CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

There are a total of 5,285,131,600 matrix ton of cargos being import and export from the world's top 15 seaports in year 2010, import and export is a very important economic issue in the world today. In a marine terminal, the efficiency or time needed to move container is always an issue. Shortest Job First and Shortest Seek Time First are example of the methods developed to increase the efficiency [1]. Both the method helps in planning and ensuring the container flow is in the most efficient way. Although the container loading and unloading are mostly well planned ahead, however, there is no perfect planning in reality. There is always some special priority container need to be unloaded or loaded first. In order to save space, containers are normally in a stack of 5 to 6 in seaport. When the bottom one needs to be removed, we need to remove the entire top container one by one. This is very slow and not efficient. Thus, we need a method that is able to remove the container without removing the top container one by one. The Mobicon system has a product name mobicon that are able to move containers to designated area. According to that design and with the help of some clamps, removing the bottom container without removing the top container one by one becomes possible. We only need to jack up all the top containers and lift the container we need. After the data collection and comparison of the efficiency of this new method with the old container removing method, the efficiency of the both system can be determined. Besides, the feasibility of the system to work in reality will also be stimulated with ADAMS.

1.2 PROBLEM STATEMENT

- When containers are stacked up, without removing the top container, the bottom one can't be taken out.

When containers are stacked up in a stack of six, the containers at the below is hard to access. In order to access to the container, we needs to remove the top 5 containers 1 by 1. This is a very time consuming process. Many people in the seaport had faced the same problem and would like to have a machine that can access to the container in a stack more efficiently [19]. Increasing efficiency in this process can helps to speed up the container arranging in seaport and thus lead to seaport can handle more cargos.

1.3 OBJECTIVE

- Develop a methodology that is able to directly take out the bottom container and increase the efficiency of the container loading and unloading process.

1.4 SCOPE OF STUDY

- Develop a methodology that is able to directly take out the bottom container in a stack of container.
- Efficiency comparison between existing system and new design.
- Study of the feasibility of the New methodology with ADAMS stimulation, the focus will be mainly on kinematic.
- Calculation of the Structure size includes the 2 girders, 2 main legs and 2 auxiliary legs according to British Standards.

1.5 FEASIBILITY OF THE PROJECT WITHIN THE SCOPE AND TIME FRAME

Due to the time constraint and man power in this project is limited, the project focused mainly on methodology, efficiency comparison and software stimulation of a preliminary design of the lifting machine will be developed. Next, the system will be stimulated in ADAMs for the kinematic analysis. Within the timeframe and with the knowledge learnt, it is feasible that this project can be done.

1.6 PROPOSED SOLUTIONS OF THE PROBLEM

a. Direct jack up the 5 containers on top and pull out the required container.
b. Clamp and lift the 5 containers on top and move them aside to access the required bottom container.
c. Clear the containers one by one by automated crane. (existing solution)
d. Directly lift the 5 containers on top by lifting gear and weight spreader.

Table 1. Weighted score matrix

criteria	weight	score 1-10	a	score 1-10	b	score 1-10	c	score 1-10	d
safety	0.7	2	1.4	9	6.3	9	6.3	1	0.7
travelling	0.1	8	0.8	5	0.5	1	0.1	5	0.5
speed	0.2	5	1	8	1.6	1	0.2	8	1.6
total	1		3.2		8.4		6.6		2.8

*safety consideration is about whether the stack of 5 containers is properly secured.

*travelling is to be minimize to increase efficiency and for safety concern.

*speed is the overall speed to complete the whole process.

The solution chosen is b according to the weighted score matrix.

1.7 DECOMPOSITION OF THE SYSTEM

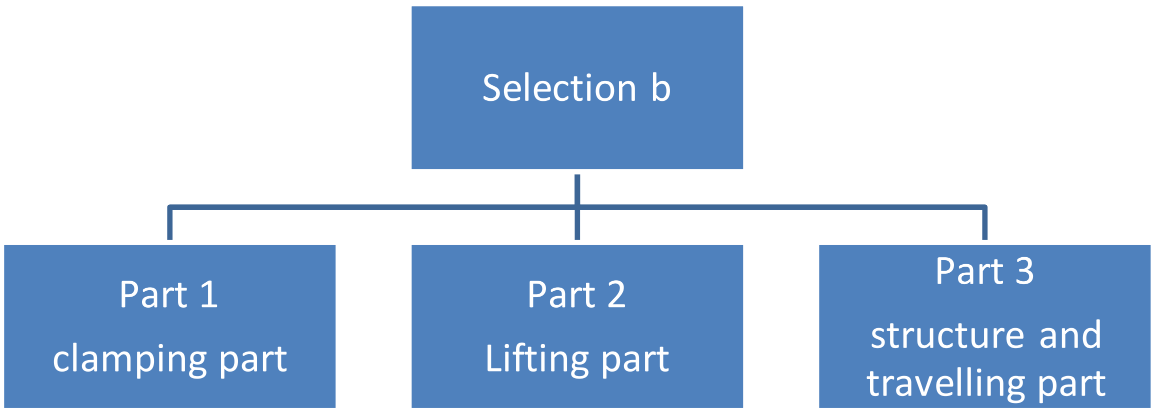

Figure 1. System decomposition

Part 1 Hydraulic operated clamped

Part 2 A pair of lifting fin is to be used, area will be enlarge to the maximum to minimize the pressure acting to the bottom of the container.

Part 3 Gantry crane structure, wheel and track (Square bar) used

CHAPTER 2

LITERATURE REVIEW

2.1 LEACHING

Today, there are thousands of seaports in the world. Among them, from the world top 15 seaports, there are a total of 5,285,131,600 matrix ton of cargos being import and export from these 15 seaports in year 2010 [11]. This figure here shows that in only one year, there are 221,633,033 twenty feet equivalent containers being moved in and out of these seaports [11]. Handling of such a huge amount of container is not a simple job. There is a certain date for certain container to be moved in and out of the seaport. Time for loading and unloading containers is a critical issue and also determined numbers of container that a marine terminal can handle.

A few method had been develop to increase the efficiency of the container flow sequence. Shortest Job First and Shortest Seek Time First are some of the examples of the method develop in shortened the time needed for container traffic. Anyhow, although all the container traffic can be planned far ahead, there is still some drawback in these methods [1]. There is no perfect planning in the reality. Sometimes, there will be some containers needed priority handling. However, due to space saving concern, containers will be stack up in 5 to 6 container per stack, if the container needed is happened to be stacked at the bottom of the stack, to remove it, we will always need to remove the container at the top of it one by one before we can reach the needed container. This process is very time consuming.

In order to increase the efficiency, we need some machine that is able to lift up all the top containers and let us pull out the bottom one. The Mobicon System is a company that has a container carrier machine name Mobicon. It is an auto shuttle that is able to pick up container to designated place. Mobicon enables a container and tank to be move from one point to another. Mobicon acts like a trailer. Besides, it is better than trailer in the sense that Mobicon can load up the container without the help of crane. It is a combination of trailer and crane. From Mobicon, I came out with an idea of lift up and remove the container. The normal procedure of taking out the bottom container will be removing the top containers that are stacking on it first. Instead of removing one by one, the new method will be clamping the container, lift up a little bit and move out container that we want.

If old method was used to remove the container, for a stack of 6 containers, we will need 6 steps. We will need to remove first to fifth containers 1 by 1 before we can reach our needed container. On the other hand, if new method is used, there are only 2 steps. We will only need to move out the 5 containers on top and take out the container that we desire. We will need to collect data of time needed for the old method and new method and compare them after that. If the new method consumes lesser time to complete the process, then the efficiency is higher in term of time consuming. Stimulation of the system with simple modeling will also be done.

After that, we will also use ADAMS, a multi dynamics stimulation solution to model the diagram for ensuring the feasibility of the system in reality [12]. In this project, ADAMS will be used to stimulate the condition containers when moving in a stack of 5 containers. The load distribution in dynamic system will mainly be emphasized. This helps us to understand the true system without really building the prototype and to reduce problems that can only be discovered in reality. Besides, when the system are already been designed, rework and redesign is always more difficult. ADAMS can helps in reducing that.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 PROJECT ACTIVITIES

Step 1: State the problem.

Step 2: Identify possible solutions.

Step 3: Select the correct solution system using weighted matrix

Step 4: Decomposition of system

Step 5: Stimulate the solution with ADAMS, MSC software, to make sure the system is physically workable.

Step 6: Data of the existing system

Step 7: Data of the new system

Step 8: Compare the efficiency of the existing system with the new system.

Step 9: Discussion and conclusion

Step 10: Recommendation

3.2 KEY MILESTONE

- The new lifting machines that are able to lift 5 containers at once are designed.
- Data from the crane system in seaport are taken.
- Comparison of new and existing system of container cranes is done.
- The system is simulated in ADAMs.
- The Structure is designed and calculated based on British Standards.

3.3 GANTT CHART

Date	20 May to 24 May	27 May to 31 May	3 Jun to 7 Jun	10 Jun to 14 Jun	17 Jun to 21 Jun	24 Jun to 28 Jun	1 Jul to 5 Jul	8 Jul to 12 Jul	15 Jul to 19 Jul	22 Jul to 26 Jul	29 Jul to 2 Aug	5 Aug to 9 Aug	12 Aug to 16 Aug	19 Aug to 23 Aug	26 Aug to 30 Aug
Detail/ week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Design of the machine	■	■	■												
Draw with autocad				■	■										
Data collection						■									
Learn ADAMs							■								
Submission of Progress Report								■							
Start to draw the machine in ADAMs								■	■						
Stimulate the system and analyse the data										■					
Pre-SEDEX										■					
Submission of Draft Report											■				

Submission of Dissertation (soft bound)															
Submission of Technical Paper															
Oral Presentation															
Submission of Project Dissertation (Hard Bound)															

Figure 2. FYP 2 Gantt Chart

3.4 TOOLS REQUIRED

3.4.1 Hardware

a. CPU

b. Monitor

c. Lifting machine

d. Lifting Gear

e. 20 ft standard container(L x W x H:6058mm x 2438mm x 2591mm)

f. Stopwatch

3.4.2 Software

a. ADAMs view simulation

3.5 SIMULATION

There are 2 simulations will be done for data collection in this project. The first experiment required an automated lifting machine and a stack of 6 containers. The lifting machine will be move in line with the stack of containers before experiment start. After that, we begin the experiment with removing the first container from the stack to location 6m from the original container location. The process will be repeated 5 times until we reach the last container at the bottom. The time needed will be taken down. For the second experiment, 5 containers will be treated as a lump and been move together. Due to the real lifting machine is still haven't been fabricated, we will use one container to represent the lump of 5 containers. 2 containers will be stacked up. A lifting machine will be place in line with the containers. The 1 container on top will be removing and place at 6m from the original location. The time needed will also be taken down as well.

3.6 OPERATING SEQUENCE

First of all the containers are in a stack of 6. Assume we need to access to container number 6, we will needs to move the lifting machine towards the container as shown in figure 3. The wheel will move the machine into position.

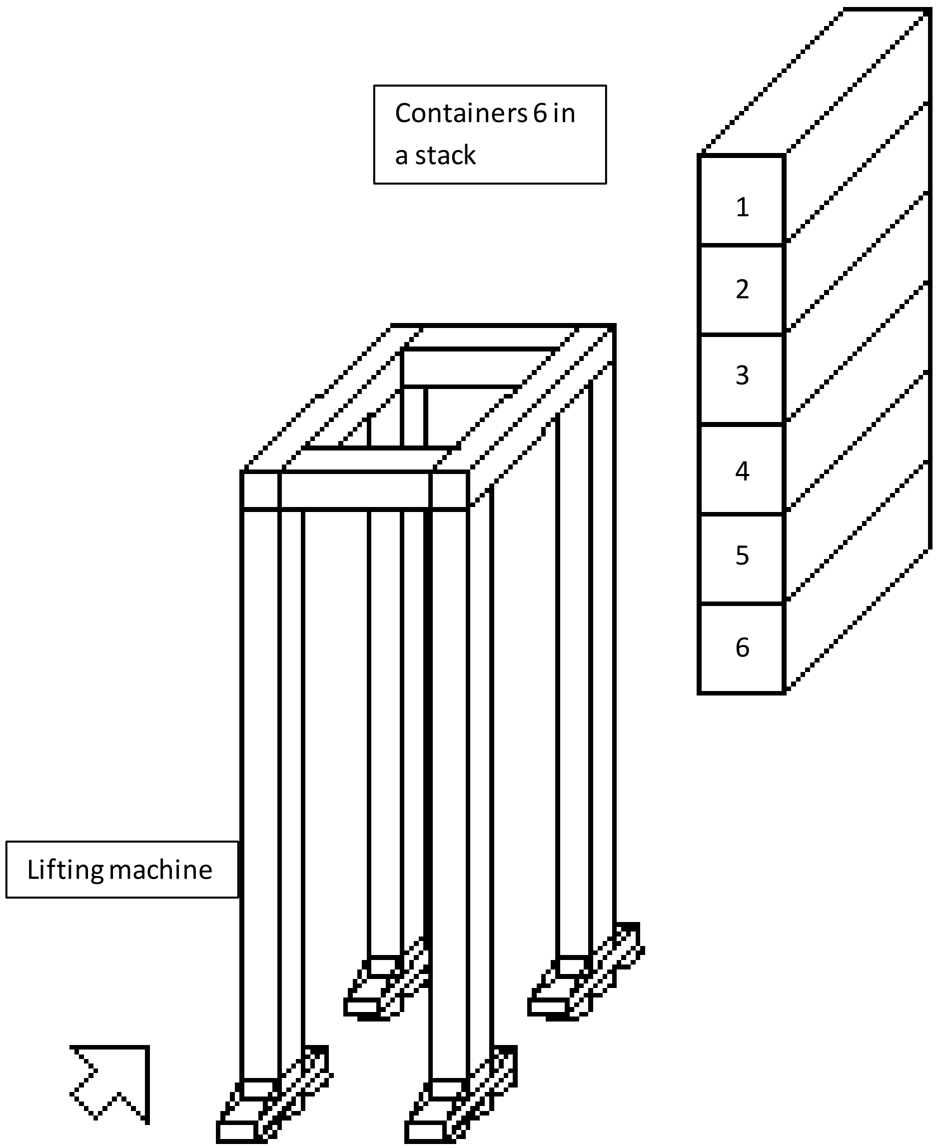

Figure 3: Step 1 the new lifting machine will move into position

In Figure 4, the lifting machine is already in position and the lifting fins are to be slot into the gap between the containers in order to lift up the 5 containers.

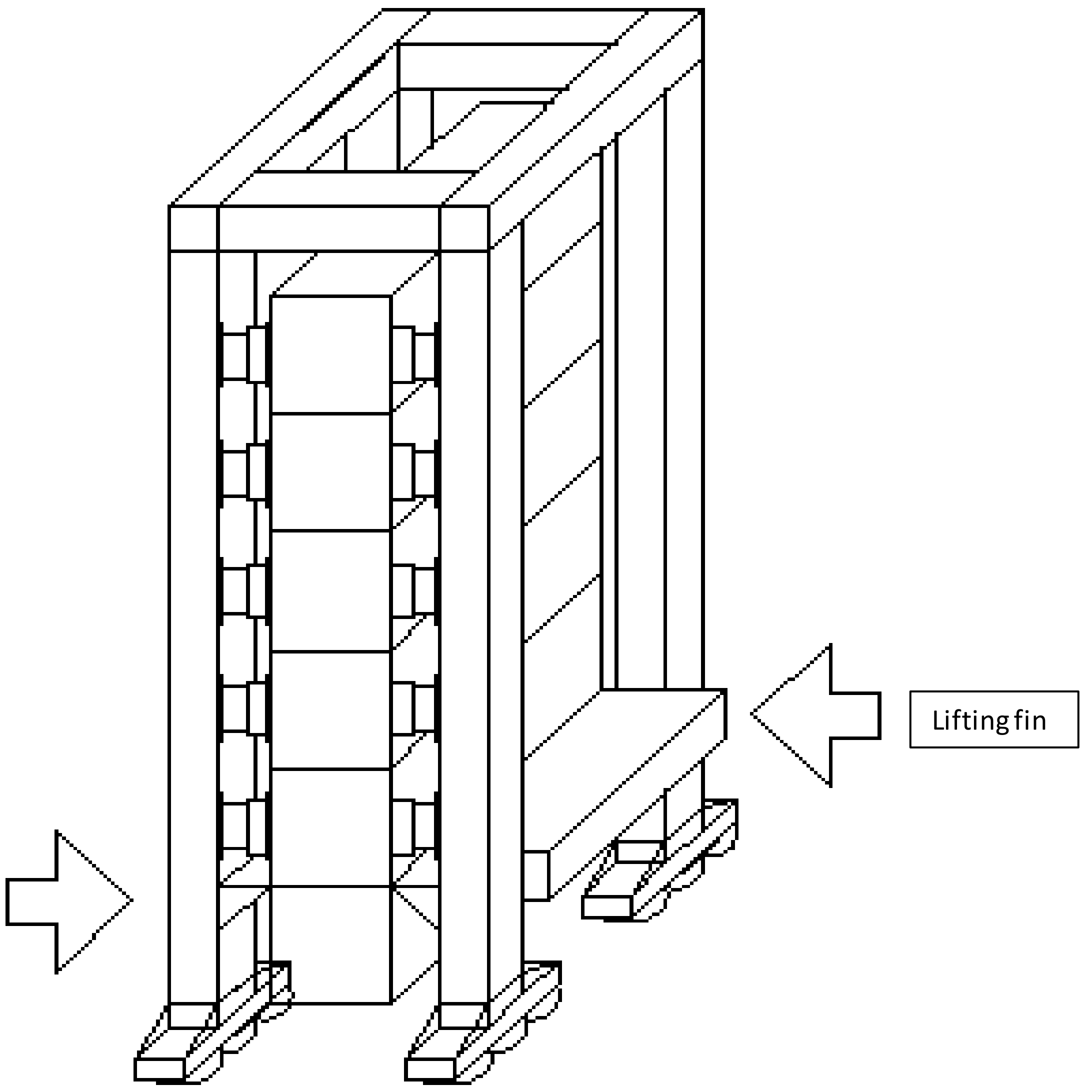

Figure 4: Step 2 the new lifting machine will clamp the containers are to be lifted and the lifting fin will slip into the bottom of fifth containers. Five containers will be lifted.

In Figure 5, we can see that the 5 containers above had been removed by the lifting machine. Now we can access to the containers number 6. We can use another crane to access to this easily. In the whole operation, we only need to position the crane, lift and move away. It is only 3 steps and container number 6 is available now.

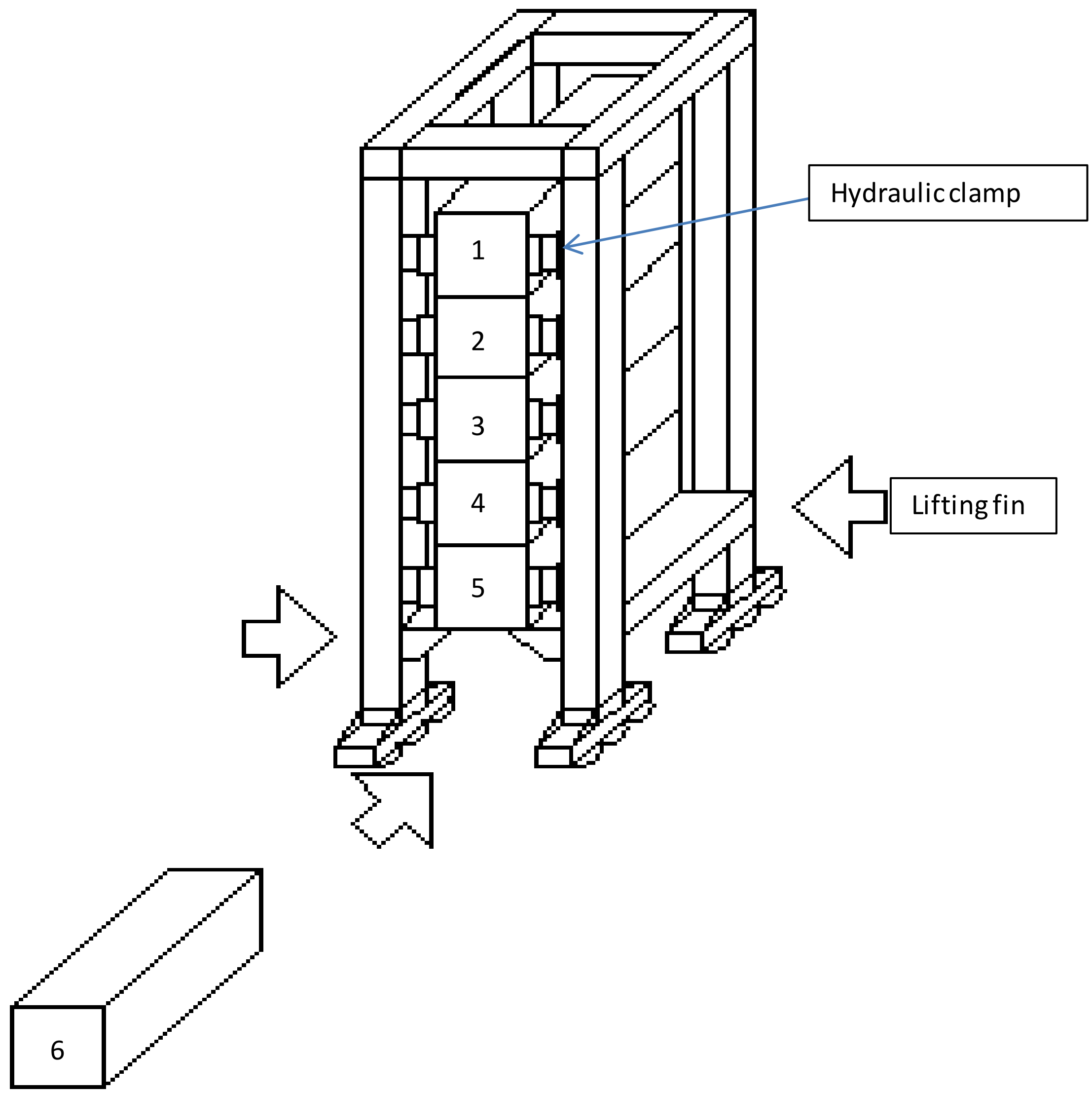

Figure 5: Step 3 the new lifting machine with the top five containers will move out and the bottom container is now available

CHAPTER 4

RESULT AND DISCUSSION

4.1 DATA GATHERING AND ANALYSIS

4.1.1 Existing automated gantry crane system in lift and stack containers

The data is collected from a seaport. An automated container lifting crane is used. The long travel of the gantry crane is fixed. We use only cross travel to in this lifting. 6 containers are stacked up and the bottom containers need to be removed. We need to remove the five containers on top one by one to access to the bottom container. The time needed to move each of the containers is recorded in seconds. 3 sets of data are recorded and average of the data was taken. In order to access to the bottom container, we need an average of 481 seconds. The details are as follows:

Table 2. On site data collection for existing system

On site data collection							
time (sec)	container 1	container 2	container 3	container 4	container 5	total time needed	
set 1	78	93	96	105	104	476	seconds
set 2	82	92	100	106	109	489	seconds
set 3	77	94	95	104	108	478	seconds
average	79	93	97	105	107	481	seconds

4.1.2 New automated gantry crane system in lift and stack containers

Due to the new crane system are not constructed, I have used some other method in defining the time needed to lift and shift the 5 containers. Due to the containers are move at once, so the containers are treated as a lump. Time needed for the automated system to move the five containers at once is based on time moving a container from a stack of 2 containers.

In the second experiment, the above containers in a stack of 2 were treated as the lump of 5 containers. The experiment is repeated 3 times as well. The average time needed to reach the last container is only 90 seconds. The details are in table below.

Table 3. On site data collection for new system

Data collection			
time (sec)		total time needed	
set 1		90	seconds
set 2		92	seconds
set 3		88	seconds
average	5 containers in one move	90	seconds

Due to in actual, we need to move 5 containers at once and it is harder compare to the 1 container that treated as a lump, to have a more accurate data, we assume the efficiency of the new system to be 75% only.

4.1.3 Existing System and New System Data Comparison

Actual time needed for existing system, T_x= 481 seconds

Ideal time needed for new system, t_n= 90 seconds

Efficiency of new system, η= 75%

Actual time needed for the new system, T_n= 90 seconds/ 0.75

T_n= 120 seconds

Efficiency of new system compared to old system

$\eta_{overall}$= T_x/T_n x 100 %

= 481 seconds/ 120 seconds x 100%

= 400.83 %

The new system is 400% faster compare to the existing system.

The new system only required 25% of the time use by existing system to reach the bottom most containers.

4.2 MODELING

4.2.1 2D modeling of the system

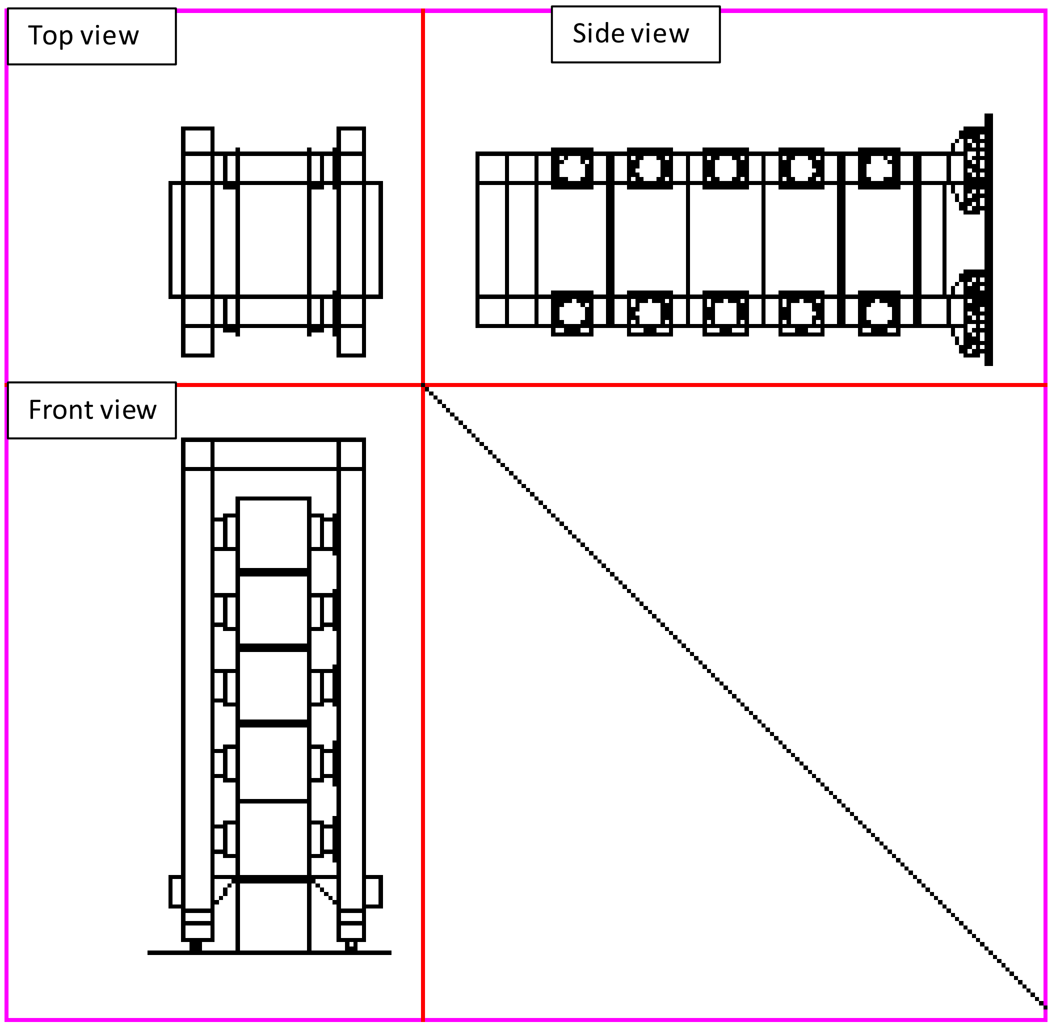

Figure 6: 2D Modeling of the system

4.2.2 Dimensioning of the system

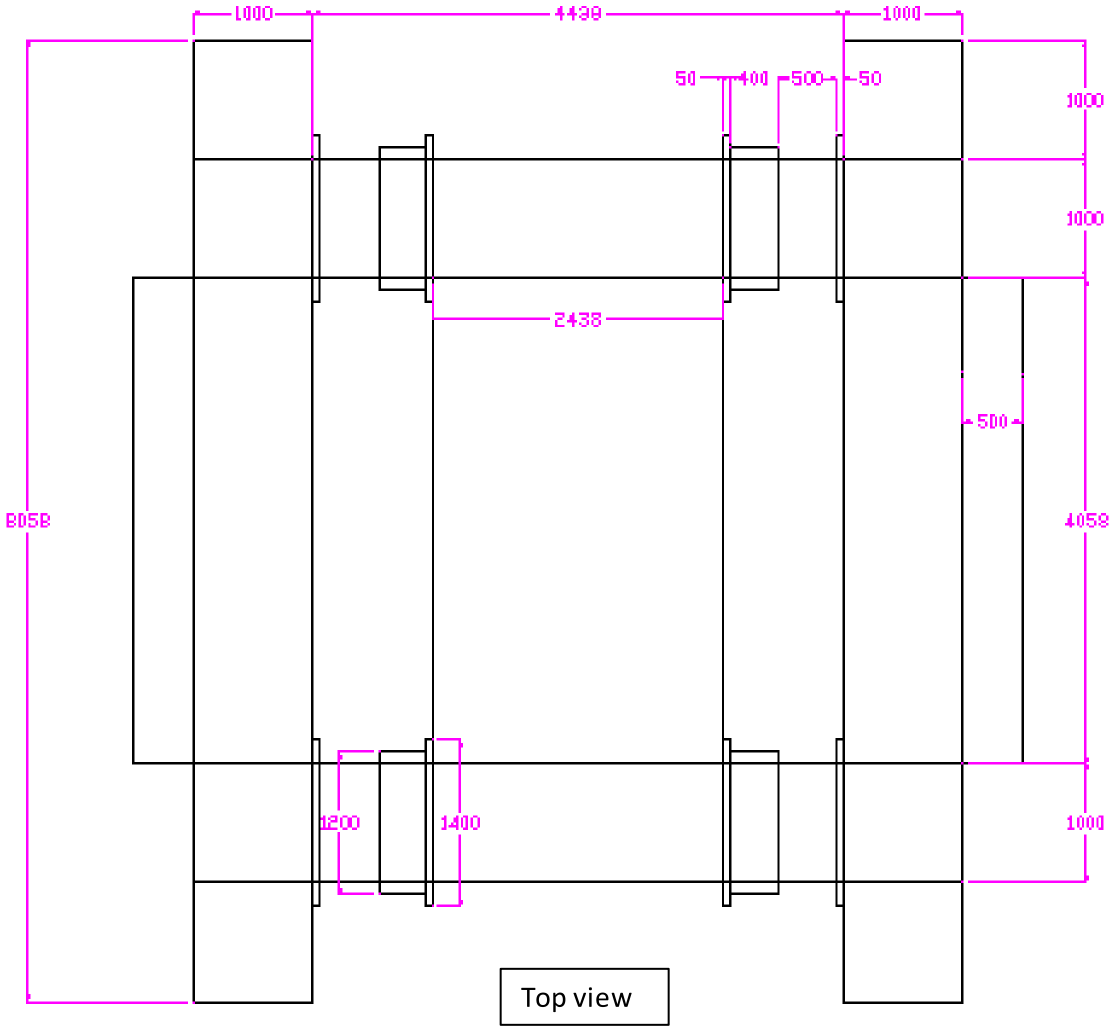

Figure 7: Top view (with dimension in mm)

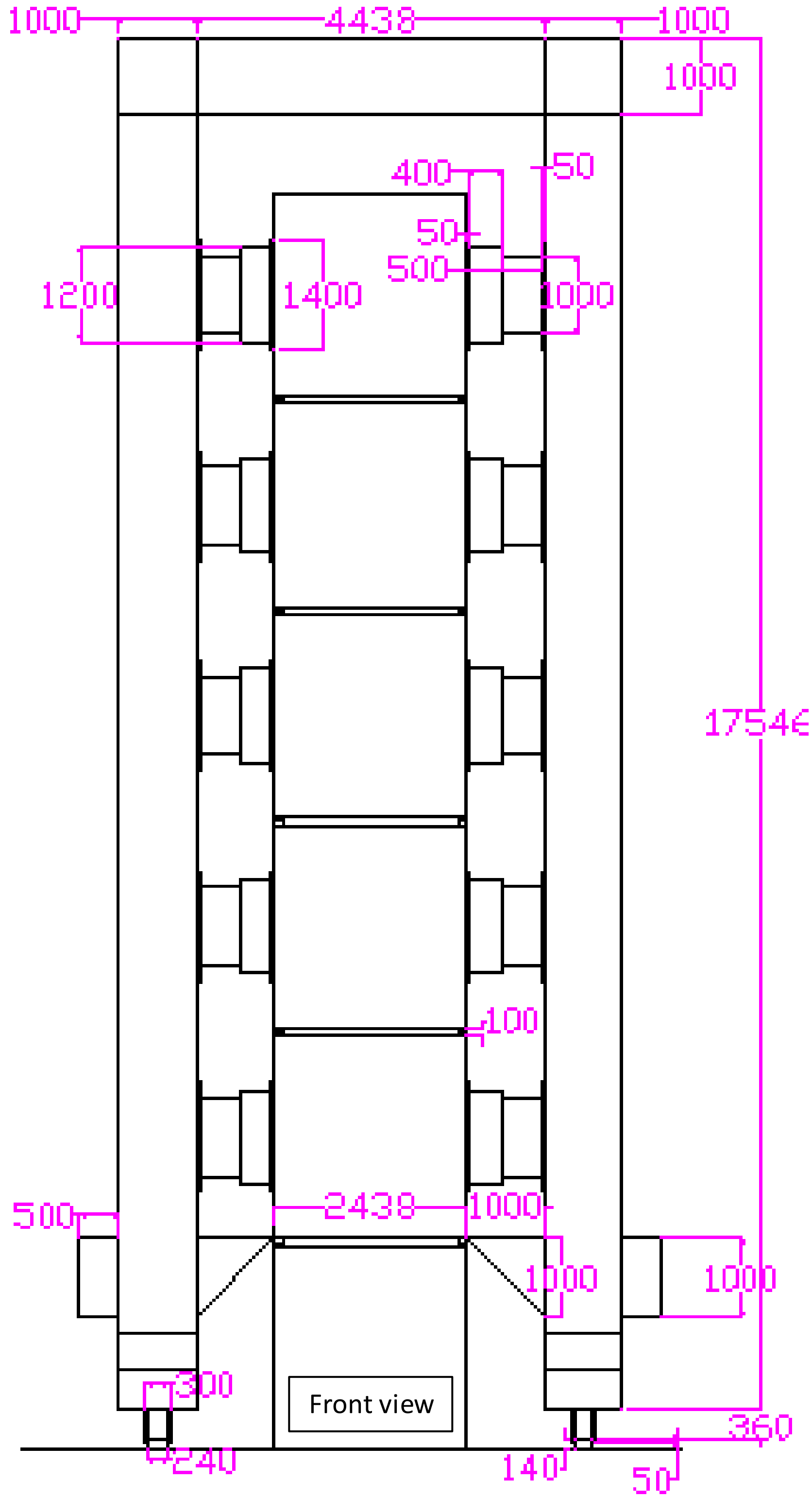

Figure 8: Front view (with dimension in mm)

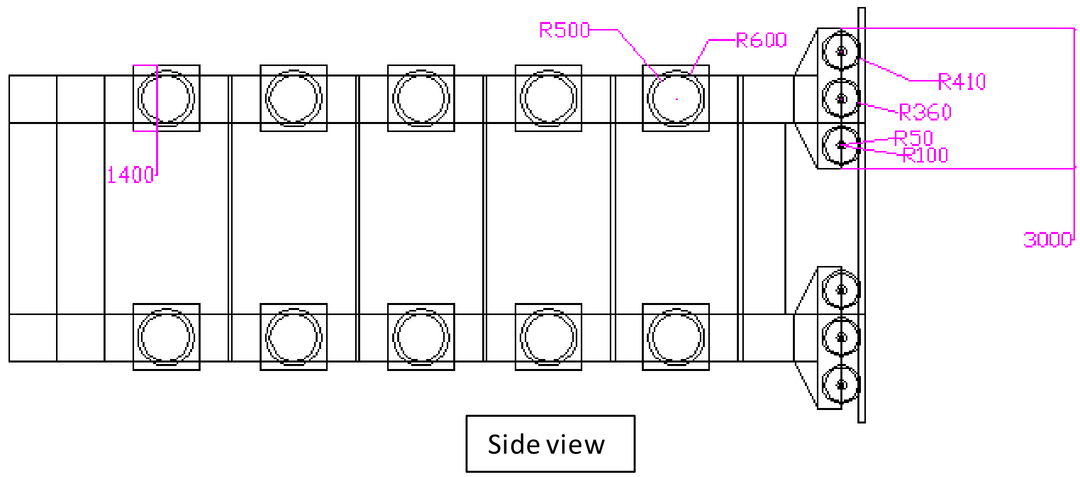

Figure 9: Side View (with dimension in mm)

4.2.3 ADAMs View software simulation

ADAMs View was used in this project to simulate the lifting fin movement. This is due to the lifting fin is the new design. The rest of the components are similar to gantry crane. ADAMs had been use to simulate the lifting fin of the system. After that, the system was build and run and the results are shown below.

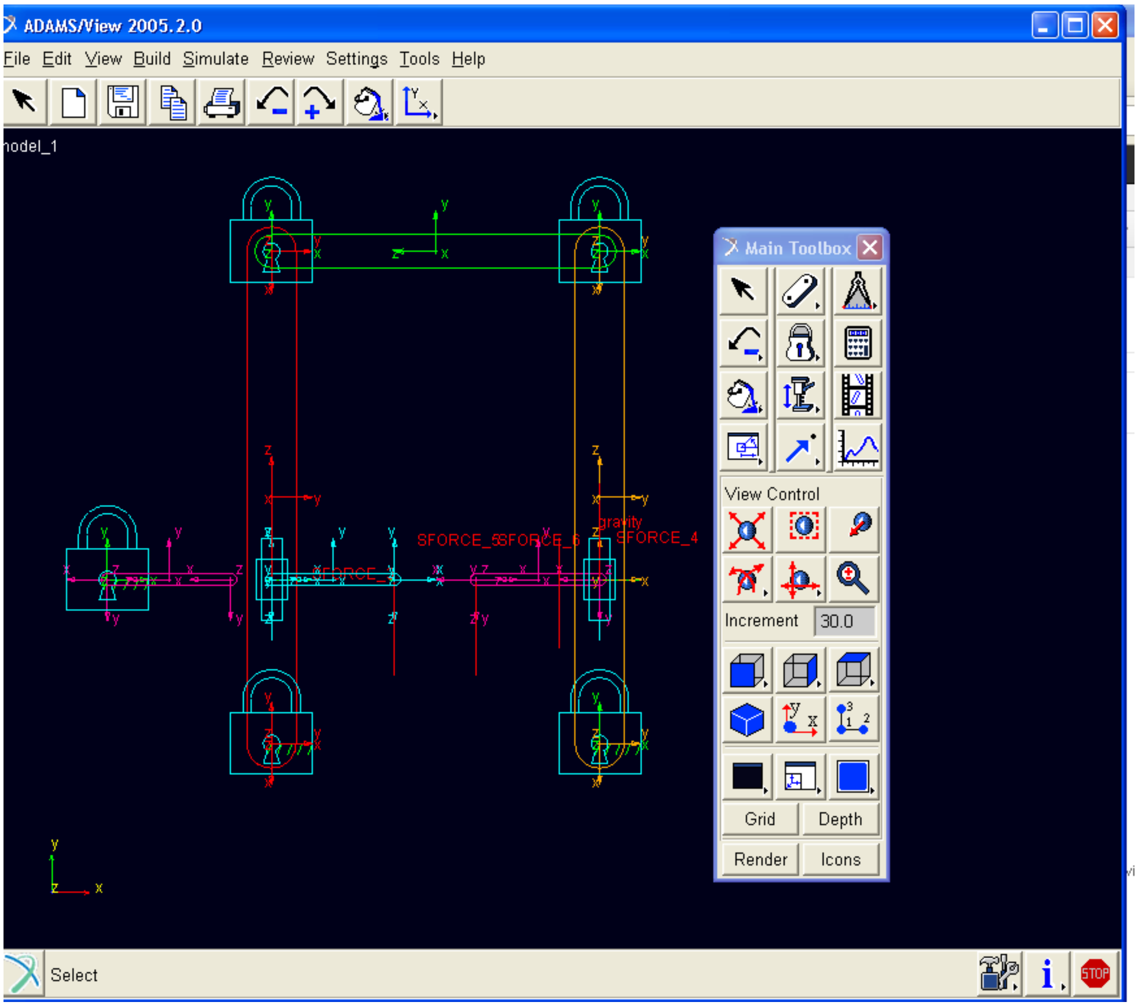

Figure 10: Adams Simulation process

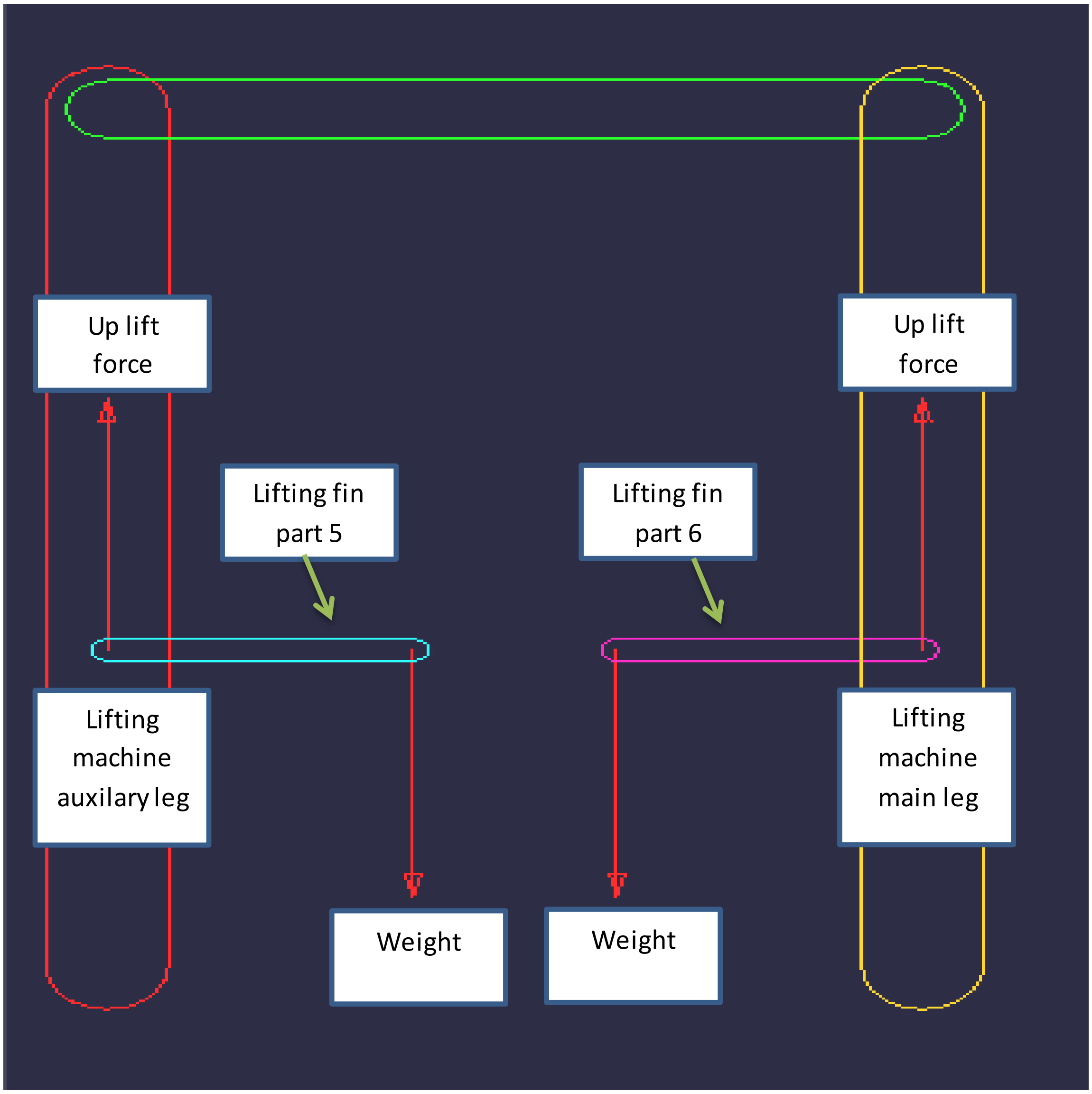

Figure 11: Lifting machine, Lifting fin with forces acting on the fin

Figure 11 shows that the lifting machine system is changed into a 2D modeling. The structure of the lifting machine is modeled in ADAMs View. We can then input the load on the fin, up lift force needed and monitor the movement of the system.

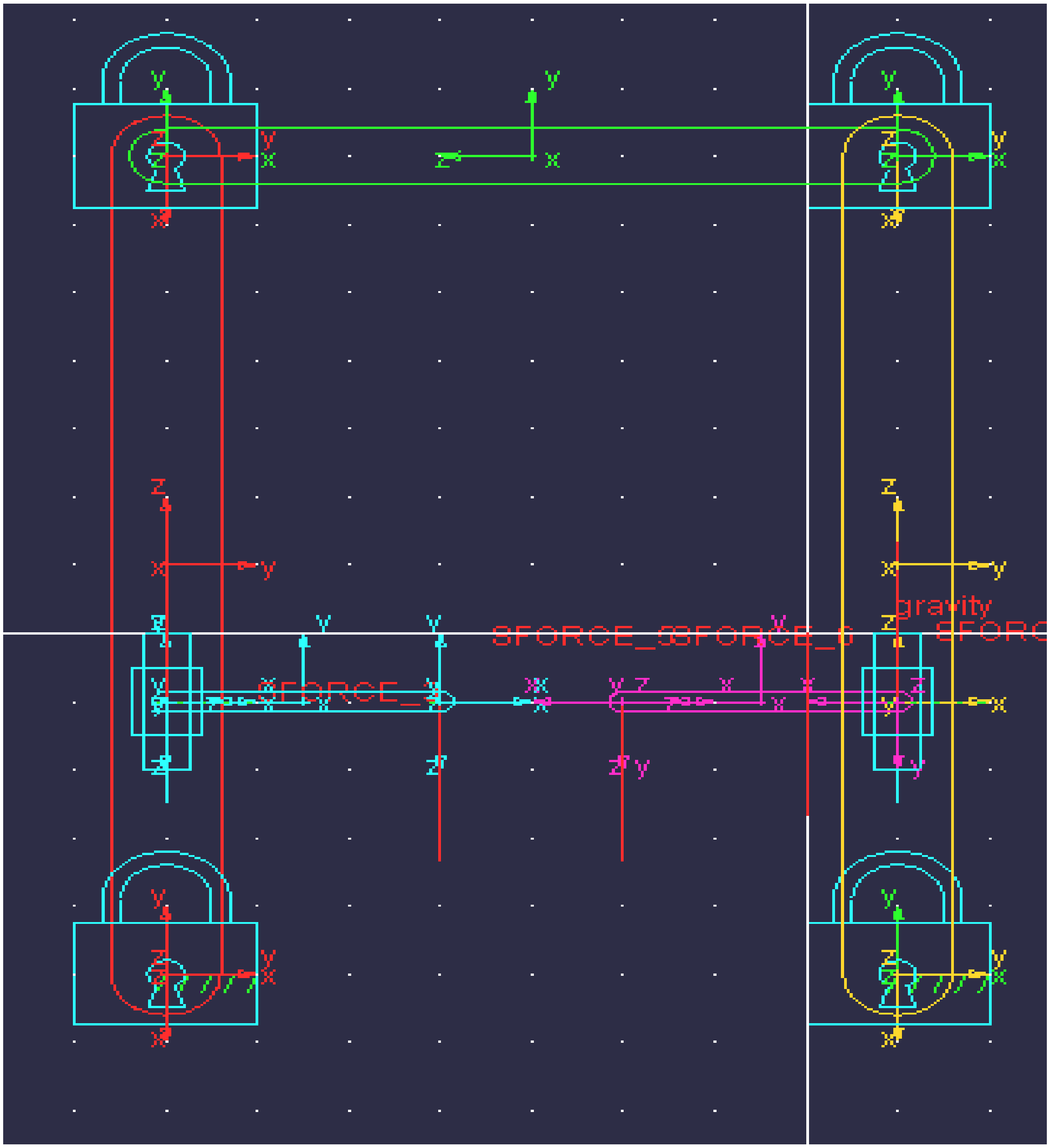

Figure 12: Lifting machine lifting fin lifting process simulation

Figure 12 shows that the main leg and auxiliary leg in the lifting machines are modeled by simple parts. The joints are locked to each other to represent a fixed joint in actual situation.

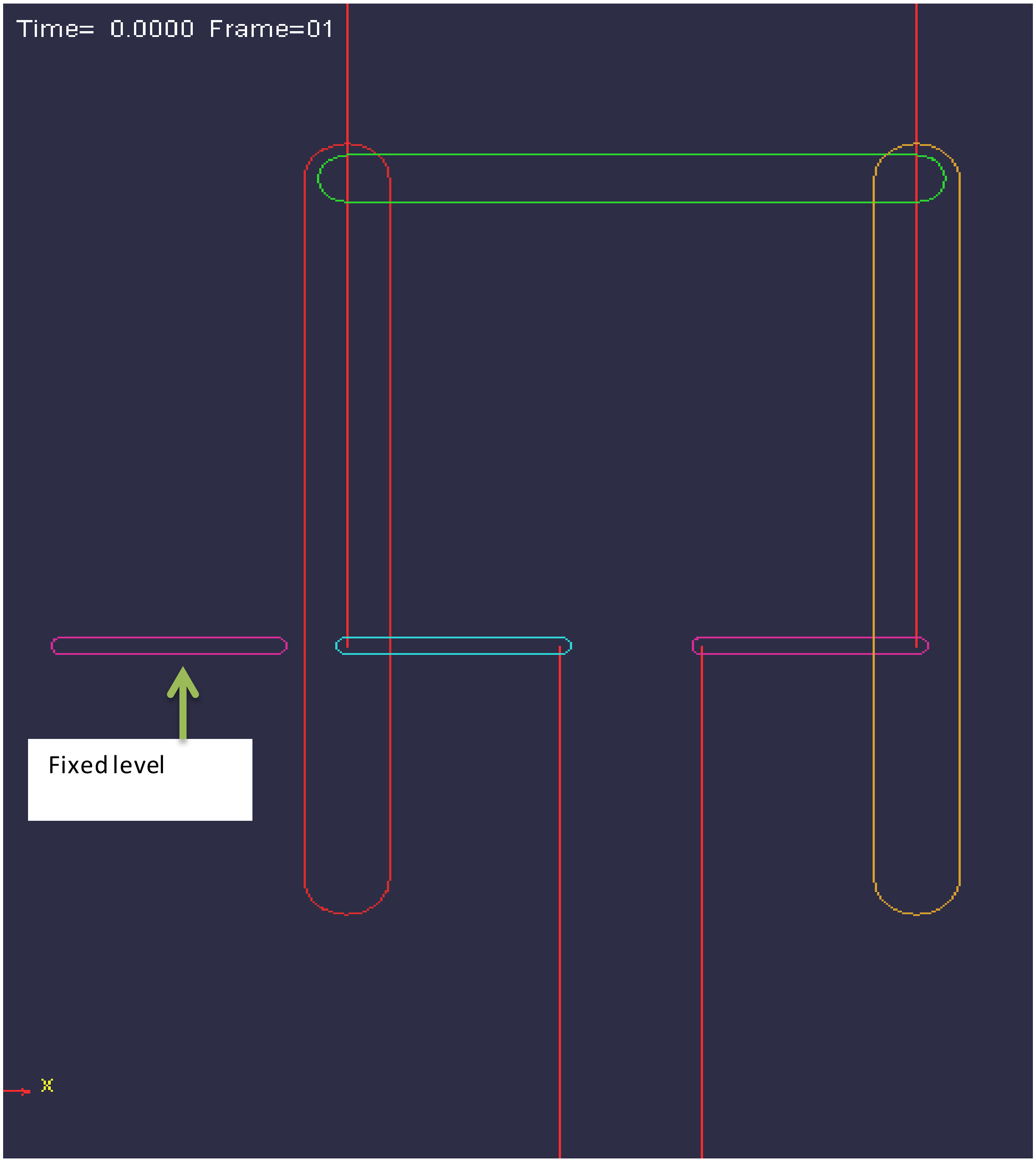

Figure 13: Lifting machine lifting fin lifting process simulation (before lift)

Figure 13 shows that the system was run in ADAMs. It is before the system move. The level of the lifting fins is the same with the leveling item shown in figure 13.

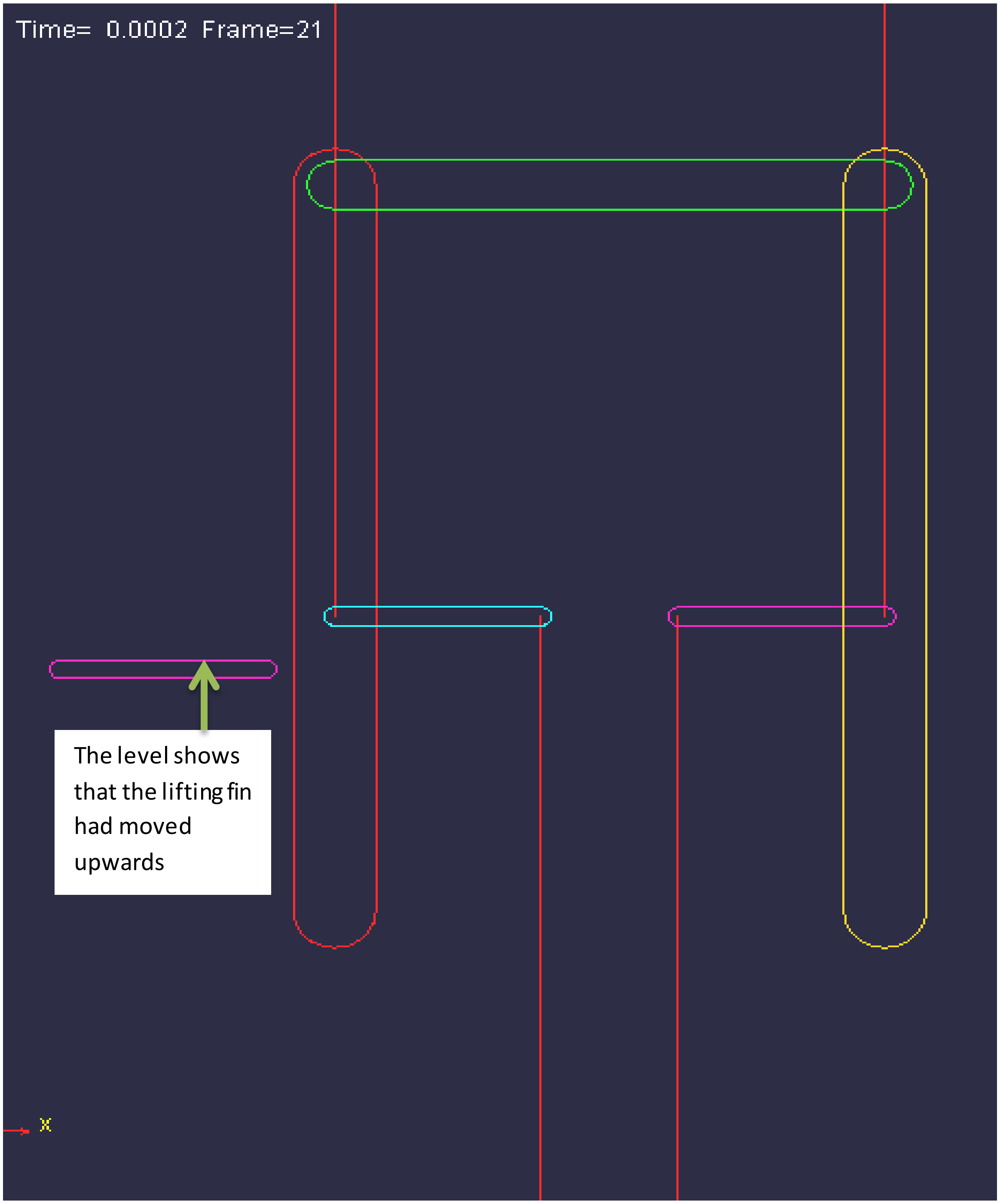

Figure 14: Lifting machine lifting fin lifting process simulation (before lift)

Figure 14 shows that the system was run in ADAMs. The movement of the system was observed and we can see that with the weight and up lift force setting, the system is workable and able to move. Just imagine containers are the weight and the 2 fins had lifted them upward.

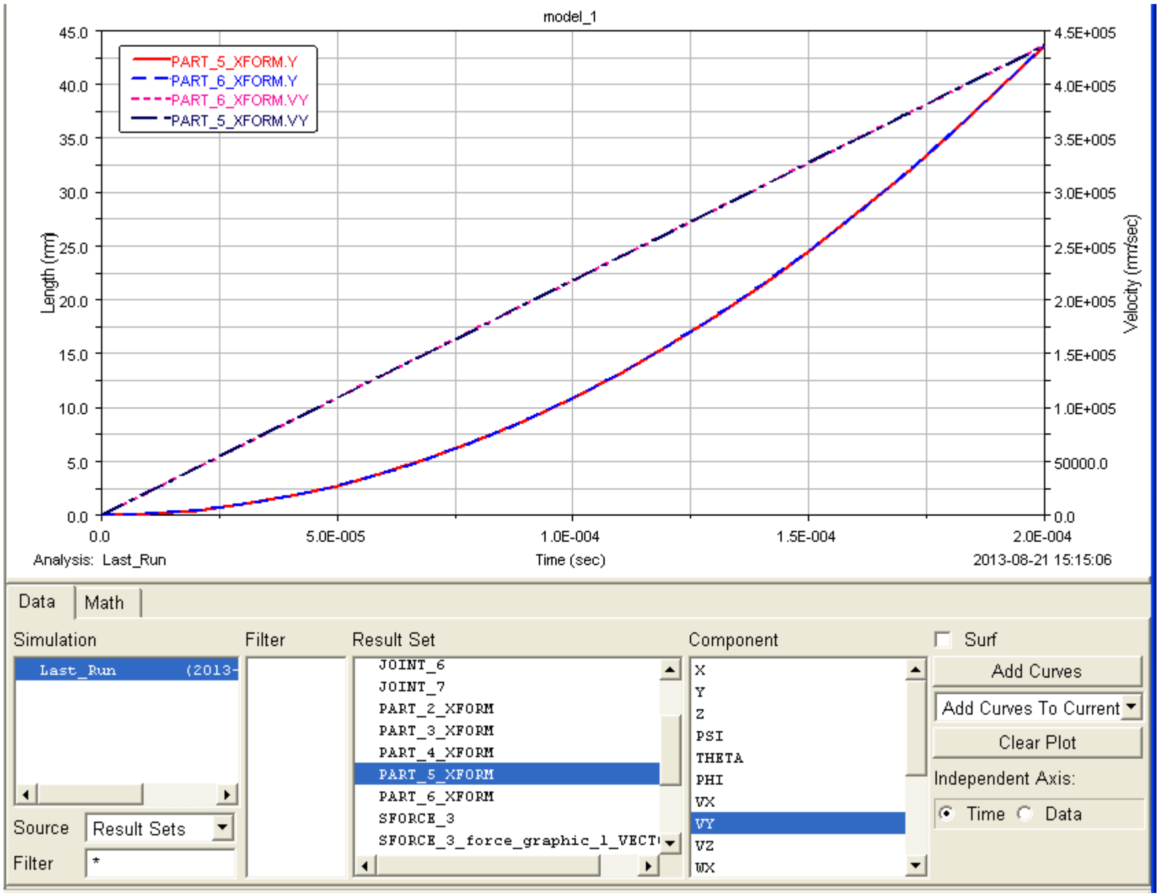

Figure 15: Graph part 5 and 6 (lifting fin) Y position and velocity result versus time (sec)

Figure 15 shows the result of the ADAMs simulation. We can see that the part 5 and 6 position starts to increase slowly and then faster afterwards. This is due to at the beginning state, the system needs to overcome the inertia.

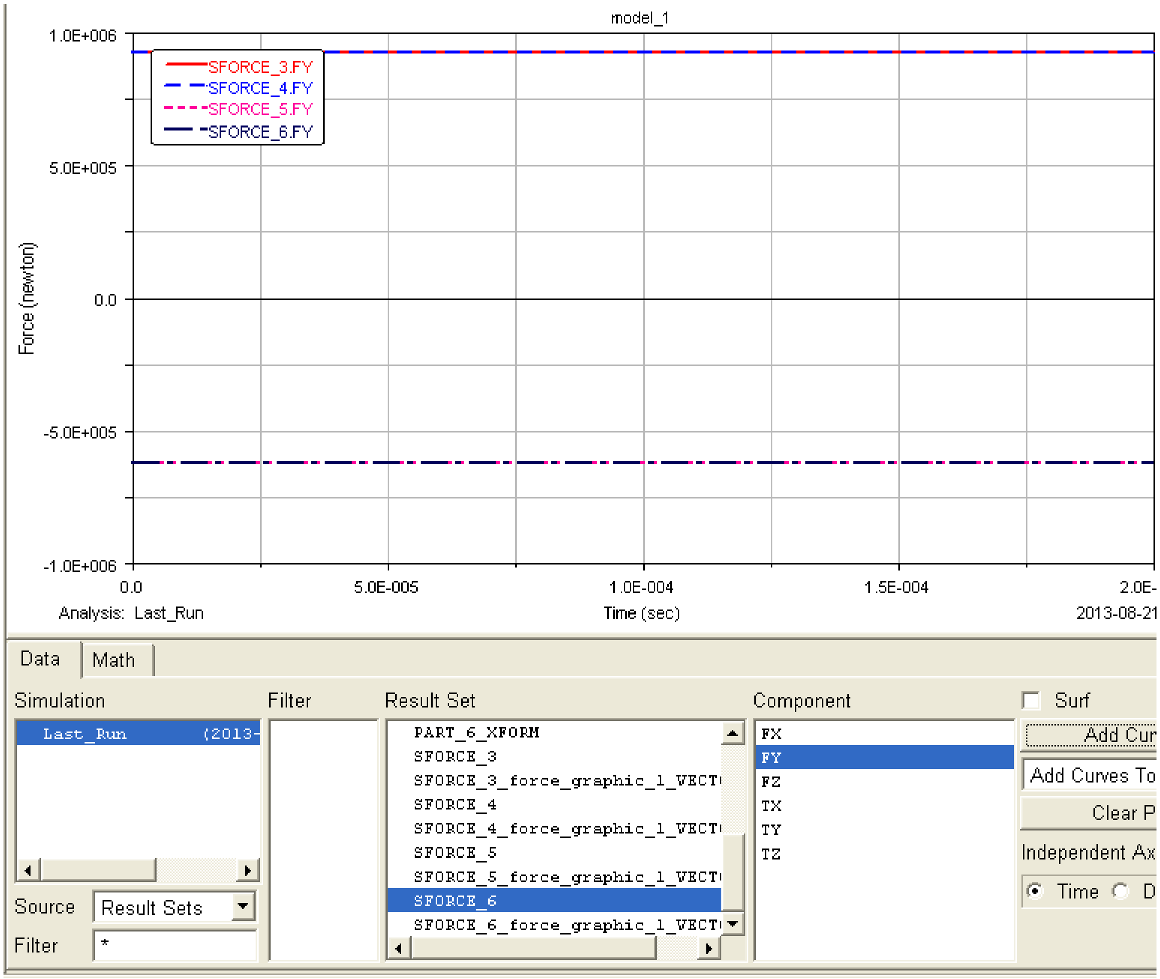

Figure 16: Force from weight of containers and lifting fin force 5 and 6 (Newton) with force from lifting fin force 3 and 4 (Newton) versus time in (sec)

Figure 16 shows the weight of the system and the force needed to move the system upward. The positive sign shows the upward force and negative graph shows the weight or downward force.

4.3 DISCUSSION

In figure 12, the new system is being transformed into a 2D form. The 2 side leg are to represent the 4 lifting machine legs in the actual lifting and link on top are used to join up the 2 legs. The system lifting fins are represented by part 5 and 6 in the drawing. 2 upward forces and 2 downwards forces are being added to represent the weight of the item to lift and lifting force. In figure 13 and 14, the system was build and run. A small part was added at the left hand side without connected to the system are used as reference to show the movement of the system. After which, the position of the lifting fin were plotted in the graph below. We can observe that the lifting process is successful with the parameters input. Besides that, the velocity of the lifting fins is also monitored. Both of them are shown in figure 15. In figure 16, we have the lifting force and weight shown in different direction. The positive force represents the lifting force and negative force represents the weight. From there we will then calculate the structure needed for lifting the weight stated. The structure is calculated based on the current crane lifting standard with British Standards, BS 2573. The acceptable stress and deflection for 2 main legs, 2 auxiliary legs and 2 girders are calculated. The calculations are shown below. Due to the copyright of British Standards, the tables are not shown in the calculations.

4.4 CALCULATION

Weight Calculation:

Weight of 1 container is assume to be 24 metric ton

Weight of 1 lifting fin is assume to be 3 tons

Total containers to carry = 5 containers

Total Lifting fin in the system = 2 lifting fins

Total weight of containers for the system = 5 x 24 tons = 120 tons

Total weight of fin for the system = 2 x 3 tons = 6 tons

Total weight of the system (need to be lifted)

= 120 tons + 6 tons

= 126 tons

Lifting Force Calculation:

In this system, we will set the safety factor to be 1.5 times.

Total lifting force needed (Newtons) =

126 x 1.5 safety factor x 9.81 x 1000 = 1854090 Newtons

We have 2 lifting fin for this system.

So the force needed for each side

= 1854090/2 = 927045 Newtons

We will need 927 k N for each side in order to lift the load with 1.5 times safety factors.

4.5 DESIGN OF DOUBLE GIRDER LIFTING MACHINE

Box Girder Selected

top width,B1 = **75 cm**

top thickness t1 = **2.2 cm**

web thickness,t3 = **0.8 cm**

web height,h = **150 cm**

bottom width ,B2 = **75 cm**

bottom thickness, t2 = **2.2 cm**

span ,L = **15 m**

total girder length, Ltotal = **17 m**

cross-sectional area of section , A = 570.00 cm2

unit girder weight, g = 0.536 tons/m

one girder weight , G1 = 9.10 tons

total girder weight Gw = 18.21 tons

moment of inertia about x-x axis, Ixx = 2361232.40 cm4

moment of inertia about y-y axis, Iyy = 485038.70 cm4

modulus of section about x-x axis, Zxx = 30585.91 cm3

modulus of section about y-y axis, Zyy = 12934.37 cm3

Radius of Gyration, Ry = 29.17 cm

slenderness ratio, = 51.42

SWL = **140 tons**

Impact factor = **1.3**

Total Load, P (unfactored) = **155 tons**

Total Load (factored) = **197 tons**

STRESS CALCULATION

Maximum vertical bending moment Mx = 3830441.80 Nm

Maximum bending stress, Sx = 125.24 N/mm2

Horizontal force due to girder weight, Wy = 0.53 kN/m

Horizontal force due to crane load, Fy = 96.63 kN

Horizontal force due to wind, Fw = 1.79 kN/m

Transverse bending moment, My = 762391.98 Nm

Transverse bending stress, shb = 58.94 N/mm2

Total bending stress, stb = **138.41** N/mm2

Based on BS 2573, Table 10,

Permissible Bending Stress, sp,b **= 147.86 N/mm2**

Duty factor = 0.95

Permissible bending Stress x duty factor = **140.47 N/mm2 >Stotal, ok!**

Shear Capacity Check

Shear stress,ss = 44388.96 kN/m2

= 44.39 N/mm2

Combine bending & shear stress, scomb = **132.99 N/mm2**

Based on BS 2573, Table 10,

Permissible combined stress, sp,comb = 232.57 N/mm2

Duty factor = 0.95

Permissible combined stress x duty factor = **220.94 N/mm2 > Scomb, ok!**

DEFLECTION CALCULATION

Permissible vertical deflection, dvp = Span / 750

= **20.00 mm**

where E = Young Modulus = 205000 N/mm2

permissible horizontal deflection, _hp = span / 500

= **27.78 mm**

Vertical deflection based on vertical load, dv = **11.0 mm <dvp, ok!**

Horizontal deflection based on horizontal load,dh = **5.4 mm <dhp, ok!**

MAIN LEG CHECK

Box Section Leg

Selected Upper Leg Box Section

Top Flange Width = **75 cm**

Bottom Flange Width = **75 cm**

Flange Thickness = **2.5 cm**

Web Height = **270 cm**

Web Thickness = **0.8 cm**

moment of inertia about x-x axis,Ixx(max) = 9586119 cm4

moment of inertia about y-y axis,Iyy(max) = 770413.4 cm4

section modulusabout x-x axis,Zxx(max) = 69717.2 cm3

section modulus about y-y axis,Zyy(max) = 20544.36 cm3

Cross-sectional area , A = 807 cm2

Selected Lower Leg Box Section

Top Flange Width **= 75 cm**

Bottom Flange Width = **75 cm**

Flange Thickness = **2.5 cm**

Web Height = **75 cm**

Web Thickness = **0.8 cm**

moment of inertia about x-x axis,Ixx (min) = 619531.3 cm4

moment of inertia about y-y axis,Iyy (min) = 340956.9 cm4

section modulus about x-x axis,Zxx (min) = 15488.28 cm3

section modulus about y-y axis,Zyy (min) = 9092.18 cm3

Height of leg, h = **20 m**

u = 0.2033

Ih = 1949254.98 cm4

Bending moment at one leg due to

uniform load sq = 109601.79 Nm

K = 1.615

P = 1970000 N

Bending moment at one leg

due to load sp = 889307.38 Nm

Horizontal force due to crane load, Fhc = 197000.00 N

Horizontal force due to wind load, Fhw = 2370.00 N/m

Bending moment due to

horizontal force sr = 2088500.00 Nm

Total bending moment,st,b = 3087409.17 Nm

Max bending stress,smax = **199.34 N/mm2**

Based on BS2573 Table 10,

Permissible bending stress, sp = Bending stress*duty factor

= 232.57 x 0.95

= **220.94 N/mm2**

sp > smax, ok!

DEFLECTION CALCULATION

allowable deflection, dallow = h/450

= **44.44 mm**

maximum deflection , dv = **42.86 mm**

dv<dv,allow, ok!

AUX LEG CHECK

height of leg, haux = 20 m

weight of aux.leg, Gaux = 3696.41 N/m

Maximum Axial Load, Pmax = 1029658.31 N

Selected Upper Leg Box Section

Top Flange Width = 80 cm

Bottom Flange Width = 80 cm

Flange Thickness = 2.2 cm

Web Height = 80 cm

Web Thickness = 0.8 cm

Ixx = 663010.56 cm4

Iyy = 388464.6 cm4

Zxx = 15711.2 cm3

Zyy = 9711.616 cm3

Cross-sectional area , A = 480 cm2

ryy = 28.45 cm

Selected Lower Leg Box Section

Top Flange Width = 80 cm

Bottom Flange Width = 80 cm

Flange Thickness = 2.2 cm

Web Height = 80 cm

Web Thickness = 0.8 cm

Ixx = 663010.56 cm4

Iyy = 388464.6 cm4

Zxx = 15711.2 cm3

Zyy = 9711.616 cm3

Cross-sectional area , A = 480 cm2

ryy = 28.45 cm

Effective length in compression (L) = 1.0 x h

= 20

Slenderness ratio (s) = = L/ryy

= 70.30 < 180

Based on B.S. 2573 Table 12

Allowable buckling stress, (Fcrip) = 182.5 N/mm2

Based on B.S. 2573 Clause 5.1.3

Allowable compressive stress (Cc) = = 0.6 x Fcrip

= 109.5 N/mm2

Compressive stress under load = = La/area

= **21.45** N/mm2 < Cc, ok!

This structure is proven capable of lifting 140 tons according to British Standards. Assume 1 container is 24 tons; we only need to move 120 tons at one move. So this structure is sufficient.

Chapter 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

As a conclusion, after the comparison of data are made, we can see that the new system that are able to lift 5 container at once are more efficient compared to the existing automated crane system that need to lift the containers one by one. The time needed to reach the bottom containers is faster by 400 percent if we are using the new system. This is because the existing method had waste most of the time in gantry crane cross travel. Instead of 5 travel time, the new system only need 1 travels time for us to reach the bottom most container. The new system can helps to increase the efficiency of the seaport.

5.2 RECOMMENDATION

In future, the system can be further developing into a fully automated system. Most seaports nowadays are on fully automated system. So the new lifting machine needs to be fully automated as well in order to fit into the working process in a seaport. Besides, the new lifting machine can also be design to carry loose items. The lifting fin can be modified to suit different purposes.

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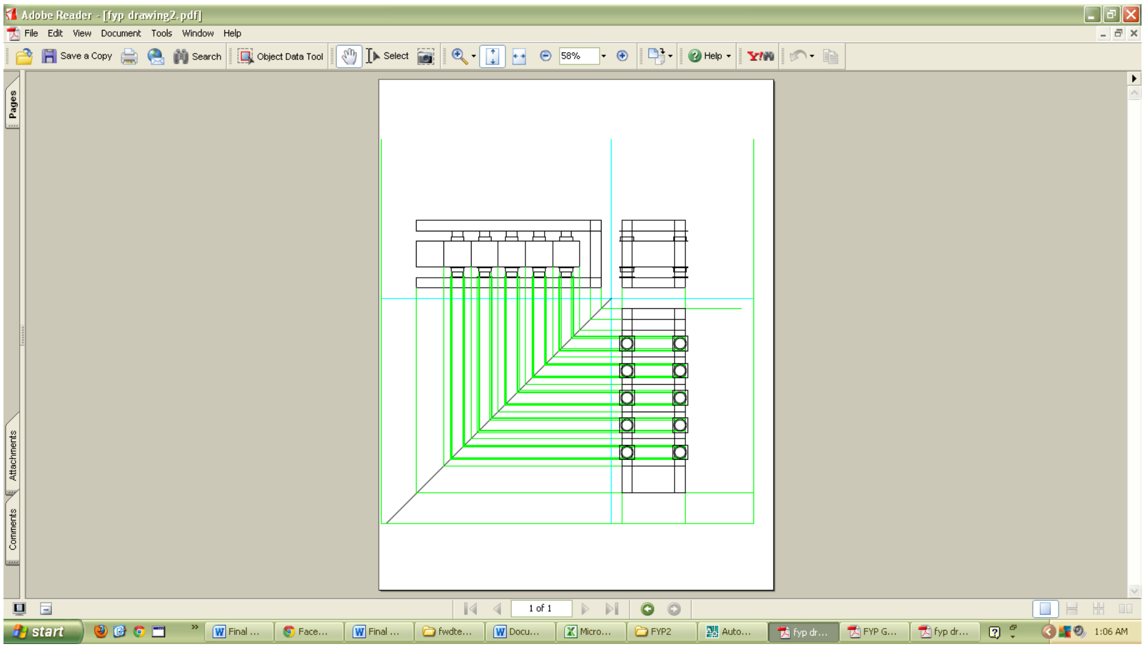
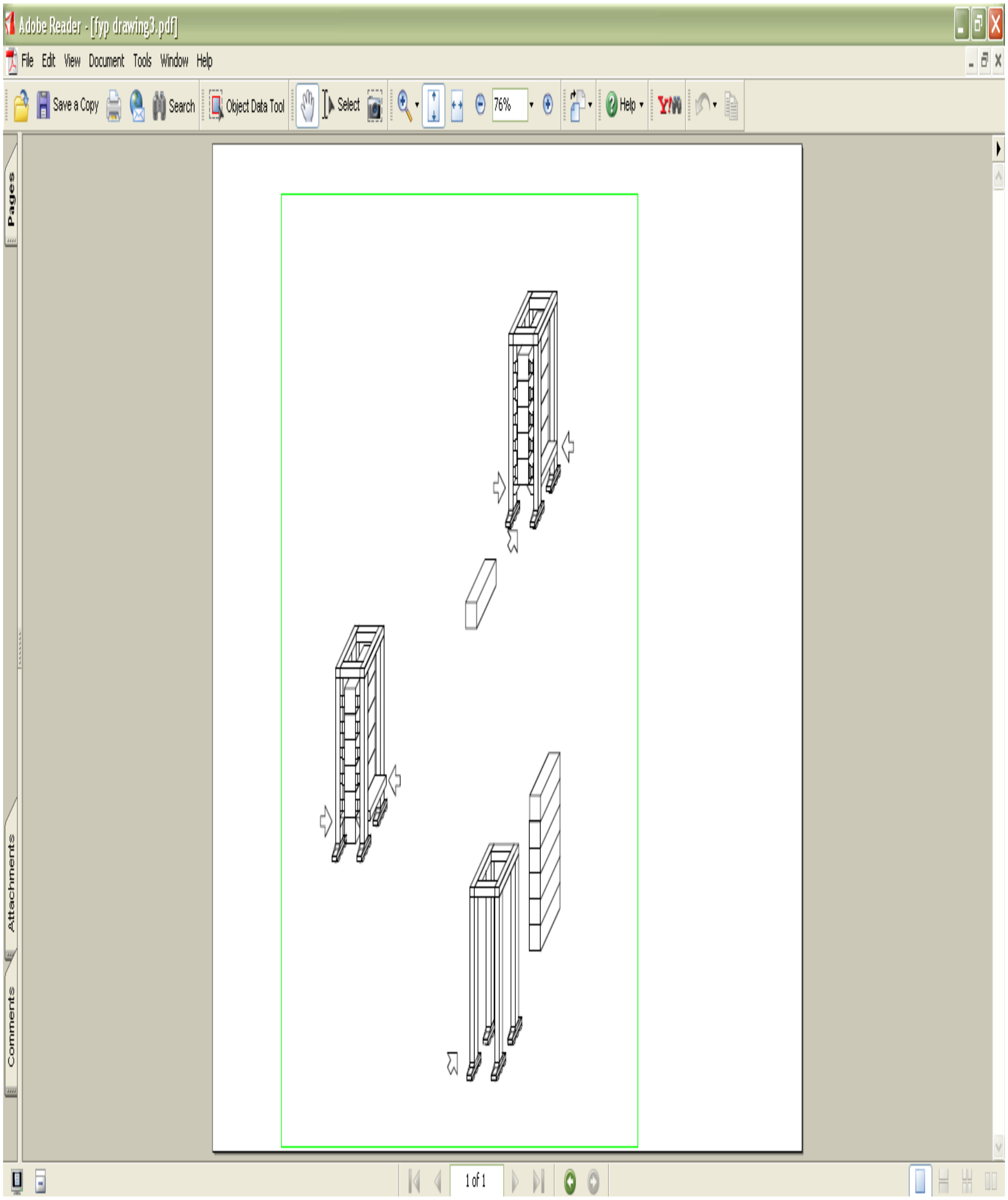
APPENDIX

Appendix 1



2D drawing of the system with autocad

Appendix 2



Isometric view for working concept drawing

Appendix 3

ADAMs View file

Appendix 4

BSI BS*2573 PART*1 83 ■ 1624669 0004911 8 ■

BSI

BS 2573 : Part 1 : 1983

UDC 621.873 :624.04

British Standard

Rules for the design of cranes

Part 1. Specification for classification, stress calculations and design criteria for structures

Règles de conception des grues
Partie 1. Classification, calculs des contraintes et critères de conception des structures — Spécifications

Regeln für den Kranbau
Teil 1. Kranbauten; Einteilung, Spannungsberechnungen und Konstruktionsmerkmale

British Standards Institution

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