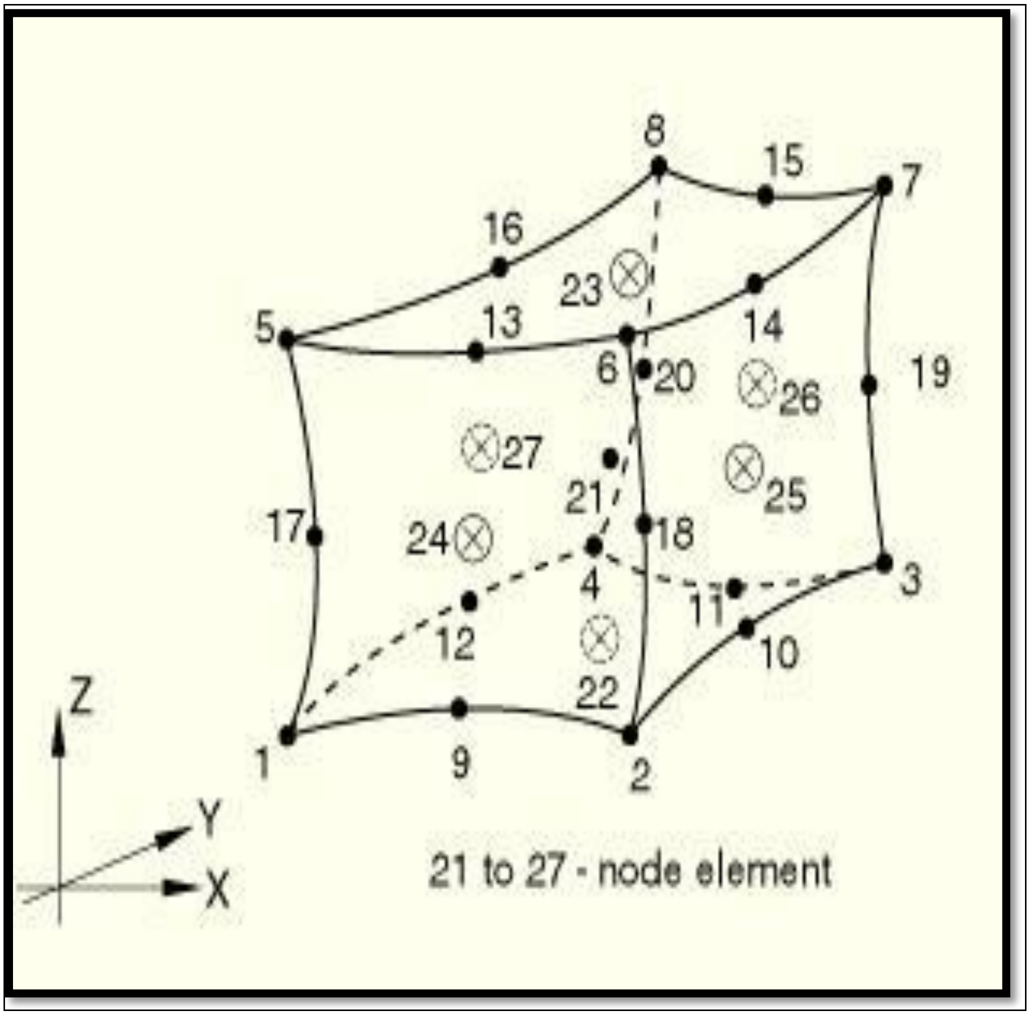


Figure 5.14: The example of continuum model.

5.3 ANALYSIS ON STRAIN AND STRESS

Strain is related to change in dimensions and shape of a material. The most elementary definition of strain is when the deformation is along one axis: original length change in length strain. When a material is stretched, the change in length and the strain are positive. When it is compressed, the change in length and strain are negative. This conforms to the signs of the stresses which would accompany these strains, tensile stresses being positive and compressive stresses negative. This definition refers to what are termed normal strains, which change the dimensions of a material but not its shape. In other words, angles do not change. In general, there are normal strains along three mutually perpendicular axes. By contrast, strains which involve no length changes but which do change angles are known as shear strains. From the experiment that already be done, the buckling output will contain negative strain which is compressed condition.

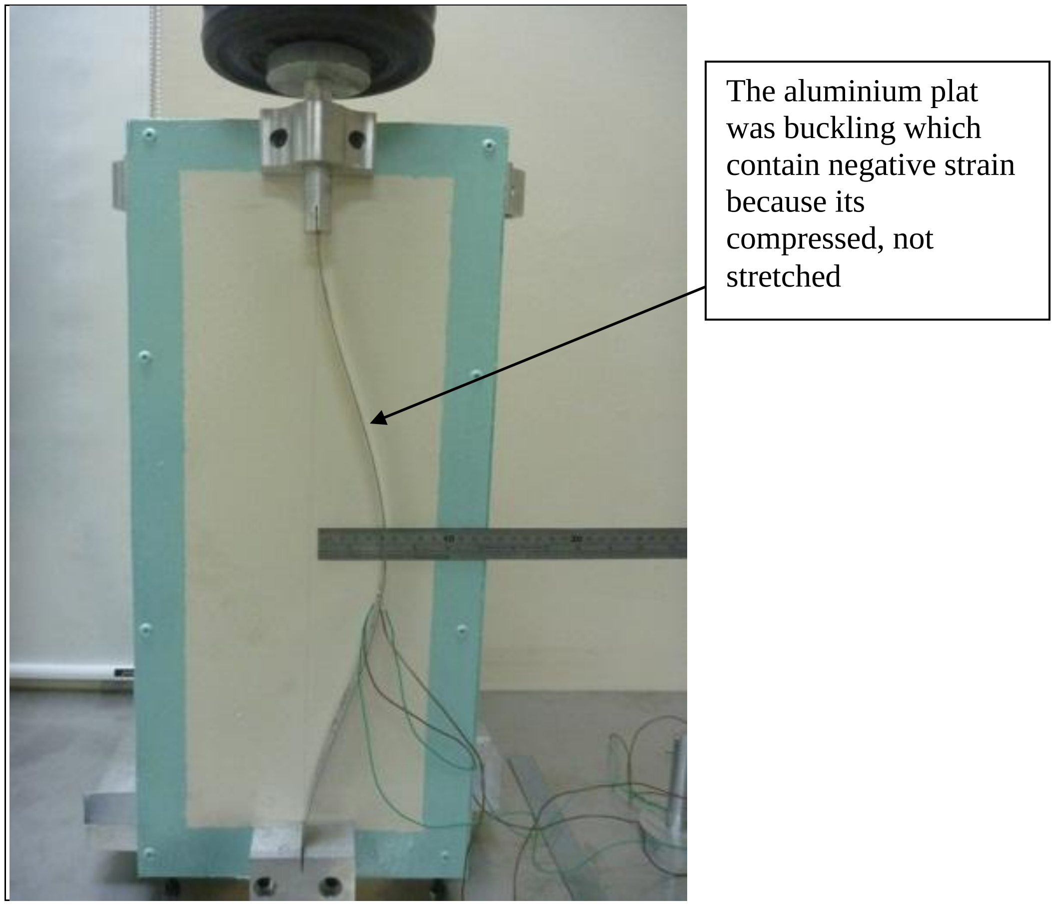


Figure 5.15: 80N loads applied on test rig

Figure 5.15 shows when 80N loads applied on the test rig, strain readings occurred and the displacement was measured. The aluminium plat was buckled which contain negative strain because its compressed, not stretched.

For normal strains the usual symbol is ε. The same system of subscripts is used as for stresses. With respect to (x, y, z) axes we have strains ε_{xx}, ε_{yy} and ε_{zz}, with, as with stresses, the first subscript giving the normal to the plane which is being displaced, and the second the direction of the displacement. Since the subscripts are always repeated, we sometimes just use a single subscript. Conventionally, the symbol for shear stress is γ and the same subscripting system gives rise to strains such as γ_{xy}, γ_{yz}, and γ_{zx}. Other quantities that are associated with strain are displacements. These are simply the distance moved by any point of material. Usually, the displacements in the (x, y, z) directions are denoted respectively by (u, v, w). When a strain is present, the displacements must vary from point to point.

For problems that are rather complicated and have hardware available, it will be often simply instrument the actual part and subject it to all types of loading right in the laboratory. This is a very direct, economical approach and always succeeds in conveying the integrity of the new design to management and others. It also creates the physical model to test right in our prototype machine shop, if needed as the experiment which is buckling test. The purpose of designing new test rig is to identify the strain and stress that occurred trough the specimen. For almost the specimens contain negative strain which is only occurred compressed output, while there is no stretched output. This is because the buckle will be identified output only, not the stretched output.

An addiction, an instrumentation options include strain gages and deflection gages. But sometimes, it may also need photo elasticity. Each has its own strengths and each is inexpensive to apply. Strain gages are bonded on resistive elements that are already calibrated to give strain values after wiring up. They give complete information on the strain field at a specific location. We can also measure residual stress and strain using strain gages. For deflection gages, it is for overall deflection data. These can be individual dials or transducers wired right into our data acquisition system. For photo elasticity is fascinating to observe and provides a “full-field” solution, enabling the engineer to have a quantitative map of the entire stress field for the part in question. This is very powerful, especially for new parts, or for old part being loaded in new ways.

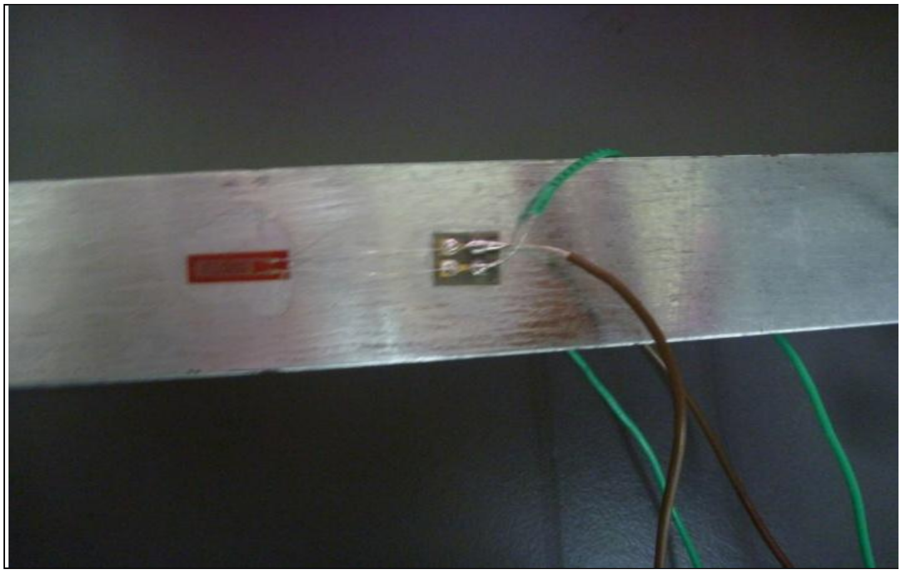


Figure 5.16: Strain gauge that attached to aluminium plat

Figure 5.16 shows when strain gauge that attached to aluminium plat. The aluminium surface must be grind first to prevent error while the experiment on progress. Furthermore, it is evidently quite straight forward to extend a nonlinear small-strain finite element code to account for finite strains. The only changes necessary are:

i. The general finite deformation measures must be calculated;
ii. The material tangent stiffness is now a function of strain;
iii. Two additional geometric terms must be added to the stiffness matrix – one of these is a volume integral over all the elements, the second is an integral over the boundary;
iv. Deal with an unsymmetrical stiffness matrix.

But for this experiment, the data is not calculated by using finite element method. The method is just for applying data from Data Logger to Finite element which it is translate by ABAQUS Software.

CHAPTER 6

RESULT AND DISCUSSIONS

6.0 INTRODUCTION

This chapter focused on result and discussion for the whole experiment. From DASY Lab software, the comparison is being done with the ABAQUS software. After that, graph is being sketched due to the result from the experiment. Each experiment consists of different result because each test has different loads. Experience has shown that ABAQUS is the easiest FEA software package to learn. It is also very good online documentation and small learning curve which means you can model much faster.

6.1 EXPERIMENTAL RESULT WITH STRAIN GAUGE (DASYLAB SOFTWARE)

From the experimental result that being done by doing strain gauge (DASYLab Software, each experiment having different strain and displacement readings due to the different loads applied. The Data Logger read all the data from the strain gauge while the data must be transfer and be explaining by DASYLab software.

6.1.1 Strain reading

Table 6.1: Strain reading

Load (N)	Strain			
	Test 1	**Test 2**	**Test 3**	**Test average**
0	-0.000124	-0.000115	-0.00011	-0.00011633
5	-0.000092	-0.000058	-0.000062	-0.00007067
10	-0.000022	-0.000008	0.000001	-0.00002900
15	0.000013	0.000026	0.000039	0.00002600
20	0.000067	0.000079	0.000095	0.00008033
25	0.00014	0.000162	0.000146	0.00014933
30	0.000205	0.000267	0.000205	0.00022567
35	0.000341	0.000387	0.000317	0.00034833
40	0.000577	0.000588	0.000636	0.00060033

6.1.2 Displacement reading

Table 6.2: Displacement reading

Displacement (mm)	Strain			
	Test 1	**Test 2**	**Test 3**	**Test average**
0	0	0	0	0
10	0.005	0.01	0.01	0.008333333
20	0.002	0.02	0.03	0.017333333
30	0.035	0.035	0.035	0.035
40	0.045	0.05	0.05	0.048333333
50	0.065	0.07	0.07	0.068333333
60	0.08	0.1	0.08	0.086666667
70	0.12	0.14	0.12	0.126666667
80	0.19	0.19	0.2	0.193333333

Table 6.1 shows strain readings while table 6.2 shows displacement reading. The test must been repeat 3 times, because we want to take the average readings.

6.1.3 Graph

Both figures below shows the graph output for the Strain and Displacement readings. Figure 6.1 shows Graph Load (N) versus Strain while figure 6.2 shows Graph Load (N) versus Displacement (mm).

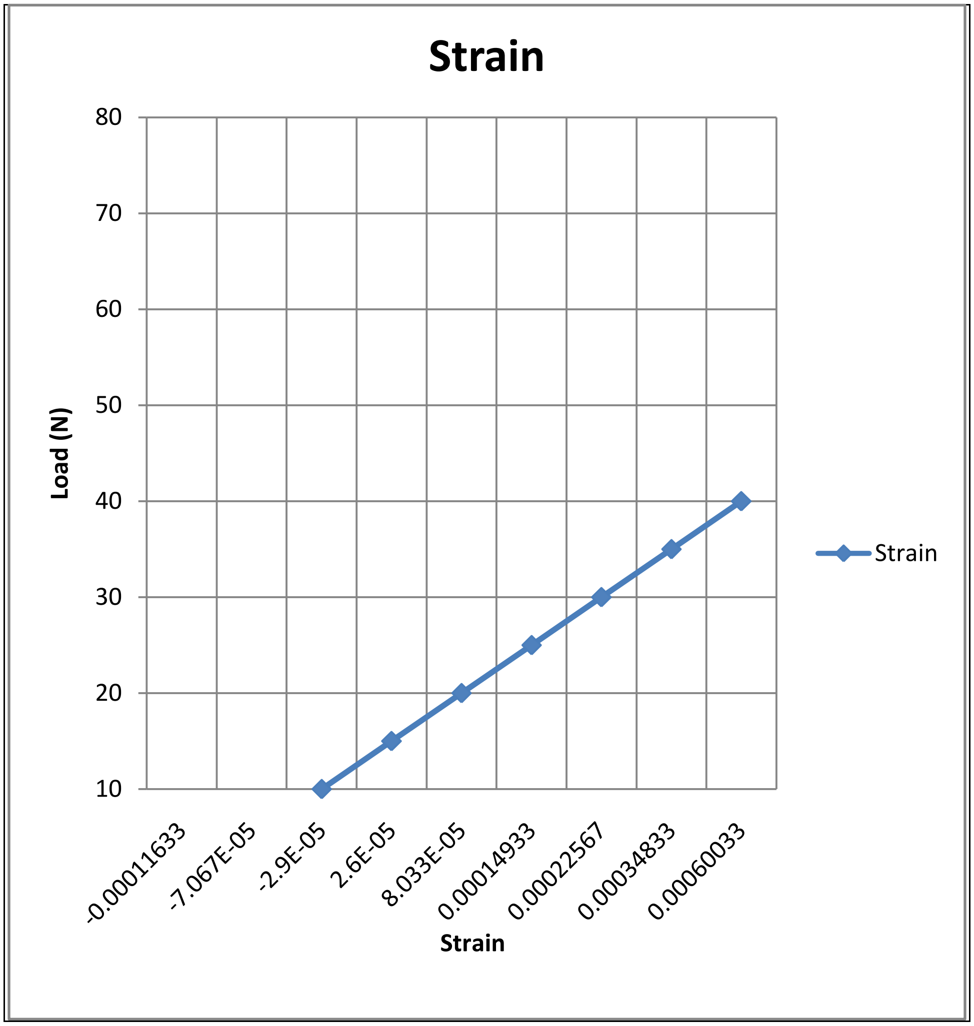


Figure 6.1: Graph Load (N) versus Strain

Figure 6.1 shows Graph Load (N) versus Strain. The load is directly proportional to the Strain. The load is increase when the displacement reading increases. The bigger number of load we put, it produce the bigger number of strain reading.

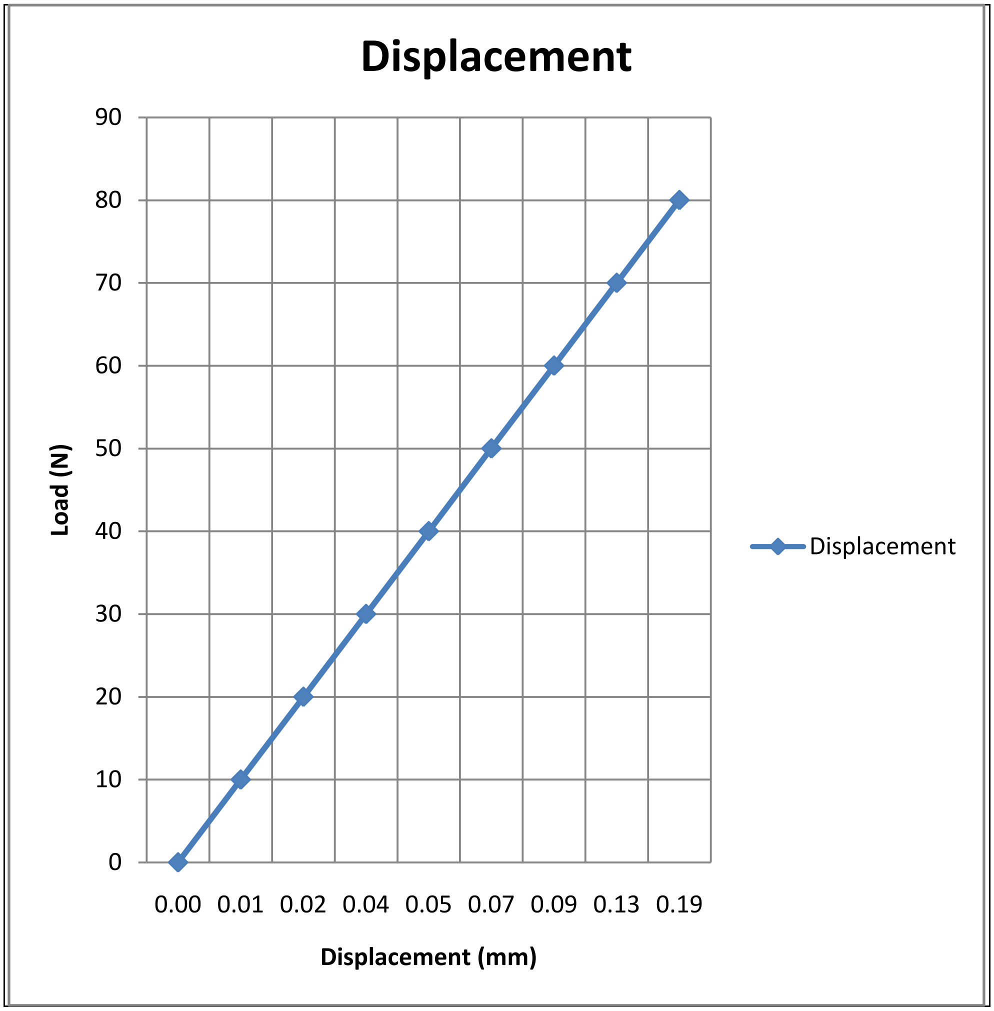


Figure 6.2: Graph Load (N) versus Displacement (mm)

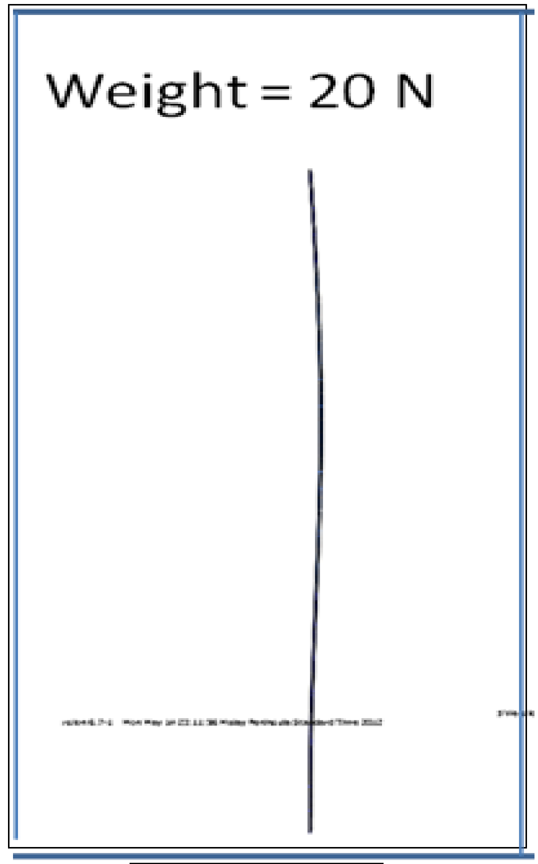
Figure 6.2 shows Graph Load (N) versus Displacement (mm). The load is directly proportional to the displacement. The load is increase when the displacement reading increases. The bigger number of load we put, it produce the bigger number of displacement reading.

6.2 SIMULATION RESULT WITH FINETE ELEMENT (ABAQUS SOFTWARE)

The entire figures below show the result from finite element (ABAQUS software).

Figure 6.3: 10N loads applied on test rig in ABAQUS software

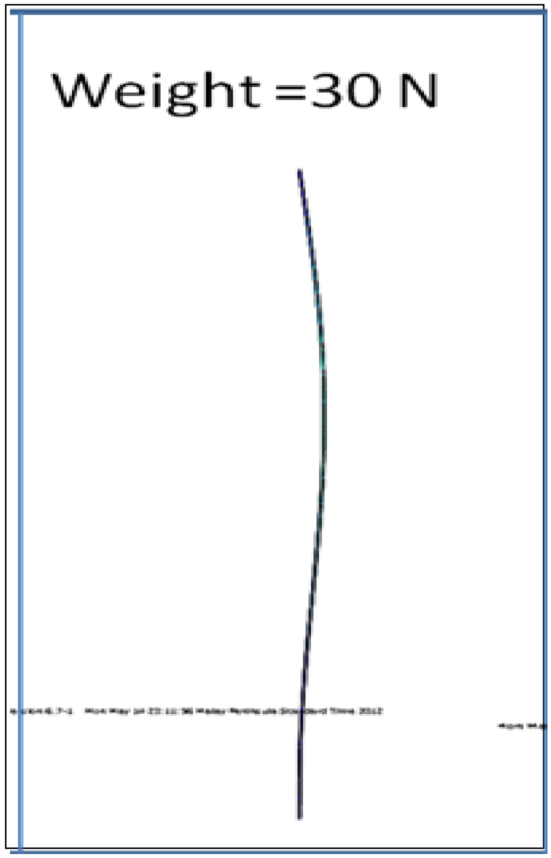
Figure 6.3 shows when 10N loads applied on the test rig in ABAQUS software. The test rig stated to buckle when the load have been applied. Its shows that strain readings and displacement readings may occur.



20 N

Figure 6.4: 20N loads applied on test rig in ABAQUS software

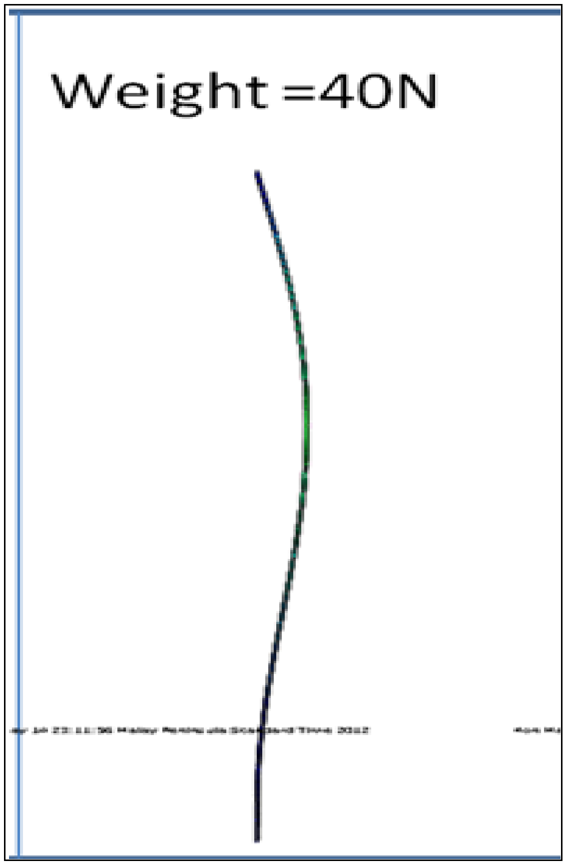
Figure 6.4 shows when 20N loads applied on the test rig in ABAQUS software The test rig stated to buckle when the load have been applied. Its shows that strain readings and displacement readings may occur.



30 N

Figure 6.5: 30N loads applied on test rig in ABAQUS software

Figure 6.5 shows when 30N loads applied on the test rig in ABAQUS software. The test rig stated to buckle when the load have been applied. Its shows that strain readings and displacement readings may occur.



40 N

Figure 6.6: 40N loads applied on test rig in ABAQUS software

Figure 6.6 shows when 40N loads applied on the test rig in ABAQUS software. The test rig stated to buckle when the load have been applied. Its shows that strain readings and displacement readings may occur.

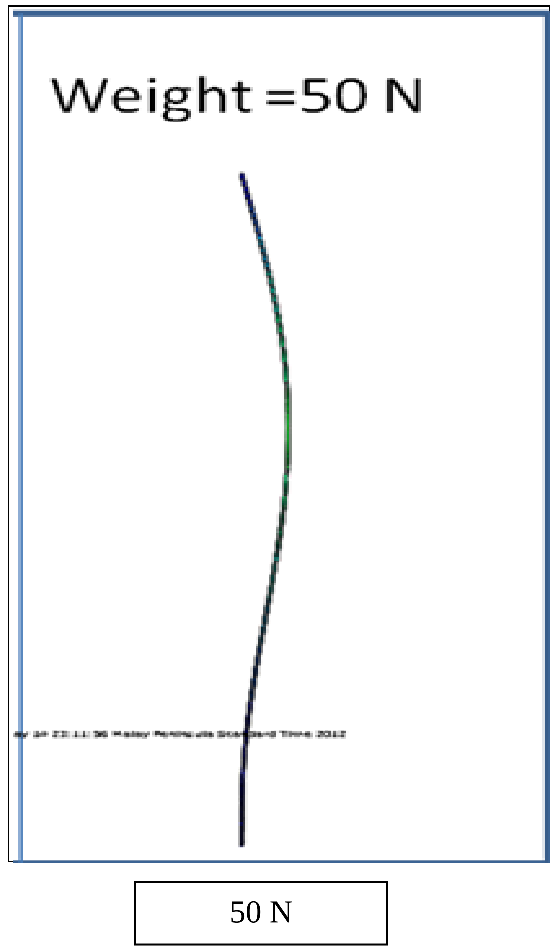


Figure 6.7: 50N loads applied on test rig in ABAQUS software

Figure 6.7 shows when 50N loads applied on the test rig in ABAQUS software. The test rig stated to buckle when the load have been applied. Its shows that strain readings and displacement readings may occur.

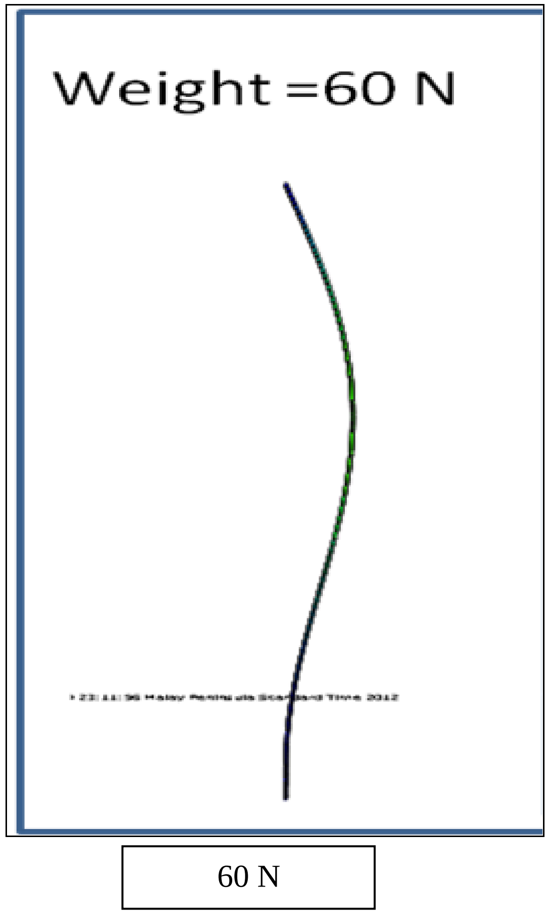
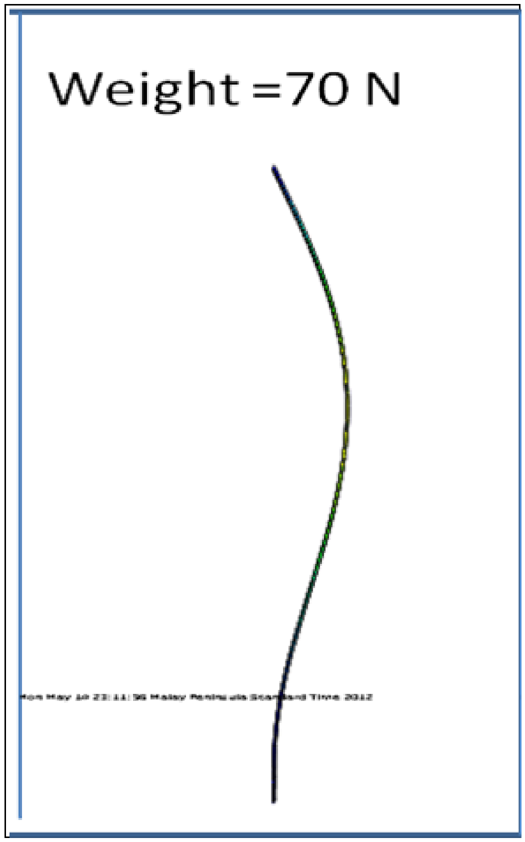


Figure 6.8: 60N loads applied on test rig in ABAQUS software

Figure 6.8 shows when 60N loads applied on the test rig in ABAQUS software. The test rig stated to buckle when the load have been applied. Its shows that strain readings and displacement readings may occur.



70 N

Figure 6.9: 70N loads applied on test rig in ABAQUS software

Figure 6.9 shows when 70N loads applied on the test rig in ABAQUS software. The test rig stated to buckle when the load have been applied. Its shows that strain readings and displacement readings may occur.

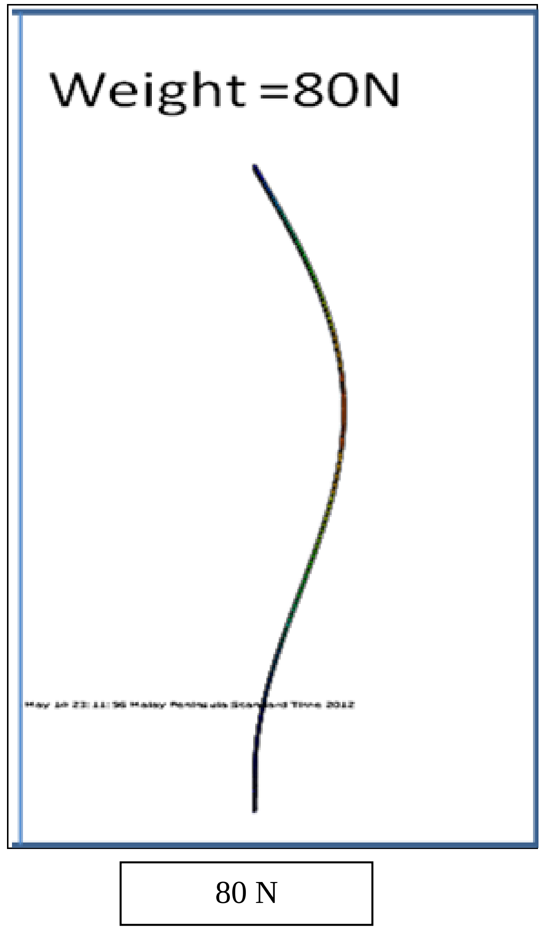
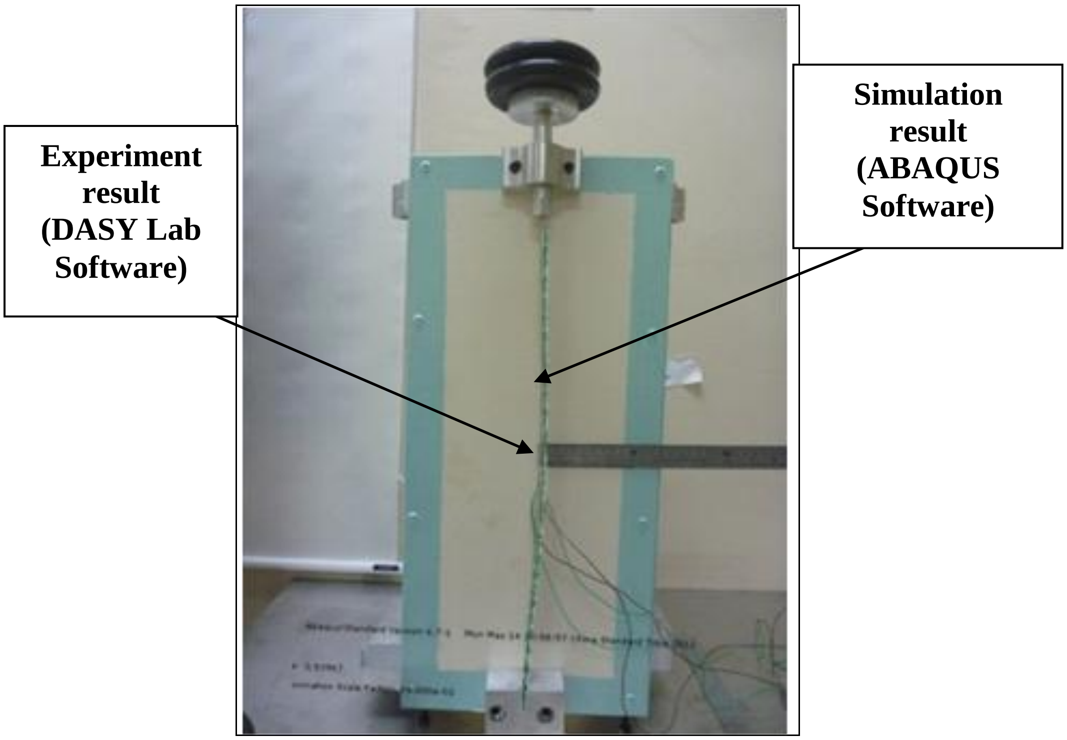


Figure 6.10: 80N loads applied on test rig in ABAQUS software

Figure 6.10 shows when 80N loads applied on the test rig in ABAQUS software. The test rig stated to buckle when the load have been applied. Its shows that strain readings and displacement readings may occur.

6.3 COMPARISON BETWEEN EXPERIMENTAL RESULTS AND SIMULATION RESULTS

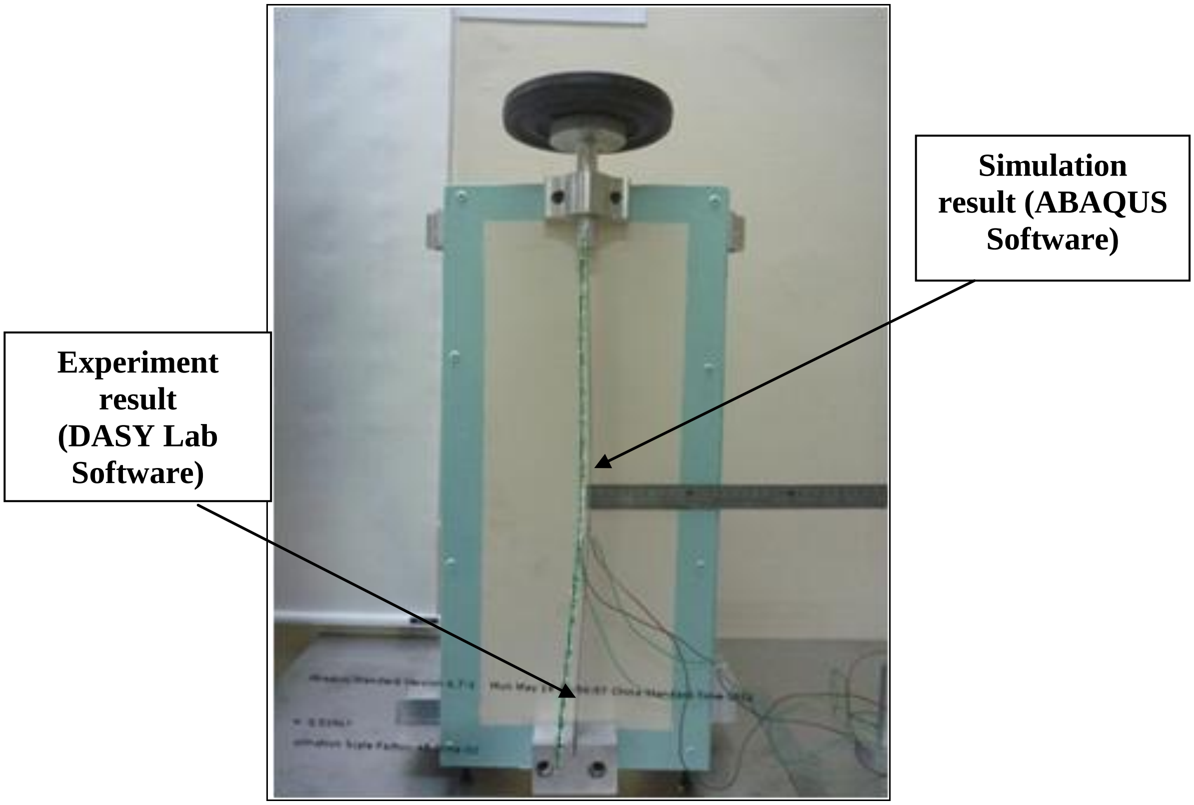
All figures below shows the comparison results between experimental and simulation.



10 N

Figure 6.11: Comparisons between experimental result and simulation result for 10 N loads

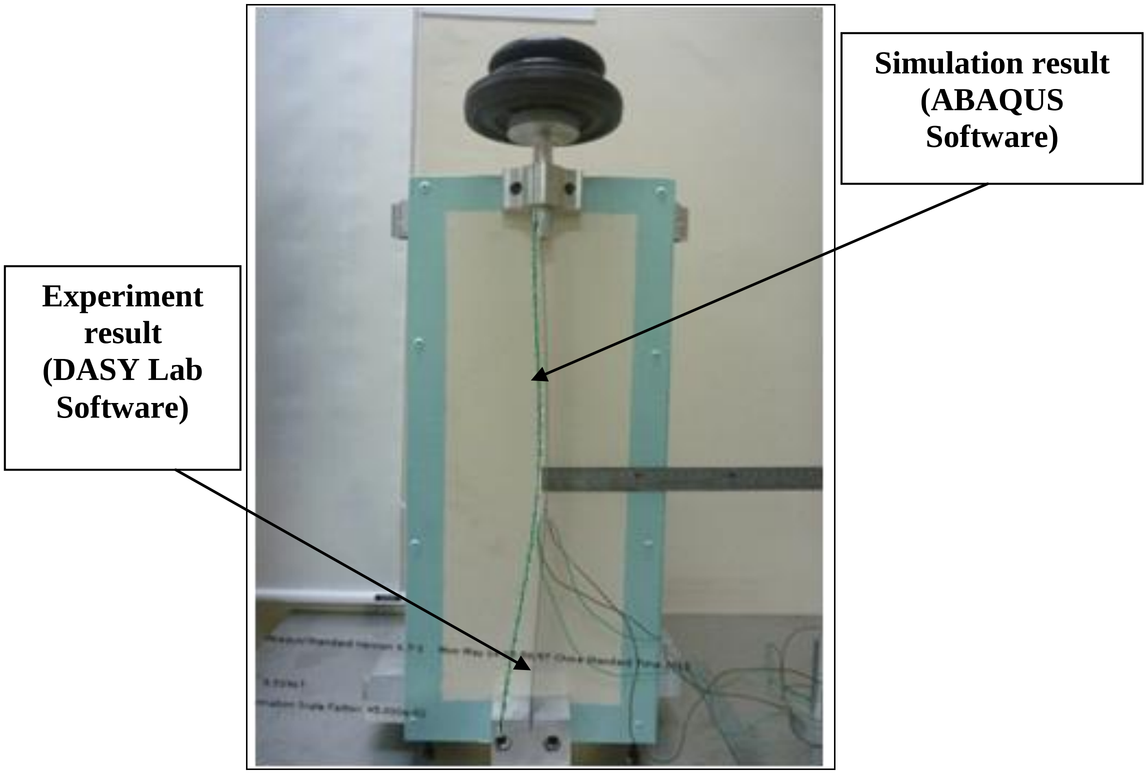
Figure 6.11 show the buckling comparison between experimental result and simulation result for 10 N loads. From experiment result which is applied by DASY Lab software, the buckle that produced is almost same with the simulation result which is from ABAQUS software. The experiment is said to be success when 10 N loads apply.



20 N

Figure 6.12: Comparisons between experimental result and simulation result for 20 N loads

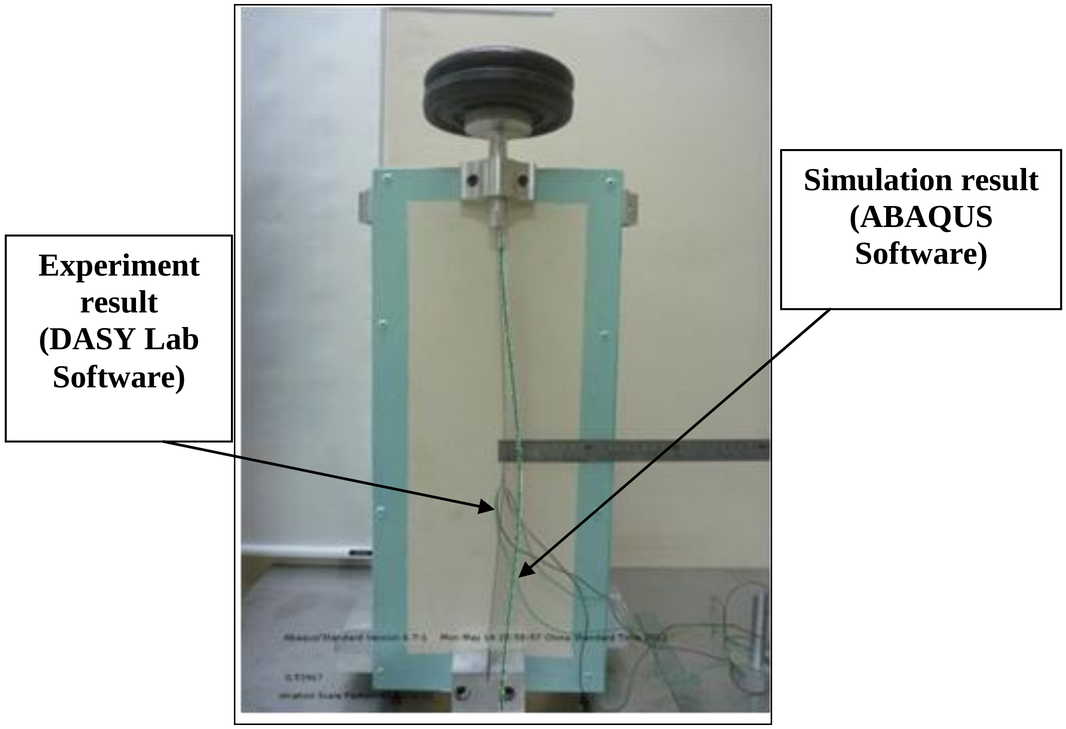
Figure 6.12 show the buckling comparison between experimental result and simulation result for 20 N loads. From experiment result which is applied by DASY Lab software, the buckle that produced is almost same with the simulation result which is from ABAQUS software. The experiment is said to be success when 20 N loads apply.



30 N

Figure 6.13: Comparisons between experimental result and simulation result for 30 N loads

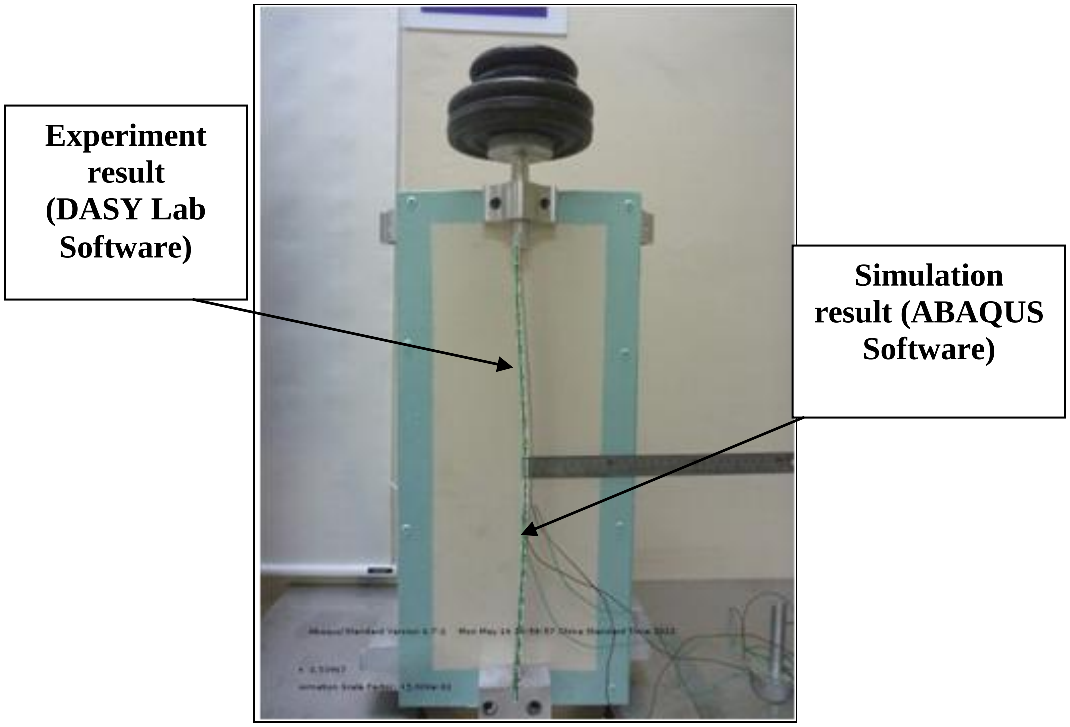
Figure 6.13 show the buckling comparison between experimental result and simulation result for 30 N loads. From experiment result which is applied by DASY Lab software, the buckle that produced is almost same with the simulation result which is from ABAQUS software. The experiment is said to be success when 30 N loads apply.



40 N

Figure 6.14: Comparisons between experimental result and simulation result for 40 N loads

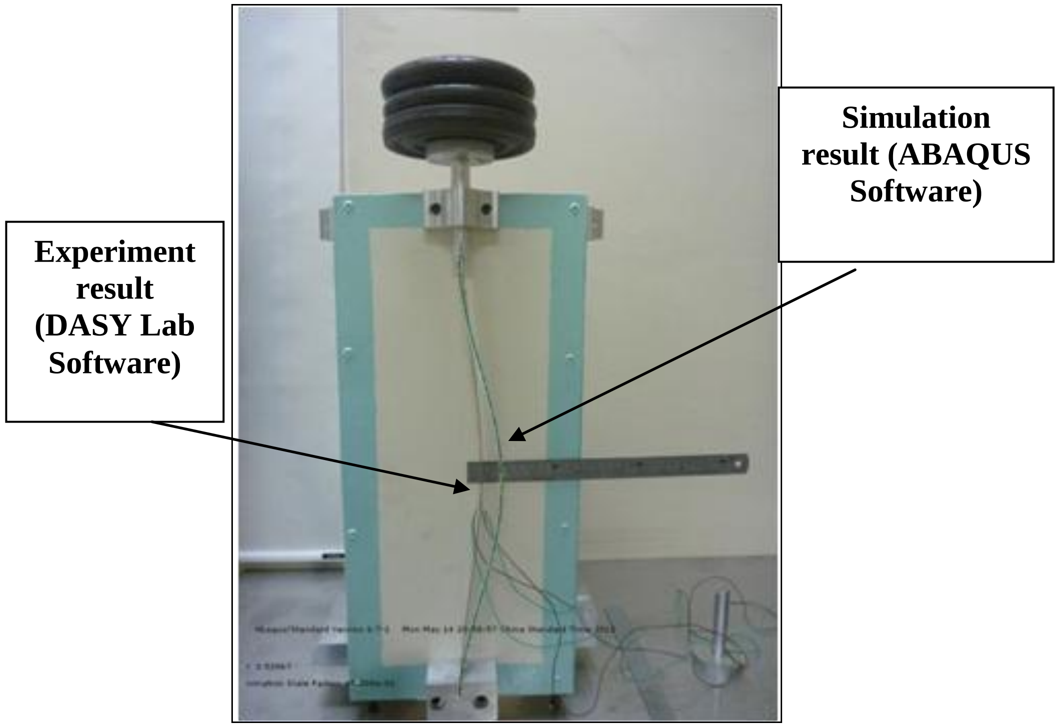
Figure 6.14 show the buckling comparison between experimental result and simulation result for 40 N loads. From experiment result which is applied by DASY Lab software, the buckle that produced is almost same with the simulation result which is from ABAQUS software. The experiment is said to be success when 40 N loads apply.



50 N

Figure 6.15: Comparisons between experimental result and simulation result for 50 N loads

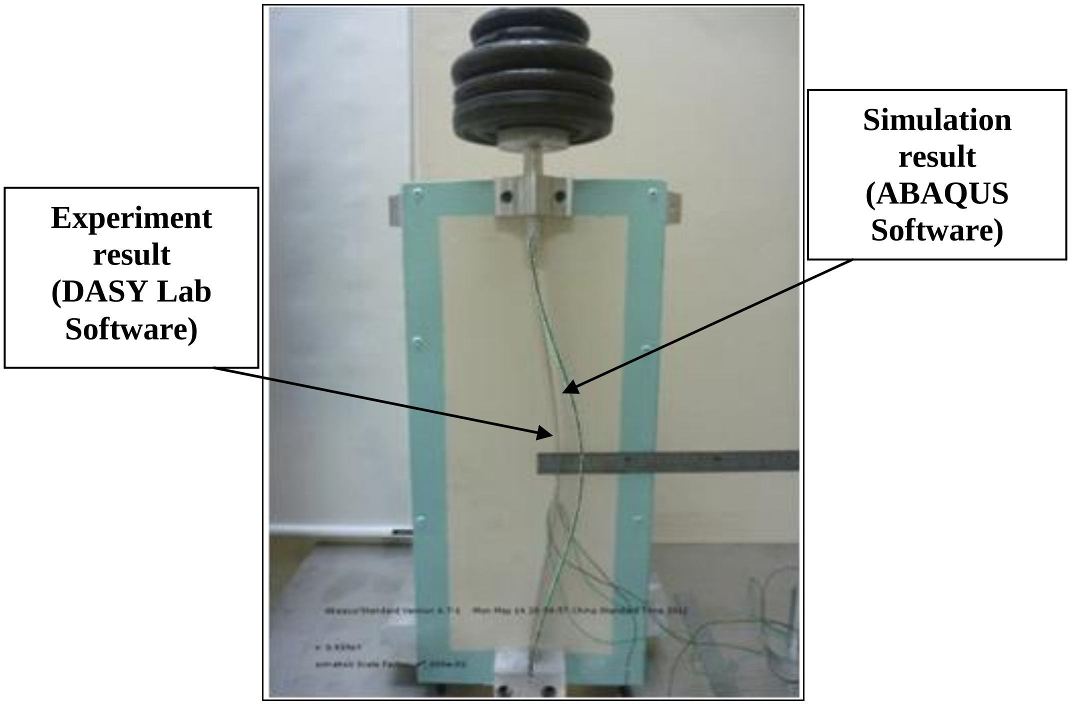
Figure 6.15 show the buckling comparison between experimental result and simulation result for 50 N loads. From experiment result which is applied by DASY Lab software, the buckle that produced is almost same with the simulation result which is from ABAQUS software. The experiment is said to be success when 50N loads apply.



60 N

Figure 6.16: Comparisons between experimental result and simulation result for 60 N loads

Figure 6.16 show the buckling comparison between experimental result and simulation result for 60 N loads. From experiment result which is applied by DASY Lab software, the buckle that produced is almost same with the simulation result which is from ABAQUS software. The experiment is said to be success when 60 N loads apply.

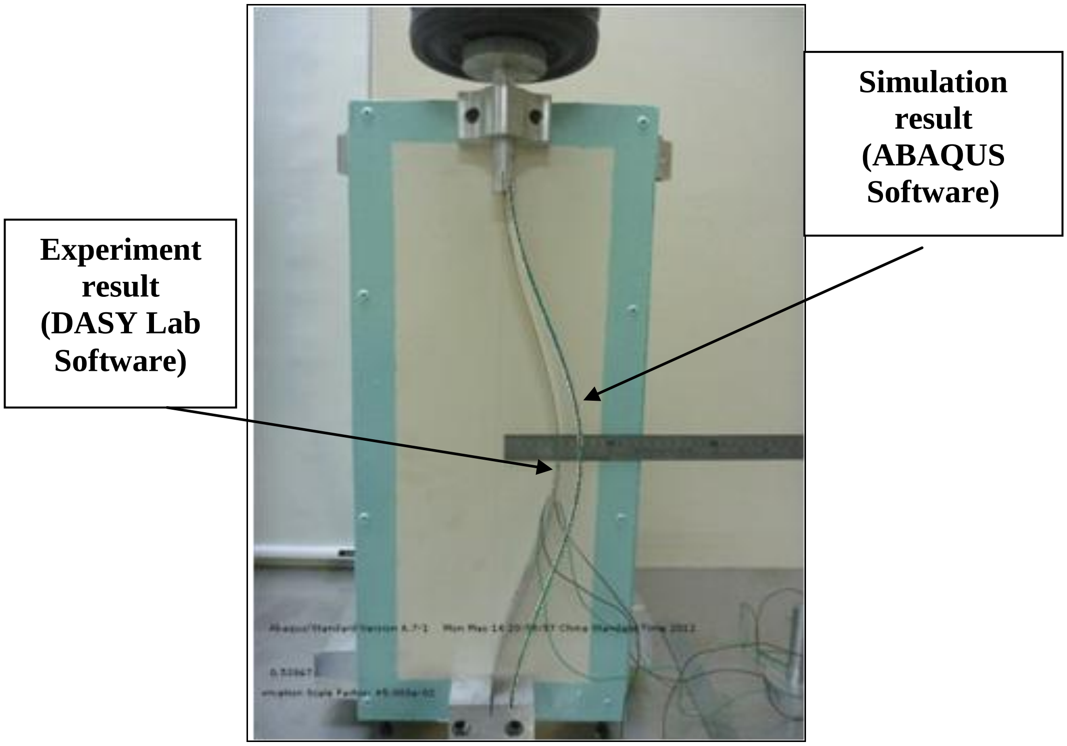


70 N

Figure 6.17: Comparisons between experimental result and simulation result for 70 N loads

Figure 6.17 show the buckling comparison between experimental result and simulation result for 70 N loads. From experiment result which is applied by DASY Lab software, the buckle that produced is almost same with the simulation result which is from ABAQUS software. The experiment is said to be success when 70 N loads apply.

.



80 N

Figure 6.18: comparisons between experimental result and simulation result for 80 N loads

Figure 6.18 show the buckling comparison between experimental result and simulation result for 80 N loads. From experiment result which is applied by DASY Lab software, the buckle that produced is almost same with the simulation result which is from ABAQUS software. The experiment is said to be success when 80 N loads apply.

CHAPTER 7

CONCLUSION AND RECOMMENDATIONS

7.0 INTRODUCTION

When the load reaches the Euler load, buckling suddenly takes place without any further load increase, and lateral deflections and grows instanteously in either equally probable direction. After buckling therefore, the equilibrium path bifurcates into two symmetric secondary paths as illustrated. Clearly the critical Euler load limits the column's safe load capacity. Figure 7.1 shows the equilibrium path bifurcates into two symmetric secondary paths

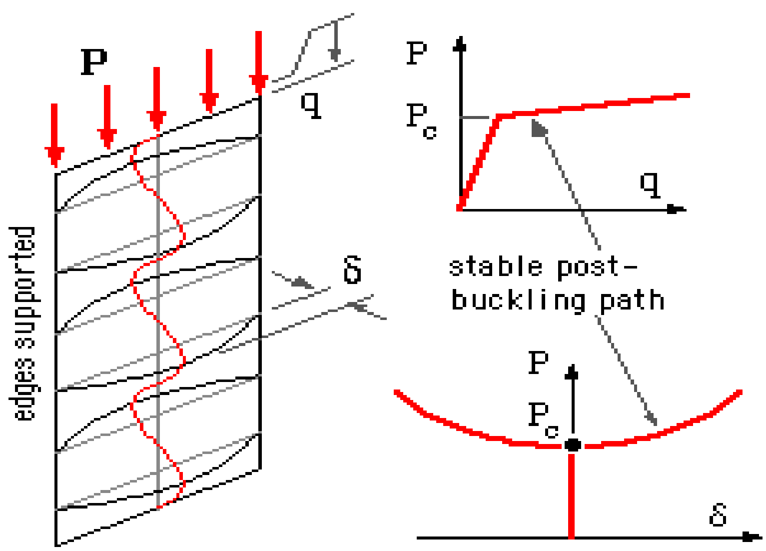


Figure 7.1: the equilibrium path bifurcates into two symmetric secondary paths

7.1 CONCLUSION

From the experiment that already be done, it can be conclude that the ABAQUS suite of software for finite element analysis (FEA) is known for its high performance, quality and ability to solve more kinds of challenging simulations than any other software. The ABAQUS suite also consists of three core products which are ABAQUS/Standard, ABAQUS/Explicit and ABAQUS/CAE. Each of these packages offers additional optional modules that address specialized capabilities some customers may need. From the experiment, the physical shape of buckle already follows the Euler's rule buckling shape and the critical load of the experimental given. Every addition of single load apply onto specimen give the addition of buckle shape, beside the value of strain on the surface of specimen also increase. Thus, the value of maximum displacement for buckle point on the specimen also increase due to increases of addition load applies .In addition, it is can be say that for every addition of force given, give the increases of surface strain value and maximum displacement on buckle point of the specimen until it is reach the Yield's Strength point. Furthermore, by using Abaqus Software it is give the comparison of the displacement value from the experimental and simulation. The highest percentage of differences between displacements values are 24%. For example finite element method must be done by using Abaqus Software while strain gauge must be done by using DASYLab software. %. Small error for the measured force, strain and displacement are expected due to material deformation during the experimental work. Lastly, learn how to draw the graph occurs that are directly proportional with each other which mean load (N) is proportional with strain reading while load (N) also proportional with displacement (mm) readings.

7.2 RECOMMENDATIONS

From this project, there are several recommendations that can be proposed. Based on the project title Experimental & Numerical study on sheet metal lateral bending with fixed and pinned ends ,the first recommendation is design new test rig on buckling test in group of four. The new test rig design is follow the mechanical and manufacturing processes on buckling test to organize into each function and purposes. The new design also followed engineering interacts with virtually all of them. There are natural tensions between the functions which if not managed correctly can prove disastrous. Secondly, there are some other modifications on material selection so that the test equipment can be more efficient on running the experiment. For example, Wall of the test equipment also can be change to aluminum so that the test equipment not too heavy and it is can be more portable. The third recommendation is to apply different software with different application which means each application must be done by their specific software. This is because, not all experiments can use any software. Some experiment must be done only by their specific software. Beside, for simulation, other setup can be done for gain other value based on experiment that had been done.

REFERENCES

Andreasen, M.; Kähler, H.; Lund, R. 1988. *Design for Assembly*. UK: IFS Publications.

Boothroyd, G., Knight, W., and Dewhurst, P. 2002. *Product Design for Manufacture and Assembly,* 2nd Edition, Marcel Dekker, Inc.

Boothroyd, G. 2001. *Product Design For Manufacture And Assembly,* Second Edition.New York: Marcel Dekker Inc. 374p.

Bannantine J.A., Comer J.J., and Handrock J.L.,1989. *Fundamentals of Metal Fatigue Analysis*, Prentice-Hall.

Boothroyd, G.; Dewhurst, P.; Knight, W. 1990. *Product Design for Assembly*. Wakefield:Boothroyd Dewhurst, Inc.

Boothroyd, G. 1994. *Product design for manufacture and assembly*. New York: Marcel Dekker.

Cook, Robert D./Plesha, Michael E./Malkus, David S.; John Wiley & Sons; 1989 *Concepts and Applications of Finite Element Analysis*, 3rd edition.

C. W. Huff, T. Finholt, 1994. *Social Issues in Computing: Putting Computers in Their Place*. McGraw-Hill New York.

Canada, Ivey Publishing, Richard Ivey School of Business, The University of Western Ontario. Zinsser, W., (1998), *On Writing Well: The Classic Guide to Writing Nonfiction, (Sixth Edition),* New York, HarperCollins Publishing.

D. Zaccaria, D. Bigoni, G. Noselli and D. Misseroni, 2011. Structures buckling under tensile dead load. *Proceedings of the Royal Society A.* 467, 1686-1700.

David M. Anderson. 2008. *Build-to-Order & Mass Customization; The Ultimate Supply Chain Management and Lean Manufacturing Strategy for Low-Cost On Demand Production without Forecasts or Inventory,"* .2008, 520 pages.

David M. Anderson. 2010. *Design for Manufacturability & Concurrent Engineering; How to Design for Low Cost, Design in High Quality, Design for Lean Manufacture, and Design Quickly for Fast Production* .2010, 456 pages.

Degenhardt R., Kling A., Klein H., Hillger W., Goetting Ch., Zimmermann R., Rohwer, K., Gleiter A..2007. Experiments on Buckling and Postbuckling of Thin-Walled CFRP Structures using Advanced Measurement Systems", *International Journal of Structural Stability and Dynamics*. Vol. **7**, no. 2 (2007), pp. 337-358

Degenhardt R., Bethge A., Rohwer K., Zimmermann R., Kling A. 2007. "Probabilistic Approach for better Buckling Knock-down Factors of CFRP Cylindrical Shells – Tests and Analyses", Proceedings of the 18th Engineering Mechanics Division Conference of the American Society of Civil Engineers, Blacksburg, Virginia, USA, 3-6 June, 2007

Degenhardt R., Kling A., Rohwer K. 2007. "Design and Analysis of Stiffened Composite Panels Including Postbuckling and Collapse", *Journal of Computers and Structures* (2007, doi:10.1016/j.compstruc.2007.04.022)

M. I. Friswell, J. E. Mottershead; Kluwer Academic Publishers; 1995.*Finite Element Model Updating in Structural Dynamics*; Klaus-Jurgen Bathe; Prentice Hall; 1995 Finite Element Procedures,Finite Element Model Updating in Structural Dynamics;

G. Boothroyd and W. Knight. 1993. Manufacturing À La Carte: Efficiency: Design for assembly. IEEE Spectrum. Sept 1993, pp. 51-53.

G. Causey. 1999. "Elements of agility in manufacturing", Ph.D. Dissertation (Mechanical Engineering), CWRU, January 1999.

Huang, G. 1996. *Design for X*. London: Chapman & Hall.

Joneja, A. *Design for Manufacturing/Assembly (DFM, DFA, DFMA*). Department of Industrial Engineering and Engineering Management (IEEM), Hong Kong University of Science and Technology.

K. Bowyer. 1997. *Undergraduate Faculty Enhancement: Workshops on Teaching Ethics and Computing*,1997.
Abstract available at: http://www.nsf.gov/cgibin/showaward?award=9752792

Lindberg, H. E., and Florence, A. L., 1987. *Dynamic Pulse Buckling*, Martinus Nijhoff Publishers, 1987, pp. 11–56, 297–298. Garret N. Vanderplaats, Vanderplaats Research & Development, Inc. 1999 O.C. Zienkiewicz, 2000. Finite elements method, Butterworth-Heinemann Linacre House, Jordan Hill, Oxford. Numerical Optimization Techniques for Engineering Design, 3rd edition (includes software).

Pekka Marjamäki, Toni Mattila, and Jorma Kivilahti, 2005. "Finite Element Analysis of Lead- Free Drop Test Boards," Proc 55th Electronic Components and Technology Conference, pp. 462-466.

R. Zimmermann, H. Klein, A. Kling. 2006. "Buckling and postbuckling of stringer stiffened fibre composite curved panels – Tests and computations", *Composite Structures*, Vol. **73**, pp. 150-161

R. E. Anderson. 1994. *"The ACM Code of Ethics: History, Process, and Implications," in Social Issues in Computing: Putting Computers in their Place*, eds. C. Huff and T. Finholt, McGraw-Hill, New York: pp. 48-71.

R. Rosenthal, R. Rosnow. 1991. *Essentials of Behavioral Research: Methods and DataAnalysis*,McGraw-Hill, New York, 1991.

S. Thipprakmas, M. Jin, K. Tomokazu, Y. Katsuhiro, M. Murakawa. 2008. Prediction of fine blanked surface characteristics using the finite element method (FEM). *Journal of Materials Processing Technolog.* **198** (2008) 391-398.

S. Ju, C. Fan, G. Wu. 2004. Three-dimensional finite element soft steel Boltem connections, *Engineering Structures*. **26** (2004) 403-413.

Thomson, W. T., 1987. *"Vibration," in Marks' Standard Handbook for Mechanical Engineers*, 9^{th} Ed., edited by E. A. Avallone and T. Baumeister III, McGraw-Hill, NewYork, pp. 5.67–5.76.

T. Da Silva Botelho, E. Bayraktar, G. Inglebert. 2007. Experimental and finite element analysis of spring back in sheet metal forming, *International Journal of Computational Materials Science and Surface Engineerin.* **1/2** (2007) 197-213.

T. Burakowski, T. Wierzchon, 1995.*Engineering of metal surface*, WNT, Warsaw.

Timoshenko, S. P., and Gere, J. M.,. 1961.Theory of Elastic Stability, 2 ed., McGraw-Hill. Wang, Y. C. and Lakes, R. S. 2004. "Extreme Stiffness Systems due to Negative Stiffness Elements", *American Journal of Physics*, **72**: 40-50.

Yang, K; El-Haik, B. 2003. *Design for six sigma: a roadmap for product development*. London: McGraw-Hill, 2003

Y. Kim, S. Yaang, D. Shan, S. Choi, S. Lee, B. You. 2006. Three-Dimensional Rigid-Plastic FEM Simulation of Metal Forming Processes, *Journal of Materials Engineering and Performance*. **15**/3 (2006) 275-279.

APPENDICES

APPENDIX A1

26-28th March 201
SPORT COMPLEX, UMP

ENTRY FORM
UNDERGRADUATE STUDENT CATEGORY

2012

Application Instruction:
This form is to be returned as soon as possible and **not later than 12th March 2012** to the secretariat office:

Student Affair & Alumni Department
En. Abdul Rahman Ahmad
Tel: +60199868200
Fax: +609–549 2535
E-mail: rahman@ump.edu.my

En. Ridzuadi Ibrahim
Tel:+60199175106

For Office Use Only
Date received:
Ref. No:
Category:
Application No:

CREATION, INNOVATION, TECH NOLOGY & RESEARCH EXPOSITION (CITREx 2012)

UNIVERSITI MALAYSIA PAHANG

ENTRY FORM

UNDERGRADUATE STUDENT CATEGORY

Personal Particular *(In CAPITAL LETTERS)*

Name of applicant/s:

MOHD SHAHRIL BIN MOHD HASSAN

Matric Card No: ME08055

Faculty: Faculty of Mechanical Engineering

H/P No: 0179601020

E-mail: shah_ayeir89@yahoo.com

Section A

1. Title of invention/innovation exactly as you wish it to appear on an award certificate (if an award is won):

Buckling test rig

2. Name of individual(s) that you wish to appear on an award certificate (if an award is won):
Mohd Shahril Bin Mohd Hassan
Mohd Adzlan Bin Mohd Azmi
Mohd Jaafar Bin Mohd Nor
Norazlianie Binti Sazali
Khairul Azha A. Jalal
Asmizam Mokhtar
Mohd Zaidi Sidek

3. In which category do you want to submit your invention / innovation for the award? (*refer to the terms of reference on page 3*)

Category A

4. How do wish to present your invention / innovation?
- ☐ Manufactured article
- ☑ Model
- ☐ Prototype
- ☐ Plan

APPENDIX A2

Section B

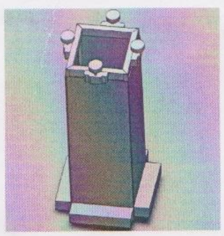
Please specify the technical features of your invention / innovation. Attach a diagram if applicable.

Higher education teaching requirs lecturers apply various methods to make the subject easier. In this case, teaching technique is the most important factor. One of the subject is on computer simualtion such as finite element method. For this subject, students need to understand the basics engineering mechanics and materials, failure prevention under static and variable loading, and characteristics of the principal types of mechanical elements. With the current practice where stduent only learn based on following the given tutorial, it is not really practical to make student understand this subject. Hence, the new method of teaching is needed to teach subject this subject based on comparison between experiment and simulation analysis.

The exhibited fixture is a new type of experiment test rig can be used for the Finite Element Course, specifically to study buckling problem in sheet metal bending. Buckling is a failure mode characterized by a sudden failure of a structural member subjected to high compressive stresses, where the actual compressive stress at the point of failure is less than the ultimate compressive stresses that the material is capable of withstanding. The load at which the specimen buckles depends on the way in which the ends are restrained. The product shows how the buckling mechanism occurs, and the influence of the end. Each specimen has a different end constraint so that comparisons can be instantly made in a highly visible way.

i. The both ends are fixed.
ii. The both ends are pinned.
iii. The ends are combination of a fixed and pinned joint.
iv. The ends are combination of a fixed and free-end.

The buckling result from the product result will be compared to computer simulation with the finite element analysis.



The Buckling test equipment

I, the undersigned, declare that the invention / innovation is my property and I agree to abide by the regulation.

Applicant Signature	Supervisor Signature
m.shahril	Zaidi
Name: MOHD SHAHRIL BIN MOHD HASSAN	Name: MOHD ZAIDI SIDEK
Date: 14/03/2012	Date: 14/03/2012

APPENDIX A3

CITREx 2012 Tentative Program

Monday, 26 March 2012	
2:30 ptg	Registration & Setup Poster + Display Item
5:00 ptg	Sport Complex will be closed

Tuesday , 27 March 2012	
8:30 am	Arrival of the Participants
9:00 am	Briefing for the Judge
9:30am – 12:30pm	Judging Session 1 / Exhibition open to the visitors
1:00 pm	Lunch Break
2:30-5:00 pm	Judging Session 2 / Exhibition open to the visitors

Wednesday, 28 March 2011	
9:00 am	Arrival of the Participants
9.30am – 12.30pm	Exhibition open to the visitors
1.00 pm	Lunch Break
2.30 – 4.30 pm	Award Giving Ceremony

APPENDIX A4

ITREX 2012

KRITERIA PEMARKAHAN

1.Keaslian rekaan/inovasi/ciptaan • Sesuatu yang baru/unik • Daya cipta	**Keaslian ciptaan / inovasi** Semua ciptaan dan innovasi hendaklah asli dan tidak pernah dipertandingkan di mana-mana pertandingan UMP lagi sebelum ini.
2.Kebolehgunaan sesuatu ciptaan/ inovasi • Berguna untuk menyelesaikan masalah • Kesungguhan semasa proses rekaan/ciptaan	Sebelum sesuatu rekaan/ciptaan direka perlulah difikirkan akan keperluan sesuatu rekaan itu. Adakah sesuatu rekaan/ciptaan memberi kesan/makna dalam kehidupan? Adakah rekaan itu membantu menyelesaikan masalah? Sebelum proses penciptaan tersebut, adakah terdapat sebarang kajian contohnya kajian atau soal selidik tentang pasaran dibuat supaya sesuatu rekaan/ciptaan tersebut memenuhi permintaan dan keperluan pasaran atau industri? Dalam erti kata lain untuk apakah aplikasi rekaan/ciptaan tersebut?
3.Tahap rekaan/ciptaan • Status produk akhir dan kesediaan untuk pasaran • Fungsi sesuatu produk	Apakah tahap ciptaan/rekaan tersebut? Adakah ia telah sedia untuk dipasarkan dan dikomersilkan? Jika ia masih di tahap ujian maka adakah ia boleh ditingkatkan lagi mutunya/kualitinya ke tahap skala industri atau adakah ia masih memerlukan lebih banyak ujian untuk meningkatkan kualitinya? Adakah produk itu mudah diperolehi? Adakah produk yang dipamerkan berfungsi atau tidak?Atau ia sekadar model sahaja?Setakat mana kemampuan produk tersebut?
4. Nilai Komersil • Potensi untuk dipasarkan • Potensi perpindahan teknologi	Apakah tahap permintaan pasaran? Saiz pasaran.Adakah telah dibuat kajian pasaran?Adakah pasaran terhad kepada pasaran tempatan sahaja atau termasuk pasaran luar negara. Apakah nilai pasaran?Berapakah nilai keuntungan yang mampu diperolehi daripada rekaan tersebut.Mungkin permintaan produk tinggi tetapi nilai produk rendah atau sebaliknya. Jika permintaan produk tinggi adakah kemungkinan adanya perpindahan teknologi.

APPENDIX A5

5.Persembahan • Usaha - persembahan adalah menarik dan penuh informasi.(informatif dan menarik).	Adakah usaha diperlihatkan dalam mempersembahkan sesuatu rekaan/ciptaan?Saiz poster yang tepat,mudah dibaca dan difahami. Adakah terdapat prototaip/model yang sesuai dipertontonkan. Adakah ia berfungsi atau sebaliknya. Penelitian dalam persediaan persembahan. Adakah terdapat pamplet disediakan.
• Pengetahuan tentang rekaan/ciptaan/inovasi dari sudut saintifik dan objektif/tujuan kejuruteraan.	Adakah pereka/pencipta tahu apa yang dilakukannya?Adakah sebarang objektif dari sudut saintifik/kejuruteraan? Bolehkah pereka berkongsi ilmu dengan orang lain?Adakah dia mampu untuk memenuhi matlamat yang disasarkannya?

APPENDIX A6

TERMS OF REFERENCE

1. This competition is only open to researchers that have official research project registered with P&I.
2. An invention/innovation must be new unless substantial modifications have been done to it since it was first competed in any other award.
3. An invention/innovation may be presented in the form of pro-series or commercial samples, already manufactured articles, prototypes, models, plans, drawings, photos and texts.
4. Inventor/innovator must complete a separate entry form for each invention/innovation per category, which they wish to compete. Not more than one invention/innovation may be submitted on each form. Photocopies of entry form may be used.
5. A security service will operate during the whole period of the Exhibition. However, the Secretariat accept no responsibility for loss, theft, damage due to fire or other cause to invention/innovation during the Exhibition or in transit.
6. By his formal application to participate in the award, each inventor/innovator undertake to ensure the delivery of his invention/innovation before **9:00 hour 12th March 2012** and to allow it to remain on display during the whole Exhibition. Any inventor/innovator withdrawing his invention/innovation before closure shall render himself liable to pay damages and shall forfeit any award given to him.
7. The inventor/innovator or his representative is required to be at the exhibit at all times, throughout the Exposition. Failure to comply may cause the forfeiting of any award given to him.
8. All expenses occur should be borne by researcher using own research grant and we recommend that poster size for this exposition is in **A1** size.
9. The decisions of the judges are final. Any complain will not be entertained.

AWARD CATEGORIES

An invention/innovation may be classed under either one of the following categories. Please pick the class which suits your invention/innovation best. You are to decide in which class it will be placed.

Category A: Mechanics – Engines – Machinery – Tools – Industrial processes – Metallurgy

Category B: Clocks and watches – Jewellery – Machinery – Tools

Category C: Electronic – Electricity – Computer Science – Radio-television – Video – Telecommunications

Category D: Building – Architecture – Civil Engineering Construction – Materials – Woodwork

Category E: Sanitation – Ventilation – Heating

Category F: Security – Rescue – Alarm

Category G: Ironware – D.I.Y.

Category H: Furnishing – Interior architecture

Category I: Domestic science – Restaurant equipment

Category J: Commercial, Industrial and office equipment

Category K: Agriculture – Horticulture – Gardening

Category L: Clothing – Textiles – Machines and accessories

Category M: Medicine – Surgery – Hygiene – Orthopedics

Category N: Optics – Photography – Cinematography

Category O: Teaching methods and materials – Musical instruments – Art materials

Category P: Transport – Motor vehicles – Ships – Aviation – Accessories

Category Q: Foodstuff – Drinks – Cosmetics – Paramedical – Health

Category R: Sport – Leisure

Category S: Practical novelties – Presents

Category T: Publicity – Printing – Packaging

Category U: Games – Toys

Category V: Protection of the environment – Energy – Water

Category W: Biotechnology and Life Science

APPENDIX A7

Universiti Malaysia PAHANG
Engineering • Technology • Creativity

CITReX

Certificate of Award

BRONZE MEDAL

This Certificate of Award is presented to

Mohd Shahril bin Mohd Hassan, Mohd Adzlan bin Mohd Azmi, Mohd Jaafar bin Mohd Nor, Norazlianie binti Sazali, Khairul Azha bin A. Jalal, Asmizam bin Mokhtar, Mohd Zaidi bin Sidek

For the invention / innovation of

Buckling Test Ring

CREATION, INNOVATION, TECHNOLOGY & RESEARCH EXPOSITION

26 – 28 March 2012, Universiti Malaysia Pahang

PROFESSOR DATO' DR. ROSLI BIN MOHD YUNUS
Deputy Vice-Chancellor (Research & Innovation)
Universiti Malaysia Pahang

UNIVERSITI MALAYSIA PAHANG • UMP