Development of An Experimental Gantry Crane Rig

by

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CERTIFICATION OF APPROVAL

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UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

January 2009

CERTIFICATION OF ORIGINALITY

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

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ABSTRACT

A project has been conducted on the development of a gantry crane experimental rig. The project focused on the analysis on the structural, rigidity and stability of the rig. The aim of the analysis is to determine whether the element or collection of elements, can safety withstand the specified forces. The challenge of this project is to find the best structural design of the gantry crane rig by computer simulation using ANSYS, and by conducting stress and deformation analysis. The design also will be considered material selection, which is the outcome of material selection is the selection of most suitable material to be used for the gantry crane structure.

ACKNOWLEDGEMENT

I would like to take this opportunity to acknowledge the people who had given their support and help throughout the completion of this project. First of all, I would like acknowledge the endless help and support received from my supervisor, Mr. Azman Zainuddin. His assistance and guidance have been the main source of motivation to work on this project. Last but not least, I would like to thank all my fellow colleagues for their assistance and ideas in completion of this project.

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CHAPTER 1

INTRODUCTION

1.1 Crane: Overview

In our environment, there is necessity to transfer the things like equipments, payloads, etc from one place to another. In the workplace for example, like construction sites and shipyards, cranes are commonly used to transfer payloads from one point to another point. These materials are usually heavy, large and hazardous, which cannot be handling by workers. In order to make the work easier, cranes have been used to lift, move, position or place machinery, equipment and other large objects. Several examples of cranes which have been used for this purpose are tower crane, boom crane, overhead crane, gantry crane and others. Figures 1.1 and 1.2 show examples of overhead crane and gantry crane respectively.

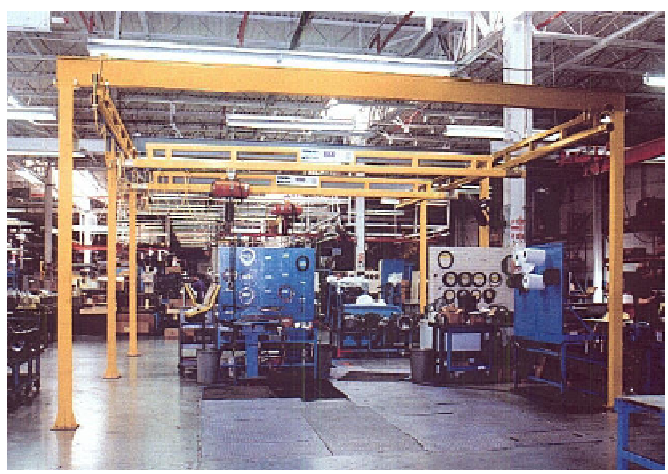

Figure 1.1 Fixed Overhead Crane

Figure 1.2 Rubber-tyred Gantry Crane

A crane consists of a hoisting mechanism (usually a hoisting line together with a hook) and a support mechanism. A cable with the load hanged on the hook is suspended from a point on the support mechanism. The support mechanism moves the suspend load around the crane workspace, while the hoisting mechanism lifts and lowers the load to avoid the obstacles in the path and locate the load at the desired location.

While operating the crane, safety is the most important factor to avoid accidents. Because of that, the crane must be operated in safe operating manner and procedures. For a crane operator, an experience causing a crane's accidents can be frightening to them. The best examples are in April 1993, the crane becomes unbalanced during two separate accidents at DOE sites in United States of America, which is in Hanford Site and Bryan Mound Site. The first accidents occurred in 28th April 1993, where a crane becomes unbalanced while the boom was being lowered. The second incident occurred 2 days later, on 30th April 1993, while loading the load, the weight of the load caused the crane to tip forward **[1].** From these incidents, guidelines have been suggested in using the cranes. Some of the guidelines are:

i. The weight of load must be checked
ii. Crane operations should be supervised by qualified personnel
iii. Crane operators must be familiar with the equipment
iv. Crane operations must be trained and qualified to operate their equipment

Although the guidelines have been sketched in order to prevent the accident, the other factors also must be considered so that the probability of accidents occurs is small or reduced at an acceptable value. There are many factors that have to be considered: the braking systems, hydraulic and pneumatic components, electrical equipments, operational aids, operating mechanisms, lifting devices, determining load weight, recognizing immediate and potential hazards, control systems and others. In term of control systems, the important issue is how to control the load swing. This is important in order to have a faster operation while maintaining the safety.

1.2 Gantry Crane

Figure 1.3 Gantry Crane

Generally, crane can be defined as a machine used for lifting and lowering a load vertically and moving it horizontally and that has a hoisting mechanism as an integral part of it. As mentioned before, a crane types has varies, depend on their application: automatic crane, cab-operated crane, cantilever gantry crane, gantry crane, jib crane, mobile crane, overhead traveling crane, power operated crane, remote-operated crane, semi gantry crane and wall-mounted jib crane. In this project, the work will be focused on a gantry crane.

Gantry crane is similar to an overhead crane, except that the bridge for the carrying the trolley or trolley is rigidly supported on two or more legs running on fixed rails or other runway. To implement the operation, the crane operator will seat inside the cart, and move the cart with the load hanged with it so that the load can achieve the desired location. A real crane may allow a cart movement to 80 to 90 meters **[2]**, regarding on the desired load location.

1.3 Problem Statement & Identification

The usage of the gantry crane is very important to complete any project in the lab. Because of this problem, student has been asked by researcher to design the gantry crane which can be used for lab purpose. The design must meet several criteria. Research has been done from existing design of the gantry crane. The findings prior to problem statement can be described below:

i. The design of gantry crane can be used in laboratory
ii. Gantry crane cannot be used for a lot of applications, because of differences in design
iii. During transit, the payload swing freely. The swinging motion makes the accurate positioning of the payloads difficult. Thus, the structure should be design to avoid this problem

In order to produce the gantry crane with minimal trouble and high reliability, a more innovative and systematic development of gantry crane is needed.

1.4 Project Objectives & Scope of Study

The main objective of this research is to design the structure of the test rig of a gantry crane for use in research. The scope of work for this project includes the simulation using ANSYS software to analyze the stress and deformation for the structure and design of gantry crane. CATIA software will be used to design the mechanism of the gantry crane.

1.5 Project Significance

The project will provide useful info regarding the stability of the experimental rig. This information will benefit the design of the rig and indirectly contribute to the research and development in gantry crane load sway control research.

CHAPTER 2

LITERATURE REVIEW

2.1 Gantry Crane Test Rig

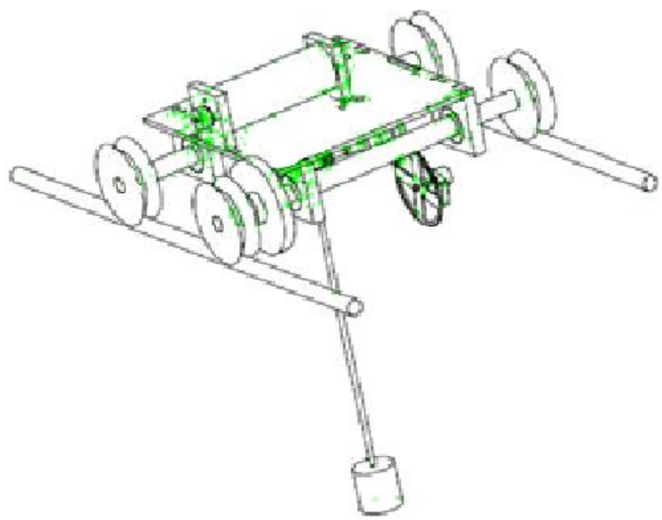

Figure 2.1 Schematic of laboratory gantry crane.

The rig, shown in Fig. 2.1, is a laboratory-scale model of a gantry crane that is typically used to move heavy loads in many manufacturing and other commercial environments. The crane is made up of a carriage (motor and cart) which rolls on rails and which supports a suspended load. The rails are mounted to the ceiling in the laboratory. The motor is a dc servomotor, which is coupled to the drive wheels through a gear train and a belt [3]. Using the current motor, the maximum speed of the crane is approximately 5 ft/sec, and the bandwidth of the system is approximately 15 Hz. Instrumentation in the system includes a tachometer and two potentiometers. The tachometer is mounted to the motor shaft for measuring motor speed (which can be related to linear speed of the crane through the kinematics.) A ten-turn potentiometer is used to measure the crane's position on the track. The potentiometer is mounted to the carriage, and its shaft is coupled to one of the axles of the crane. The coupling is designed such that the potentiometer rotates just fewer than ten turns as the crane traverses the length of the track. By using the coupling kinematics, the potentiometer signal is related to crane position. The second potentiometer is a single-turn potentiometer that is mounted to the point of attachment of the suspended load, and is used to provide angular position of the load under the crane.

The motor is powered by a voltage-regulated power amplifier which can provide +/- 24 volts and approximately 5 amps with the power supply that is presently in place.

Voltage to the motor is governed by the controller that can be implemented two ways in the present system. A 486- based personal computer is available with a data acquisition board.

2.2 Gantry Crane Girders

The main function of the crane gantry girders is to support the rails on which the traveling cranes move. These crane gantry girders are subjected to vertical loads from crane, horizontal lateral loads due to surge of the crane and longitudinal force due to acceleration and braking of the crane as a whole. Because of the weight of the crane, several aspects must be considered like impact and horizontal surge.**[4]**

Table 2.1 Impact and surge of cranes

Type of Loads	Additional Loads
Vertical-electrical operated	25% of max static wheel load
Hand operated	10% of max static wheel load
Horizontal, lateral to rails	5% of weight of crab plus weight lifted per rail
Electrically operated	2.5% of weight of crab plus weight lifted per rail
Hand operated	
Horizontal, along axis	5% of max static wheel load

Horizontal forces, lateral and longitudinal are assumed not to act together with the vertical loads. Only one of them is assumed acting with the vertical load at a time. Under normal circumstances, the crane girders must be designed as laterally unsupported beam carrying vertical and horizontal load at the level of the top flange.

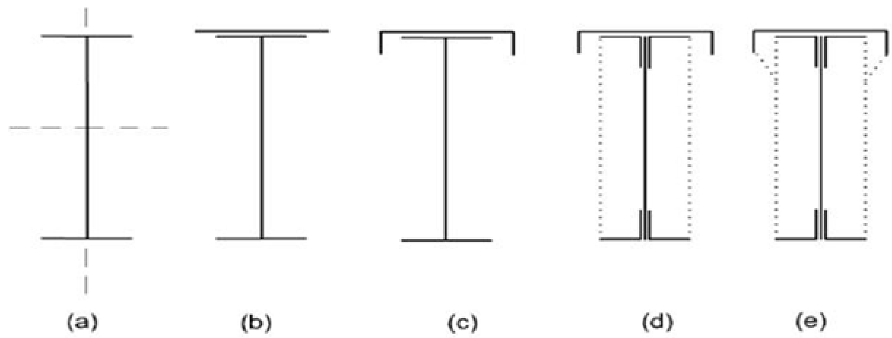

Figure 2.2 Typical sections adopted for crane girders.

(a) Wide flange beam without any reinforcement and used for short spans and very light crane loads.

(b) Cover plate is used on the compression face which improves the lateral buckling strength of the beam

(c) A channel has been used instead of the cover plate to further increase I_w.

(d) And (e) shows plate girder sections used for longer spans and heavier crane loads

2.3 Modelling of Gantry Crane

To ensure that the developed control algorithm is appropriate and suite with the focused problem, one aspect that cannot be ignored is the model of gantry crane itself. Some researchers take the characteristic of pendulum as their model to derive dynamic equation that representing the gantry crane. At this point, more attention is needed because all of the processes forward will be based on the developed model.

Therefore, this point becomes an interest for researchers to do a work related on this, and they have come out with their suggested model, where a lot of consideration and factors have been taken on their models.

One of the works regarding on modeling to calculate the dynamics response of structure to moving loads, that been implemented by Wu and members [5]. They have taken a mobile gantry cranes as a model, and the dynamics response characteristics has been simulated, and then an improvement has been implemented to it. In order to improve the model, the model has been divided into two parts: the static framework and the moving sub-structure; and the finite element techniques have been used in order to model the system. Moreover, the dynamics response of an overhead crane system has been studied by Oguamanam, Heppler and Hansen [6]. The equation of motion has been derived by using Hamilton's principles and operational calculus is used to determine the vibration of the beam, and hence to get the dynamics of suspended load. The payload dynamics has been examined under three different situations in order to determine the effect of the length of the pendulum, the effect of the mass of the carriage and the load, and the effect of carriage speed.

The work also has been done in develop a new strategy based on the idealized model. For example, O'Connor [7] has used numerical solution to find a way with many non-ideal dynamics effect of the crane. The model that been used is gantry crane, which is in practice, the operator, which combining intuition, experience and skill, will locate the load hanging on the cable by stopping the trolley somewhat short of the target position and then letting the load move to that location by a further movement of the trolley. This makes sense on how to develop the automatic control based this situation, which combining understanding, quantification, automation and then optimization. In other words, the gantry a controller has to learn from the previously unknown dynamics response in the first part of the motion exactly how to terminate the motion, i.e. self adapting, even the system dynamics become more complex.

CHAPTER 3

METHODOLOGY

3.1 Research Methodology

Research regarding development of an improvement gantry crane had been made through methods as below:

i. Studied on previous crane development and design
ii. Approach several lectures regarding the project

3.2 Tools Required

In completing the project, several tools/software needed as shown as below:

No	Tools	Function
1	CATIA software	Design and drawing of gantry crane
2	ANSYS software	Load and stress analysis

3.3 Project Activities

Throughout the project, activities will start from problem identification until completion of designing the gantry crane rig had been made through methods as below:

i. Problem identification
ii. Literature Review
iii. Study on existing gantry crane
iv. Establish design criteria
v. Determine design requirement
vi. Generate conceptual design
vii. Evaluate design- Analysis using ANSYS

The process of methodology is shown by figure 3.1 below:

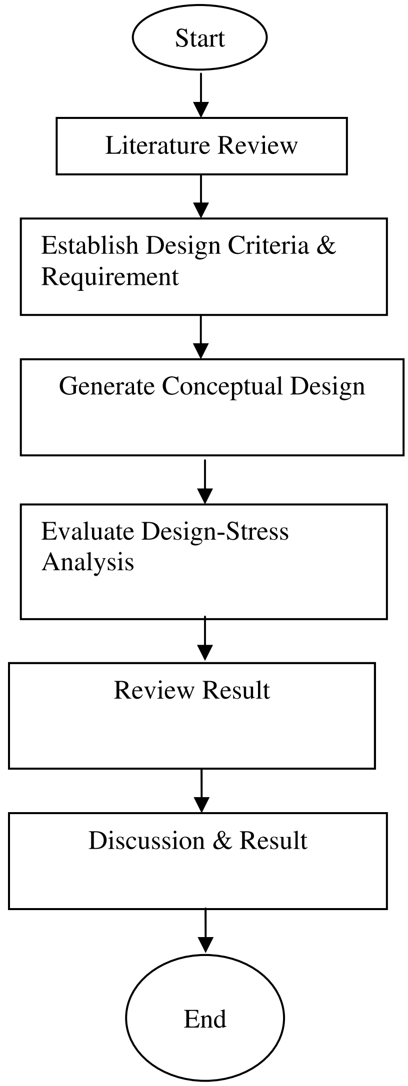

Figure 3.1 Methodology process

CHAPTER 4

PROJECT WORK, DISCUSSION AND RESULT

This chapter discuss on the mechanical design process for experimental gantry crane rig. Topic covered in this chapter including specification of design, limitation, and material selection. The result for this discussion will be the completion of detail drawings and result from analysis using ANSYS.

4.1 Engineering specification

This subtopic will discuss about the specification and requirement in designing the gantry crane rig.

4.1.1 Limitation of gantry crane

For the design, it is expected to follow several limitations as shown below:

i. Maximum travel :
   a. x-axis =1 meter
   b. y-axis=1 meter
   c. z-axis=1 meter

ii. Payload weight=1 kg

iii. Deformation not exceeding 5 mm

4.1.2 Dimensions of gantry crane

Due to the maximum travel of the trolley, dimensions of gantry crane rig design should follow dimensions below:

i. Height not exceeding 1500 mm

ii. Width not exceeding 1300 mm

iii. Length not exceeding 1200 mm

The dimension should be minimal as possible but not so close to maximum travel. This is because in design the gantry crane rig, location of motor, roller and other equipment must be considered. Other than that, the gantry crane should be small so that it can be move easily in the lab.

4.2 Part Design

In designing, several considerations have been made. In this subtopic, several part of the gantry crane is determined.

Motor

The motor should be powerful enough to move the trolley and 2 rollers for the gantry crane. DC model motor from Como Drills is selected because this motor has in-line metal gears fitted and the final output speed is determined by the motor supply voltage

Frame

The frame must be strong enough to sustain load from beam, and other equipment, such as motor, circuit and beam

Bridge

Rig is where the trolley will move in x direction. The structure of the rig is using I-beam, which is stronger compared to normal beam. Besides that, the trolley can easily be installed on the rig.

4.2.1 Aluminium I Beam

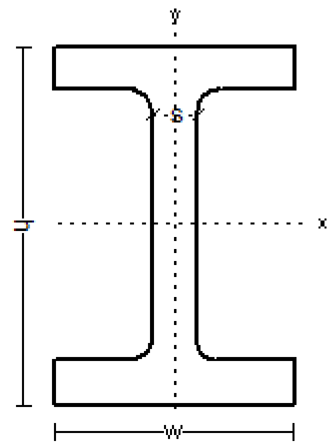

Figure 4.1 Cross Section of I Beam

Properties in imperial units of aluminium I beam are indicated below:

Table 4.1 Dimensions of I Beam

Designation	Dimensions					Static Parameters			
						Moment of Inertia		Section Modulus	
Imperial(in x in)	Depth,h (in)	Width,w (in)	Web Thickness,s(in)	Sectional Area (in2)	Weight (lb/ft)	I_x (in4)	I_y (in4)	W_x (in3)	W_y (in3)
3 x 2 1/2	3	2 1/2	0.13	1.39	1.64	2.24	0.52	1.49	0.42
3 x 2 1/2	3	2 1/2	0.15	1.73	2.03	2.71	0.68	1.81	0.54
4 x 3	4	3	0.15	1.97	2.31	5.62	1.04	2.81	0.69
4 x 3	4	3	0.17	2.38	2.79	6.71	1.31	3.36	0.87
5 x 3 1/2	5	3 1/2	0.19	3.15	3.7	13.9	2.29	5.58	1.31
6 x 4	6	4	0.19	3.43	4.03	22	3.1	7.33	1.55
6 x 4	6	4	0.21	3.99	4.69	25.5	3.74	8.5	1.87
7 x 4 1/2	7	4 1/2	0.23	4.93	5.8	42.9	5.78	12.3	2.57
8 x 5	8	5	0.23	5.26	6.18	59.7	7.3	14.9	2.92
8 x 5	8	5	0.25	5.97	7.02	67.8	8.55	16.9	3.42
9 x 5 1/2	9	5 1/2	0.27	7.11	8.36	102	12.2	22.7	4.44
10 x 6	10	6	0.25	7.35	8.65	132	14.8	26.42	4.93
10 x 6	10	6	0.29	8.75	10.29	156	18	31.2	6.01
12 x 7	12	7	0.29	9.93	11.67	256	26.9	42.6	7.69
12 x 7	12	7	0.31	12.2	14.29	317	35.5	52.9	10.1

In this project, selected I beam is been shown in red cell. The purpose selecting this I beam is because to minimize the cost and make sure that the I beam can sustain the load.

4.3 Generate Conceptual Design

After fulfill the engineering specification, proceed to generate the conceptual design. At this stage, conceptual designs have been made after considering the specification and limitation using CATIA software. Each of this design will be analyzed using ANSYS software to evaluate in term of structural analysis. The design is shown below:

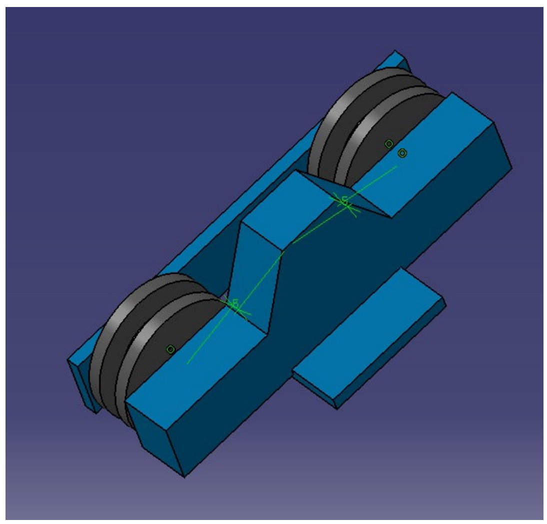

Figure 4.2 Roller

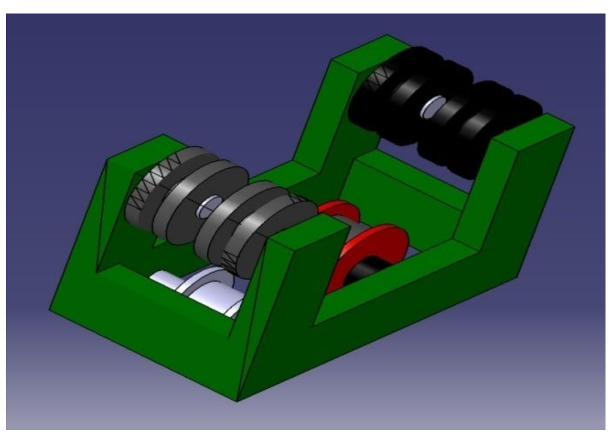

Figure 4.3 Trolley

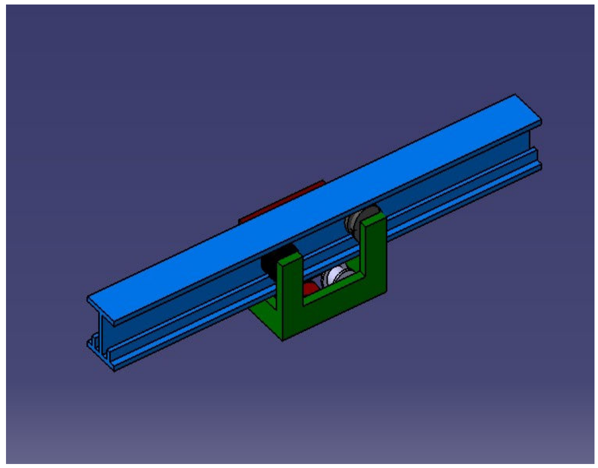

Figure 4.4 Trolley and Rig

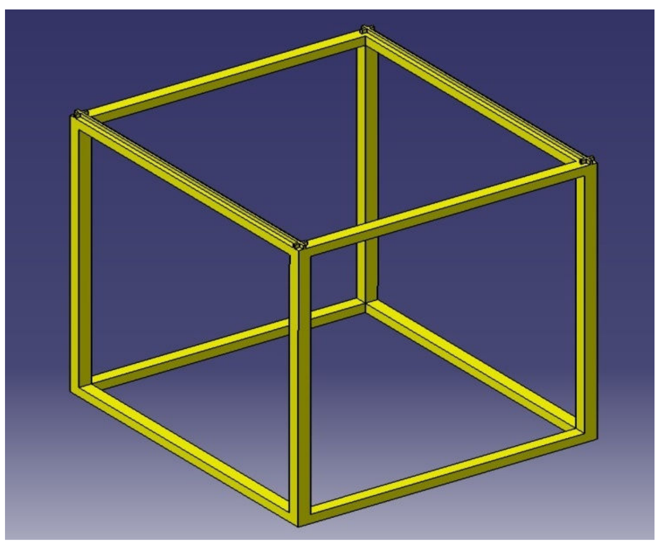

Figure 4.5 Frame

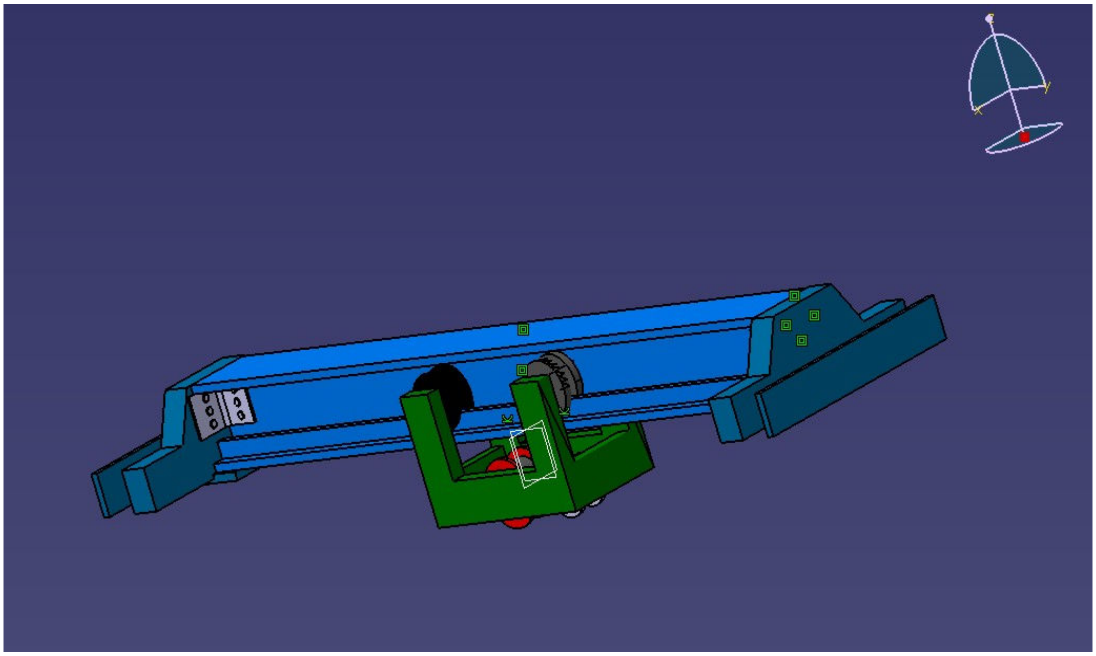

Figure 4.6 Connection of Bridge

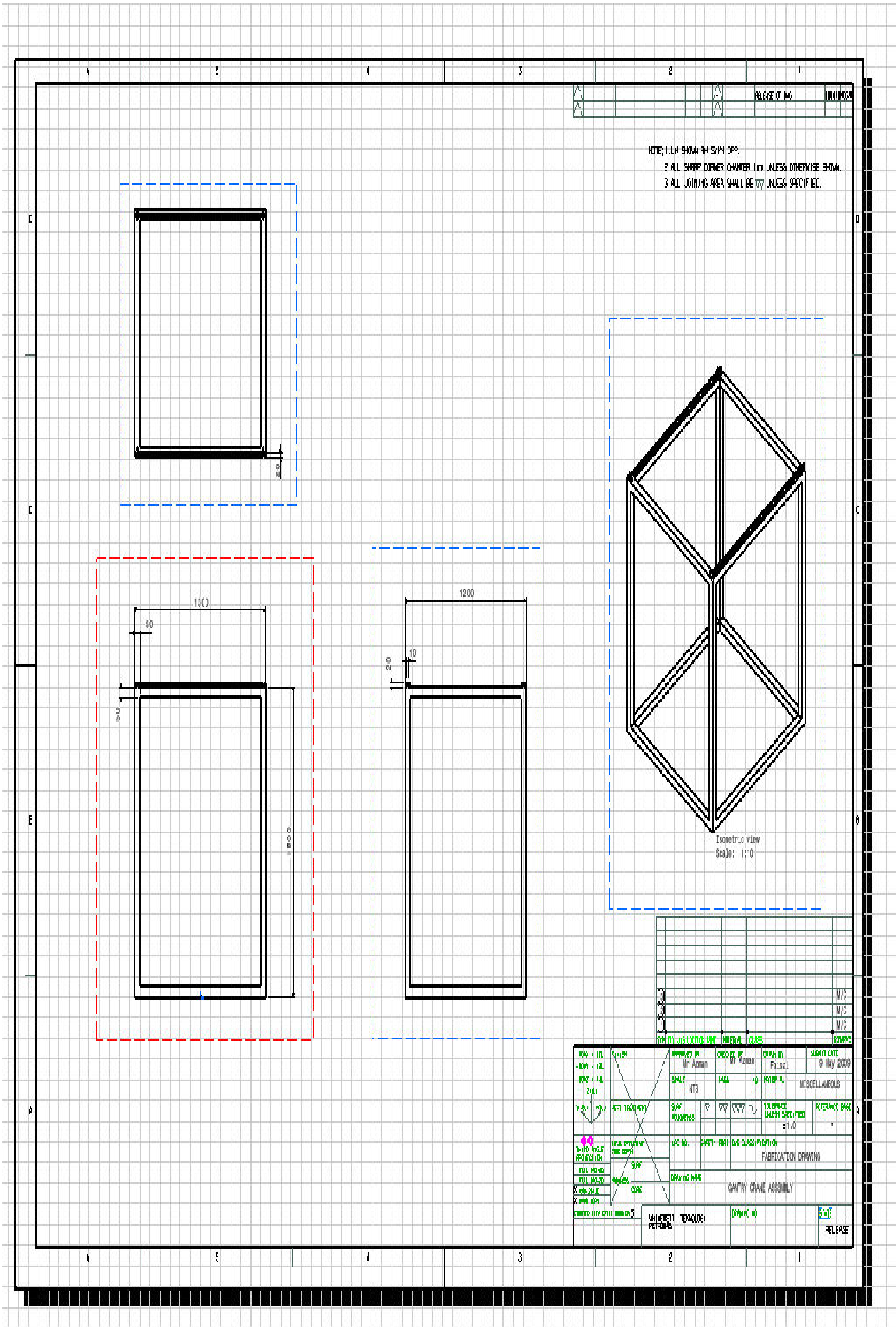

Figure 4.7 Isometric View of frame

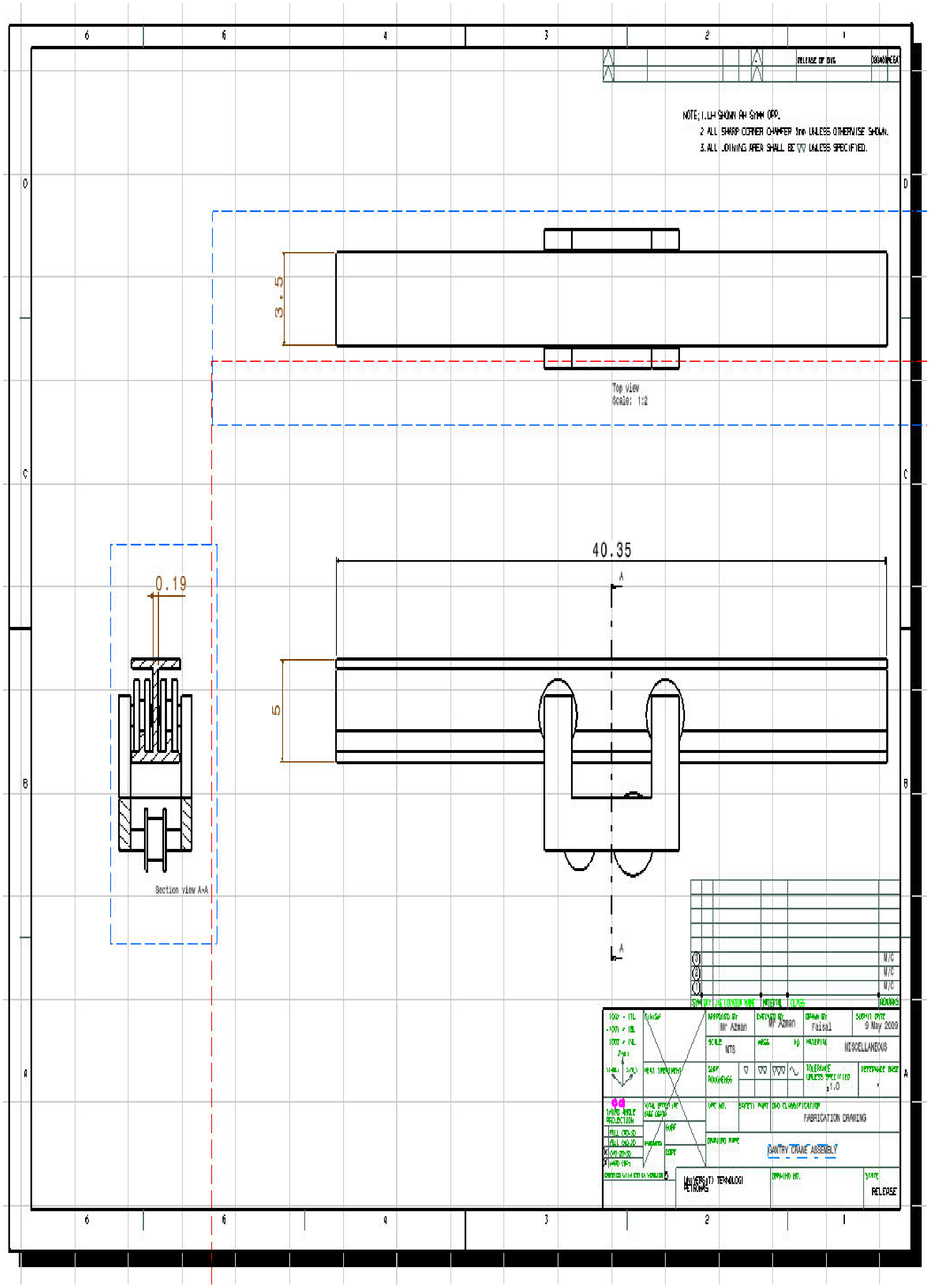

Figure 4.8 Isometric View of Bridge

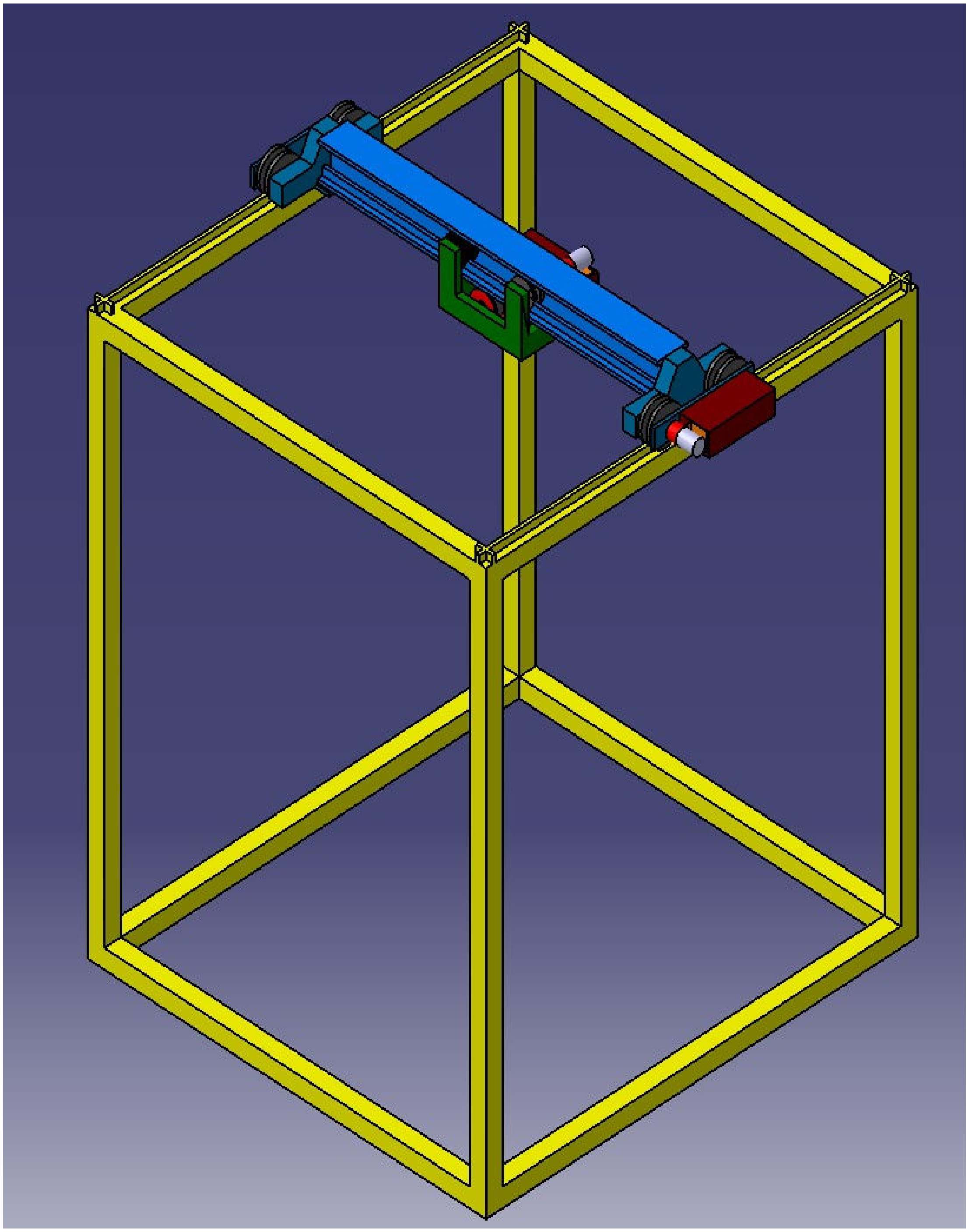

Figure 4.9 Design of gantry crane

4.4 Material selection

To do and analysis using ANSYS, the first thing needed is material selection. The outcome of material selection is the selection of most suitable material to be used for the gantry crane structure. Approach of material selection here consists of 3 steps:

4.4.1 Important Material Properties

Material properties are determined from the function needed for the design of gantry crane. **Table 4.1** shows the functions and results of corresponding material properties:

Table 4.2 Important Material Properties[8]

Functions	Material Properties
Low mass	Density
Minimal Deflection	Elongation
Avoidance of plastic deformation	Yield Strength
Able to withstand sudden impact	Hardness
Low Material Cost	Price
Corrosion	Corrosion Resistance

4.4.2 Comparison Properties with Database

Database containing wide range of material and its properties are obtained. Some of the selected materials are listed below. Then preliminary screening then was made to determine candidate materials that fit for the functions. Discarded materials were mainly due to its properties, shown in red cells did not either meet or close to the required functions. **Table 4.2** shows the screening process of materials:

Table 4.3 Screening of Materials[8]

Material	Material Properties						Status
	Density ($\frac{lb}{in^3}$)	Yield Strength (MPa)	Elongation (%)	Hardness (HV)	Price per pound	Corrosion rate	
Polyethylene (PE)	0.034	13	600	-	0.30	Low	Discard
Nylon (PA)	0.042	62	27	-	3.00	Low	Discard
Carbon Steel (1010)	0.28	275	35	110	0.40	High	Accept
Stainless Steel (430)	0.28	275	20	260	1.25	Low	Accept
Aluminum Alloy (1100-H14)	0.098	117	9	26	0.73	Low	Accept
Copper Alloy (C11000)	0.323	344	4	60	0.92	Low	Accept
Nickel Alloy (N02200)	0.321	186	50	170	5.30	Low	Discard

4.4.3 Investigate Candidate Materials

In order to select the final material, weighted property index method is used. One material is selected as the datum and other materials are compared. 'S' value means the properties are relatively same with datum. '+' show it is better than datum and '−' shows it is worse than datum. Table 4.3 below shows the method in selecting the final material [9]:

Table 4.4 Weighted Property Index Method for Material Selection

Materials	Properties								
	Density ($\frac{lb}{in^3}$)	Yield Strength (MPa)	Elongation (%)	Hardness (HV)	Machinability Index (Annealed)	Price per pound	Corrosion rate	**Overall total**	**Weighted total**
Weightage	5	1	4	2	4	5	3		
Carbon Steel (1010)	0.28 D	275	35 A	110 T	100	0.40 U	High M	**0**	**0**
Stainless Steel (430)	0.28 S	275 S	20 S	260 +	165 +	1.25 -	Low +	**+2**	**+4**
Aluminum Alloy (1100-H14)	0.098 +	117 -	9 +	26 -	180 +	0.73 -	Low +	**+1**	**+8**
Copper Alloy (C11000)	0.323 -	344 +	4 +	60 -	150 +	0.92 -	Low +	**+1**	**0**

From Table 6 above, copper and carbon steel has about the same score. Meanwhile for stainless steel, the score is slightly higher and aluminum gave the highest marks. Aluminum alloy has very low density thus giving lightweight parts, relatively good yield strength, small elongation due to stress, good machinability and high corrosion resistant. Thus it is best to select aluminum alloy 1100-H14 as the final material to be used. Aluminium will be choosing as a beam in a design, while for the frame, project focus on to minimize the cost. Comparing all these materials, mild steel/ low carbon steel will be choose as a frame.

4.5 Evaluation of Design

After specify all the materials for design and structure of the gantry crane, analysis using ANSYS software have been done. Analysis of this project is in term of:

i. Von-Misses Stress Analysis
ii. Deformation Analysis
iii. Shear Stress Analysis

Before do an analysis, several steps must been done. Below is the list step involved in ANSYS:

i. Insert stress analysis
ii. Verify all the materials for the design
iii. Determine Structural load
iv. Identify support

For the payload of the gantry crane, it is assume that total load is equal to load of payload and trolley itself. Therefore, for analysis, the author use 200N as a payload acting on the I beam.

4.5.1 Von-Misses Stress Analysis

Von-Mises is a criteria used in predicting the onset of yield in ductile materials. From the analysis, the result is shown as below:

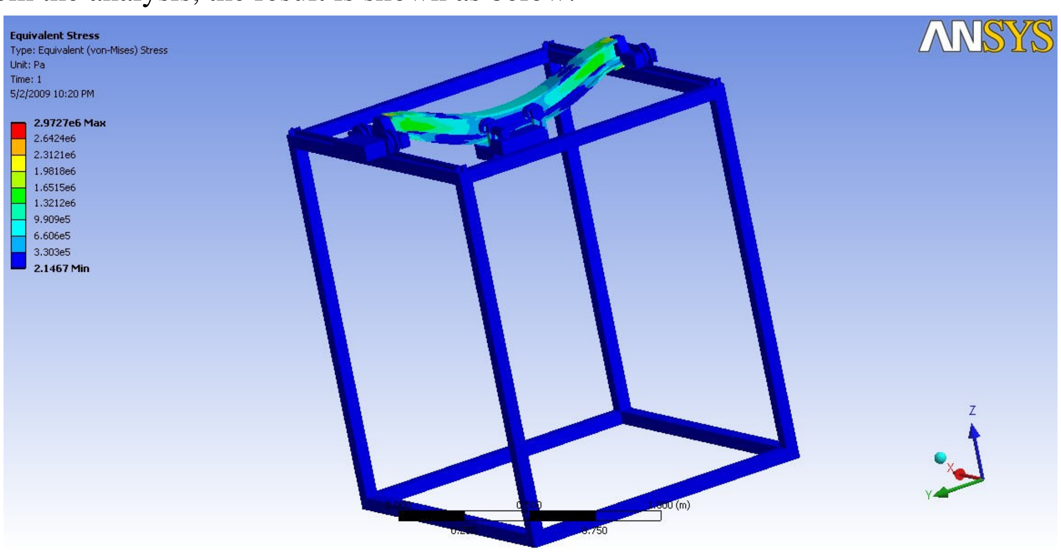

Figure 4.10 Equivalent (von-Mises) Stress

From the analysis of Von-Mises, the maximum of stress is 2.9727 MPa.

4.5.2 Shear Stress Analysis

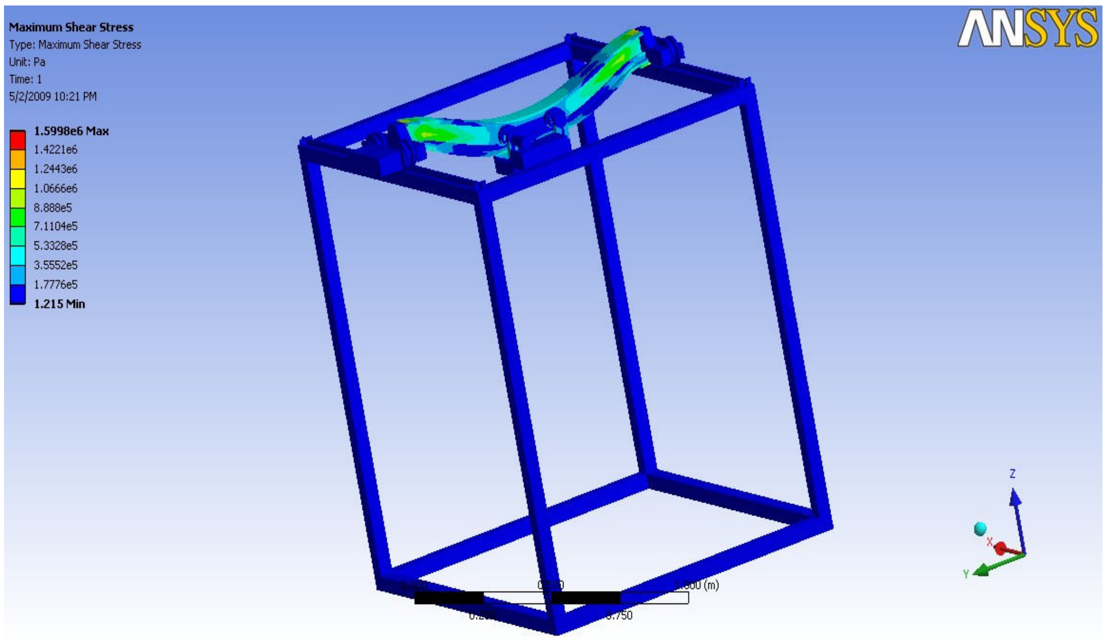

Figure 4.11 Shear Stress Analysis

The result of shear analysis is the design can accept shear stress up to 1.5998 MPa.

4.5.3 Deformation Analysis

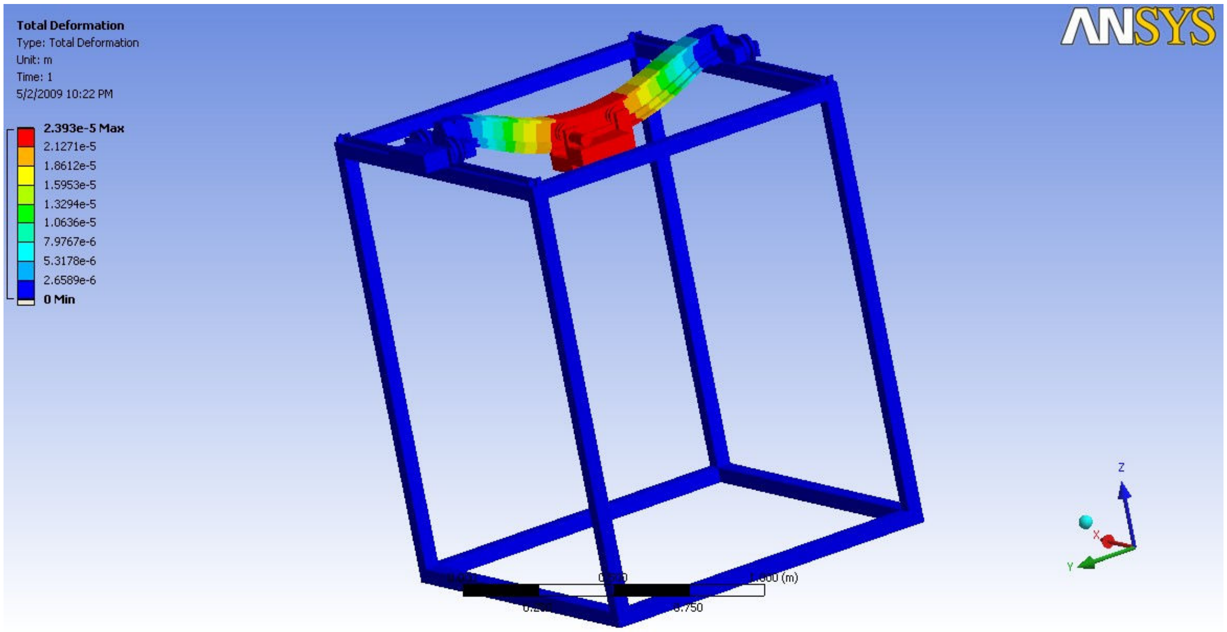

Figure 4.12 Total Deformation

For the third analysis, after apply 200N of load, total deformation occur at I beam is 0.00002393 meter. Result of analysis using ANSYS is plotted in the table below.

Table 4.5 Final Result

Object Name	*Equivalent Stress*	*Maximum Shear Stress*	*Total Deformation*
State	Solved		
Scope			
Geometry	All Bodies		
Definition			
Type	Equivalent (von-Mises) Stress	Maximum Shear Stress	Total Deformation
Display Time	End Time		
Results			
Minimum	2.1467 Pa	1.215 Pa	0. m
Maximum	2.9727 MPa	1.5998 MPa	2.393e-005 m
Minimum Occurs On	Part 1		Part 2
Maximum Occurs On	Part 6		Part 5

CHAPTER 5

CONCLUSION

5.1 Conclusion

The aim of development an experimental gantry crane was achieved. From the result obtained, we can conclude that the design of gantry crane rig is acceptable after considering several limitations and analysis using ANSYS. Through the design phase development, 3 major results had been obtained which are the form generation, drawings and material selection.

From the corrective actions taken by the author, it can be conclude that the project is success and understand about development and analysis of gantry crane experimental rig. However, the design is not been analysed in term of vibration. The vibration which occur during operate the gantry crane might affect the result. As a conclusion, the project is success.

REFERENCES

1. Crane Safety. *Issue No 8: Occupational Safety Observer.* http://tis.eh.doe.gov/docs/oso/oso93_08.html. 1993. August 1=8
2. Hans Butler, Ger Honderd and Job Van Amerogeon. Model Reference Adaptive Control of a Gantry Crane Scale Model. *IEEE Control Syatems, 1991* 1991.57-62.
3. William W Clark and Richard Hake. Project Based Learning Using a Laboratory Gantry Crane
4. Prof S.R.Satish Kumar and Prof A.R. Santha Kumar. Design of Steel Structures. Indian Institute of Technology Madras
5. Jia-Jang Wu, A.R. Whittaker and M.P. Cartmell. The Use of Finite Element Techniques for Calculating the Dynamic Response of Structures to Moving Loads. *Computers and Structures*, 1999. 78: 789 –799.
6. D.C.D. Oguamanam, J.S. Hansen and G.R. Heppler. Dynamic Response of an Overhead Crane System. *Journal of Sound and Vibration (1998)*, 1997. 213(5): 889 – 906.
7. William J. O'Connor. Gantry Crane Control: A Novel Solution Explored and Extended. *Proceedings of the American Control Conference.* May 8-10, 2002. 250 – 255
8. Kenneth G Budinski, Michael K Budinski. 2005, *Engineering Materials: Properties and Selection,* Upper Saddle River, New Jersey, Pearson Prentice Hall
9. Joseph E Shigley, Charles R Mishke. 2003, *Mechanical Engineering Design, New York*, McGraw Hill

APPENDICES

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Supervisor: Mr Azman Bin Zainuddin
Final Year Project Schedule: Development of An Experimental Gantry Crane Rig

No	Detail	July-08		Aug-08				Sep-08				Oct-08				Nov-08				Dec-08				Jan-09				Feb-09				Mar-09				Apr-09			
		W1	W1	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14		Exam Week			Semester Break						W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
1	Selection of project topic																																						
	PRELIMINARY RESEARCH WORK																																						
2	Problem Identification																																						
3	Literature Review																																						
4	Develop Task																																						
	PROJECT WORK																																						
5	Generate Conceptual Design																																						
6	Modeling of Gantry Crane																																						
7	Simulation																																						
8	Evaluate Design																																						
9	Compute Simulation																																						
10	Develop Design																																						
11	Discussion And Result																																						

ii- Material Data

Mild steel

TABLE 25
mildsteel > Constants

Structural	
Young's Modulus	2.1GPa
Poisson's Ratio	0.303
Density	7860. kg/m³
Thermal Expansion	0. 1/℃
Thermal	
Thermal Conductivity	0. W/m·℃
Specific Heat	0. J/kg·℃
Electromagnetics	
Relative Permeability	0.
Resistivity	0. Ohm·m

Structural Steel

TABLE 26
Structural Steel > Constants

Structural	
Young's Modulus	2.e+011 Pa
Poisson's Ratio	0.3
Density	7850. kg/m³
Thermal Expansion	1.2e-005 1/℃
Tensile Yield Strength	2.5Mpa
Compressive Yield Strength	2.5MPa
Tensile Ultimate Strength	4.6MPa
Compressive Ultimate Strength	0. Pa
Thermal	
Thermal Conductivity	60.5 W/m·℃
Specific Heat	434. J/kg·℃
Electromagnetics	
Relative Permeability	10000
Resistivity	1.7e-007 Ohm·m

FIGURE 2
Structural Steel > Alternating Stress

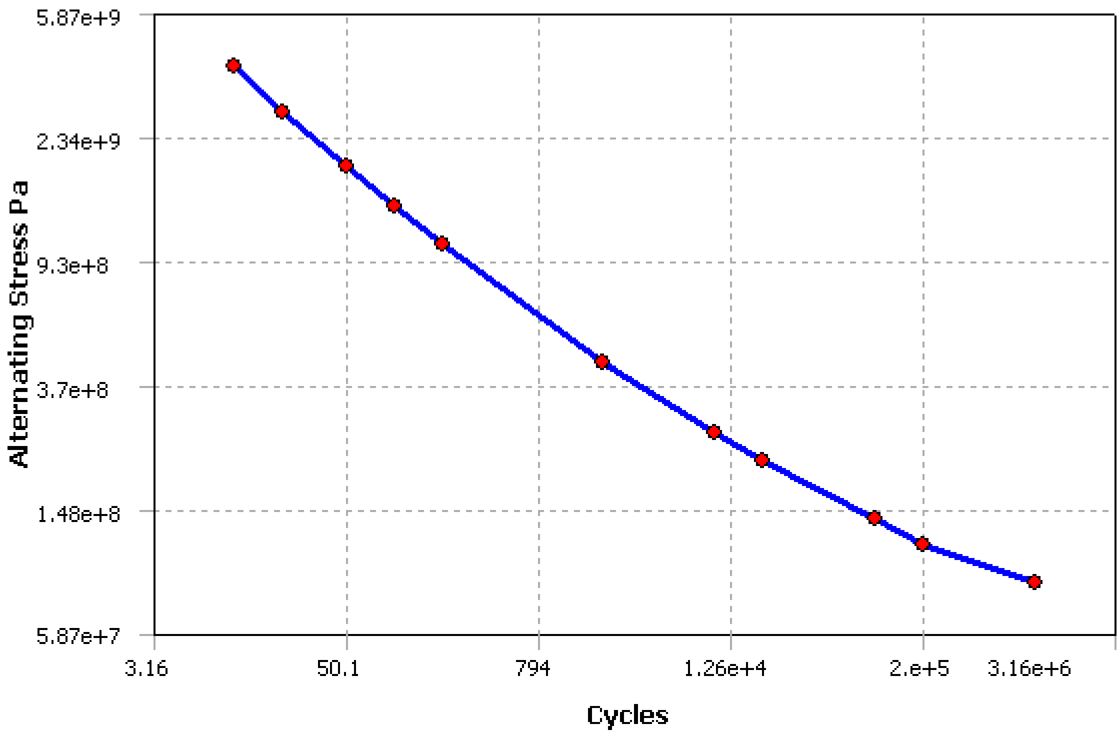

TABLE 27
Structural Steel > Alternating Stress > Property Attributes

Interpolation	Log-Log
Mean Curve Type	Mean Stress

TABLE 28
Structural Steel > Alternating Stress > Alternating Stress vs. Cycles

Cycles	Alternating Stress Pa
10.	3.999e+009
20.	2.827e+009
50.	1.896e+009
100.	1.413e+009
200.	1.069e+009
2000.	4.41e+008
10000	2.62e+008
20000	2.14e+008
1.e+005	1.38e+008
2.e+005	1.14e+008
1.e+006	8.62e+007

FIGURE 3
Structural Steel > Strain-Life Parameters

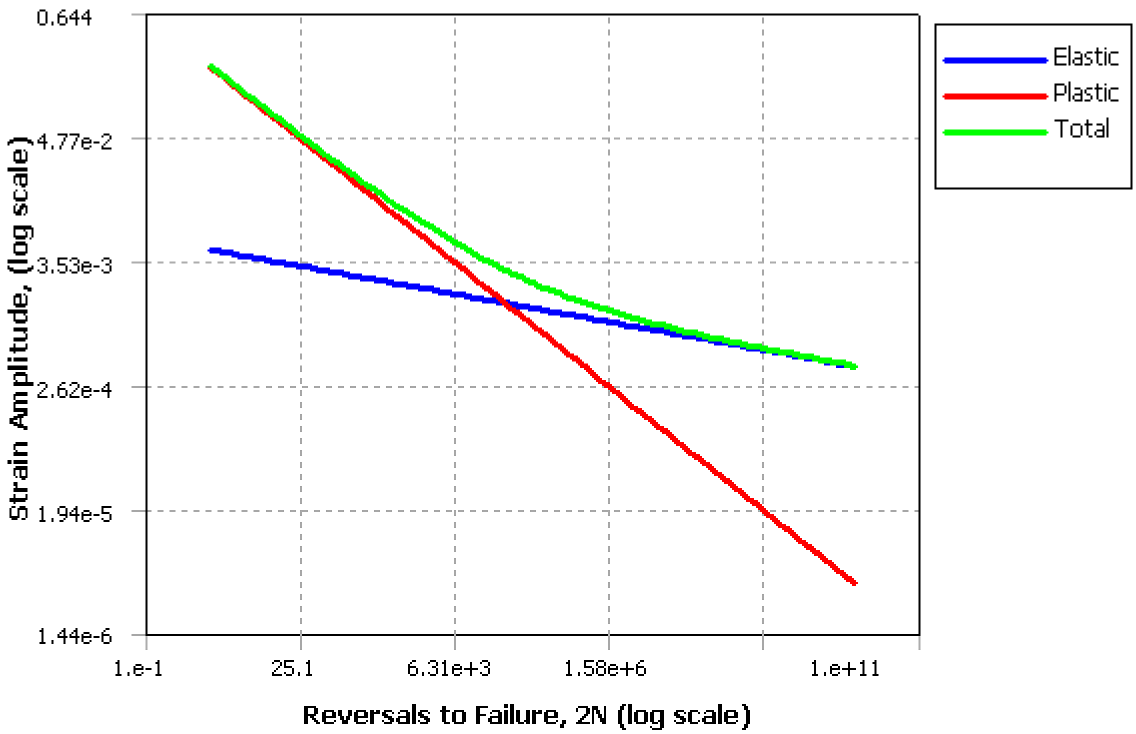

TABLE 29
Structural Steel > Strain-Life Parameters > Property Attributes

Display Curve Type	Strain-Life

TABLE 30
Structural Steel > Strain-Life Parameters > Strain-Life Parameters

Strength Coefficient Pa	9.2e+008
Strength Exponent	-0.106
Ductility Coefficient	0.213
Ductility Exponent	-0.47
Cyclic Strength Coefficient Pa	1.e+009
Cyclic Strain Hardening Exponent	0.2

Aluminum Alloy

TABLE 31
Aluminum Alloy > Constants

Structural	
Young's Modulus	7.1e+010 Pa
Poisson's Ratio	0.33
Density	2770. kg/m³
Thermal Expansion	2.3e-005 1/℃
Tensile Yield Strength	2.8e+008 Pa
Compressive Yield Strength	2.8e+008 Pa

Tensile Ultimate Strength	3.1e+008 Pa
Compressive Ultimate Strength	0. Pa
Thermal	
Specific Heat	875. J/kg·°C
Electromagnetics	
Relative Permeability	1.
Resistivity	5.7e-008 Ohm·m

FIGURE 4
Aluminum Alloy > Thermal Conductivity

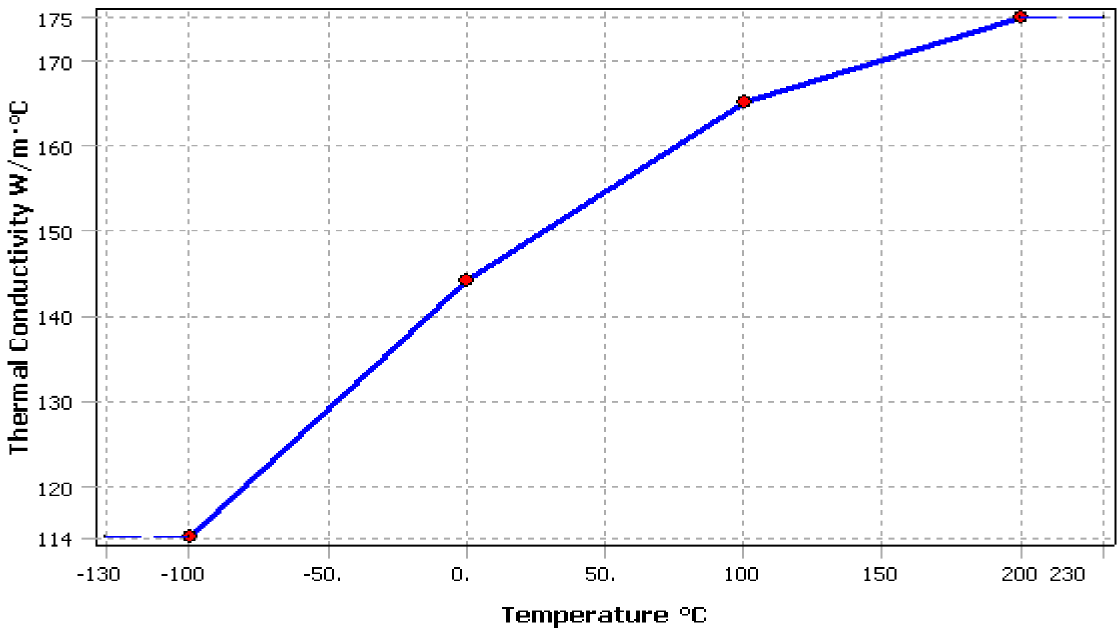

TABLE 32
Aluminum Alloy > Thermal Conductivity > Thermal Conductivity vs. Temperature

Temperature °C	Thermal Conductivity W/m·°C
-100.	114.
0.	144.
100.	165.
200.	175.

FIGURE 5
Aluminum Alloy > Alternating Stress

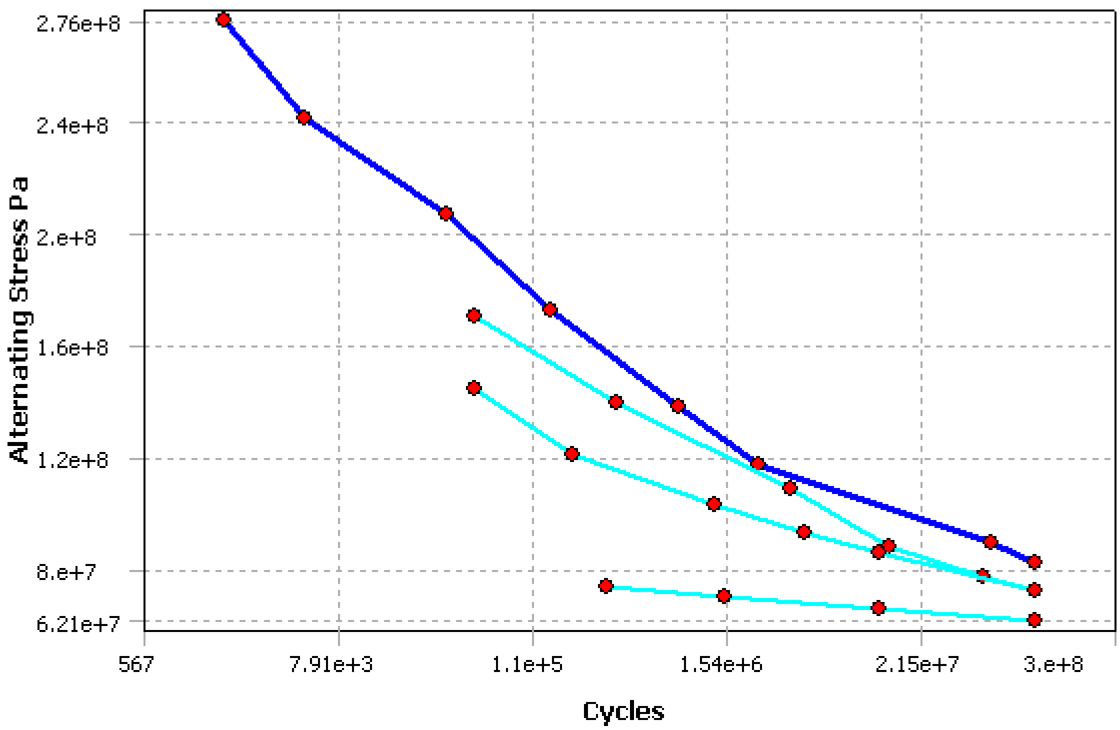

TABLE 33
Aluminum Alloy > Alternating Stress > Property Attributes

Interpolation	Semi-Log
Mean Curve Type	R-Ratio

TABLE 34
Aluminum Alloy > Alternating Stress > Alternating Stress Curve Data

Mean Value
-1.
-0.5
0.
0.5

TABLE 35
Aluminum Alloy > Alternating Stress > Alternating Stress vs. Cycles

Cycles	Alternating Stress Pa
1700.	2.758e+008
5000.	2.413e+008
34000	2.068e+008
1.4e+005	1.724e+008
8.e+005	1.379e+008
2.4e+006	1.172e+008
5.5e+007	8.963e+007
1.e+008	8.274e+007