Palestine Polytechnic University

College of Engineering and Technology

Mechanical Engineering Department

Graduation Project

Building Tilt Table Ratio Unit (TTR)

Project Team

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June - 2014

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According to the project supervisor and according to the agreement of the Testing Committee Members, this project is submitted to the Department of Mechanical Engineering at College of Engineering and Technology in partial fulfillments of the requirements of (B.SC) degree.

Supervisors Signature

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Examine Community Signature

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Department Head Signature

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June - 2014

ABSTRACT

This project "Tilt Table Ratio (TTR) Unit" was designed and small scale prototype model was build. The apparatus is able to measure the rollover angle of the vehicle at rest, to measure the angle we use potentiometer and use load sensor to measure the traction between the outer wheels and the stand, a hydraulic power was used to lift the outer side of the stand at full scale project and electrical one was used in prototype. This project can be used in vehicle modification center.

في هذا المشروع تم تصميم وحدة فحص زاوية تدحرج المركبة جانبياً في حالة الوقوف التام، وتم بناء نموذج مصغر للمشروع. ولقياس الزاوية سيتم استخدام المقاومة المتغيرة، وتم استخدام وحدات لقياس الوزن لقياس التصاق العجلات الخارجية مع الجهاز، واستخدم ايضا نظام هيدروليكي لرفع الجهاز من الجهة الخارجية للمشروع بحجمه الكامل، بينما تم استخدام نظام كهربائي في النموذج.

List of Contents:

CHAPTER3: Mechanical Design

CHAPTER4: Hydraulic Design

CHAPTER5: Software Programing

CHAPTER6: Safety

CHAPTER7: Prototype

List of Figures:

CHAPTER ONE

Introduction

1.1 Rollover Scenario.

1.2 Importance of Rollover.

1.3 Existing Tilt Table

1.4 Project Overview.

Vehicle tendency to rollover is one of the most important vehicle safety attributes. In this chapter, the rollover mechanism, and present scenarios in which rollover could happen will be introduce.

1.1 Rollover Scenario

Much attention has been paid to automotive rollover accidents during recent decades. Rollover accidents are serious threat to the life of automobile occupants. Rollover is defined as a vehicle rotation of 90° or more around its longitudinal axis. The vehicle body will contact the ground, and the occupants will be injured. Figure 1.1 shows a vehicle rollover scenario. [5]

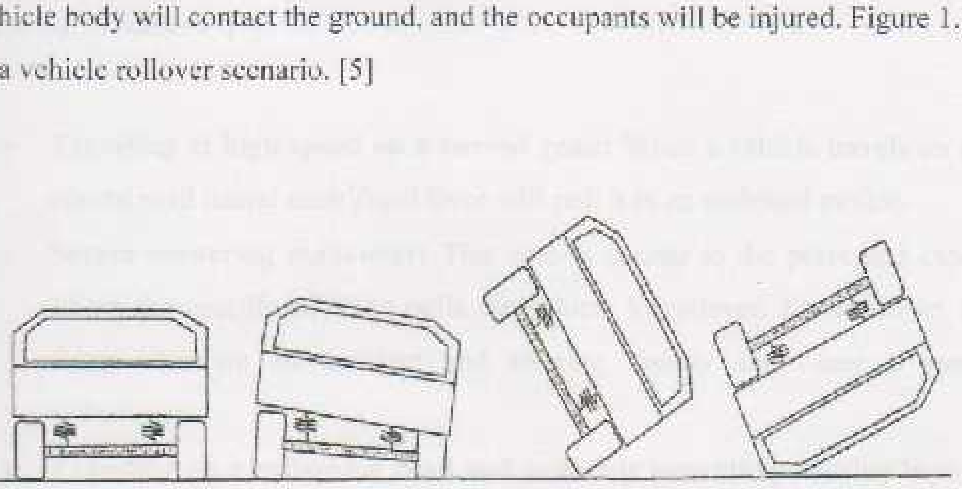


Figure 1.1 A vehicle rollover scenario. [4]

Several factors will affect the vulnerability of a vehicle to rollover. Among these factors are tire and vehicle characteristics, environmental conditions, and drivers. A combination of vehicle and tire design is among the reasons for rollover. For example, vehicles with a higher center of gravity (CG) such as trucks are more vulnerable to rollover when a simple but severe steering input is given. Environmental conditions also may cause rollover. Such conditions are related primarily to road conditions such as ice or bumpy roads. Drivers with dangerous driving habits such as police, ambulance drivers likewise may cause rollover. Rollover accidents may result from one or a combination of these factors. [5]

Rollover can happen on a flat road, on a cross-slope road, or off road. Rollover can be divided into two categories: tripped rollover, and untripped rollover. Tripped rollover is caused by a vehicle hitting an obstacle. This rollover is caused by vehicle inclination where the center of gravity of the vehicle exceeds the stable point. National Highway and Traffic Safety Administration (NHTSA) reports show that only 10% or less of all rollover crashes occur under untripped conditions for the on-road environment. However, major rollovers occur in an off-road environment where the road conditions are unpredictable. Rollover for on-road accidents is usually caused by dangerous maneuvers that are induced either by high lateral acceleration or by yaw instability. The high lateral acceleration produces sufficient centrifugal force to pull the vehicle and cause it to rotate around its outside tire. During yaw motion, the tires produce saturated forces that cause tire sliding and rollover. Most rollover occurs under the following conditions: [5]

- **Traveling at high speed on a curved road:** When a vehicle travels on a curved road lateral centrifugal force will pull it in an outboard motion.
- **Severe cornering maneuver:** This case is similar to the preceding case where the centrifugal force pulls the vehicle to rollover. For example, a driver avoiding an accident and steering rapidly can cause a yaw disturbance.
- **Traveling on a collapsing road and suddenly providing steering input for a vehicle with a low level or roll stability:** This kind of rollover is also caused by a yaw disturbance.
- **Losing control due to a rapid decrease of friction, such as driving on an icy road:** Steering can cause yaw motion because forces on the tires in the lateral direction are strong enough to nil the vehicle. The forces also produce lateral acceleration on the vehicle center of gravity. The forces are produced by the friction between the tires and the road, therefor, these rollover scenarios are called friction rollovers.
- **Laterally sliding off the road:** An example of this case would be a vehicle that can be decelerated by a barrier.
- **Sliding from a cliff:** in which a vehicle is sliding from a cliff.

1.2 Importance of Rollover

Rollover has been an important safety issue of vehicles. Rollover is a major reason for severe and fatal injuries, especially for trucks and sport utility vehicles (SUVs). National Automotive Sampling System (NASS) data (Hinch et al., 1992) shows that approximately 85 to 90 percent of rollover occurred in single-vehicle accidents. The vehicles were out of control prior overturning. In these single-vehicle crashes, more than 50% resulted in fatalities with the vehicles rolling over. Rollover crashes are the most dangerous type of collision for all classes of light vehicles. The rate of rollover accidents for SUVs and small trucks is higher than that of passenger cars. [5]

Rollover accidents account for a small percentage of all vehicle accidents, but they account for a large percentage of fatal accidents. In 1997, NASS (James *et al.*, 1997) reported that only 8% of car accidents resulted in rollover but rollover accounted for 17% of all fatal injuries. In 1996, rollovers were 1.8% of all crashes in the United States but represented 9.9% of all fatal crashes (SAE Paper No. 1999-01-0122). Some reports showed that approximately 50% of single-vehicle accident fatalities resulted from rollover, and approximately 10% of multi-vehicle accident fatalities were caused by rollover (SAE Paper No. 950315). Almost 10,000 people die each year in rollover accidents in the United States (Hinch *et al.*, 1992). [4]

1.3 Existing Tilt Table

There are basically three settings in which tilt tables currently exist, namely, research, manufacturing, and regulatory enforcement organizations. Each of these will be discussed in turn. [4]

In the first area, the primary facility on which research work is currently in progress is in Australia. The facility was built by the Australian Road Research Board, outside of Melbourne, and research was funded through a group of sponsors which included the Department of Transport, the trucking industry, and various manufacturers of motor trucks, trailers, suspensions, and hitch mechanisms. [4]

Another device, upon which the pioneering research by Isermann was based, is currently in Munich, West Germany and is used by the M.A.N. Corporation. The device was originally built in Wolfsburg in cooperation with the University of Hanover, under original sponsorship which included at least M.A.N. The device is no longer used in public domain research, but is used by this vehicle manufacturer. [4]

A third tilt table used in a research context is at the National Road and Traffic Research Institute of Sweden. This device employs one hydraulic actuator at each axle position. The device is portable and requires adjustment of the actuator locations to match axle positions of each vehicle which is measured. [4]

1.4 Project Overview

Figure 1.2 is a simple tilt test table, with a vehicle placed on its surface. The table is tilted from the horizontal by an angle ϕ. The vehicle is in steady state. The vehicle weight, in Mega grams (Mg), can be divided in two directions: one perpendicular to the tilt table surface, and the other parallel to the tilt table surface. The weight perpendicular to the tilt table surface is the actual weight acting on the vehicle, called the simulated weight, and the corresponding force can be expressed as the following where ϕ: rollover angle, m_s: simulated mass (component of the mass acting perpendicular to the plate). [5]

$$F_1 = m_s * g = mg\cos(\phi) \quad (1.1)$$

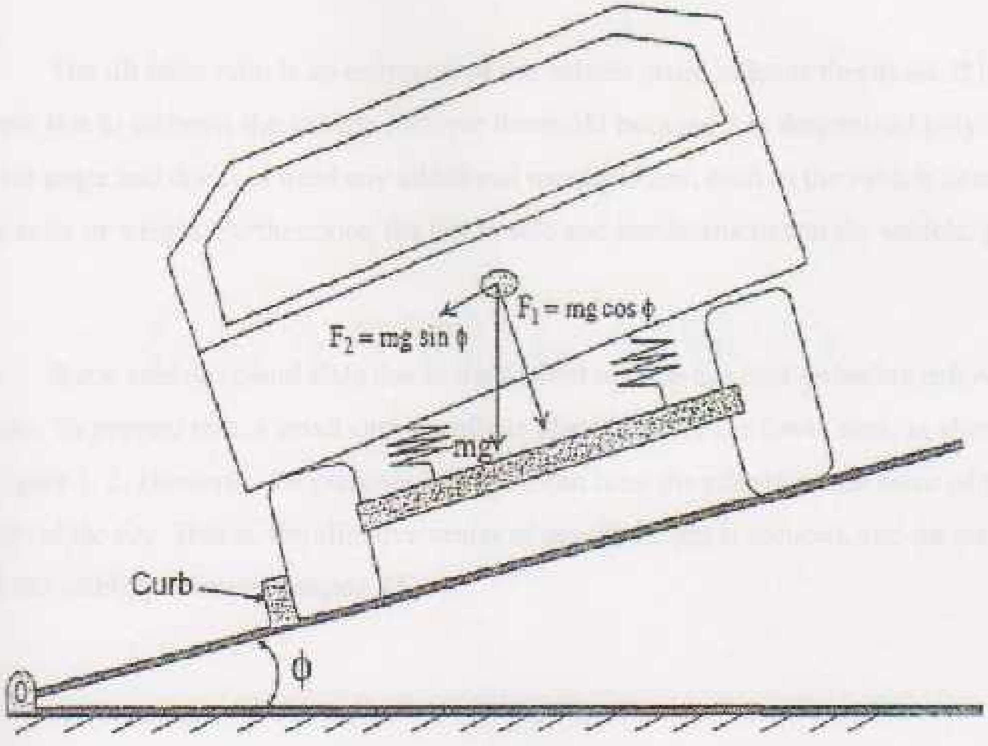


Figure 1.2 Tilt test table with a vehicle placed on it. [4]

The weight parallel to the tilt table surface models the simulated centrifugal force. Assume that a simulated lateral acceleration, a_s, is acted on the vehicle, and a centrifugal force pulls the vehicle into rollover. The centrifugal force can be expressed as the following where m_s is the simulated mass, a_s is the simulated lateral acceleration. [5]

$$F_2 = m_s * a_s = mg\sin(\phi) \qquad (1.2)$$

During the test, the tilt of the table is increased slowly until the tire at the high side loses contact with the surface of the table. The angle at which this occurs is called the tip-over angle. Dividing Eq.1.1 by Eq. 1.2, the ratio of the simulated lateral acceleration over g is obtained and is called the tilt table ratio (TTR), which is expressed as

$$TTR = \frac{a_s}{g} = \tan(\phi) \qquad (1.3)$$

The tilt table ratio is an estimator of the vehicle static rollover threshold. It is a simple test to estimate the vehicle rollover threshold because it is determined only by the tilt angle and does not need any additional measurement, such as the vehicle center of gravity or weight. Furthermore, the test is safe and nondestructive to the vehicle. [5]

Some vehicles could slide due to the limited surface-tire friction before rollover occurs. To prevent that, a small curb usually is placed next to the lower tires, as shown in Figure 1. 2. However, the presence of a curb can raise the effective side force of the center of the tire. That is, the effective center of gravity height is reduced, and the static rollover stability is overestimated. [5]

CHAPTER TWO

Analysis

2.1 Introduction.

2.2 Mechanical Structure.

2.3 Hydraulic System.

2.4 Electronic System.

2.1 Introduction

This chapter contains project parts and their properties and focuses on the technical specification.

2.2 Mechanical Structure

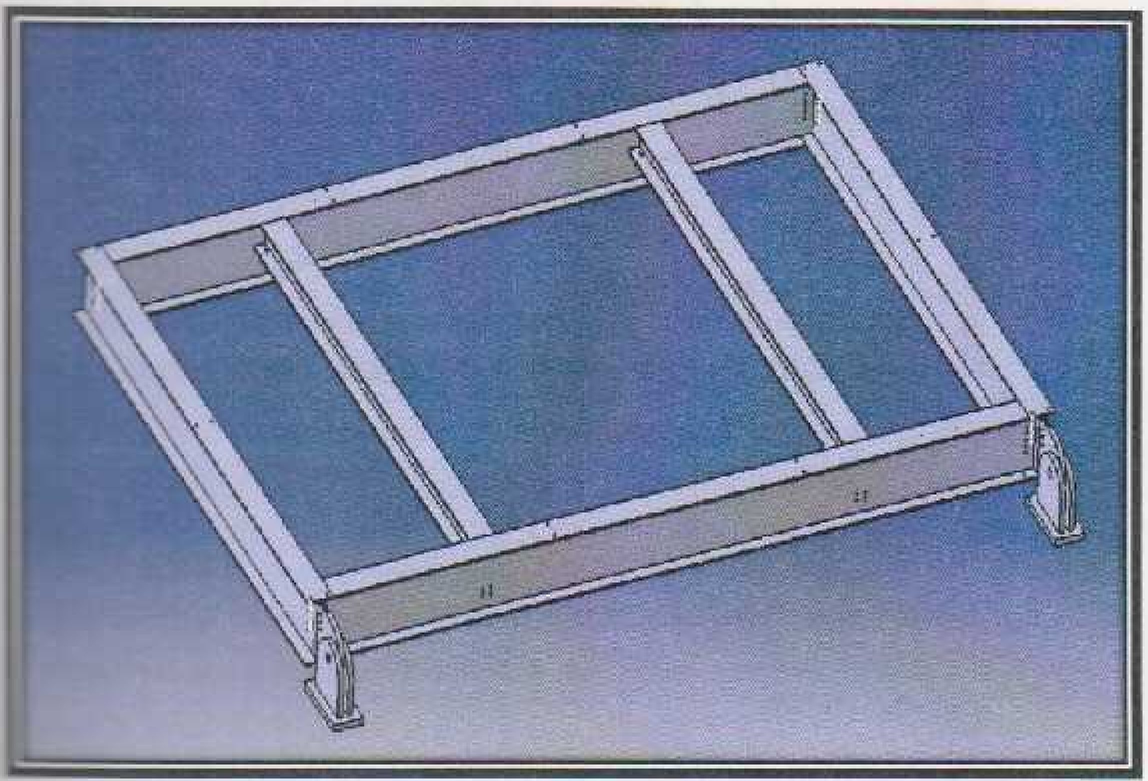


Figure 2.1 structure of the (TTR).

As shown in figure 2.1 the structure of the project consists of steel beams that form the framework, two joints, and two extra beams to fix the joint to the ground.

2.2.1 Load Analysis

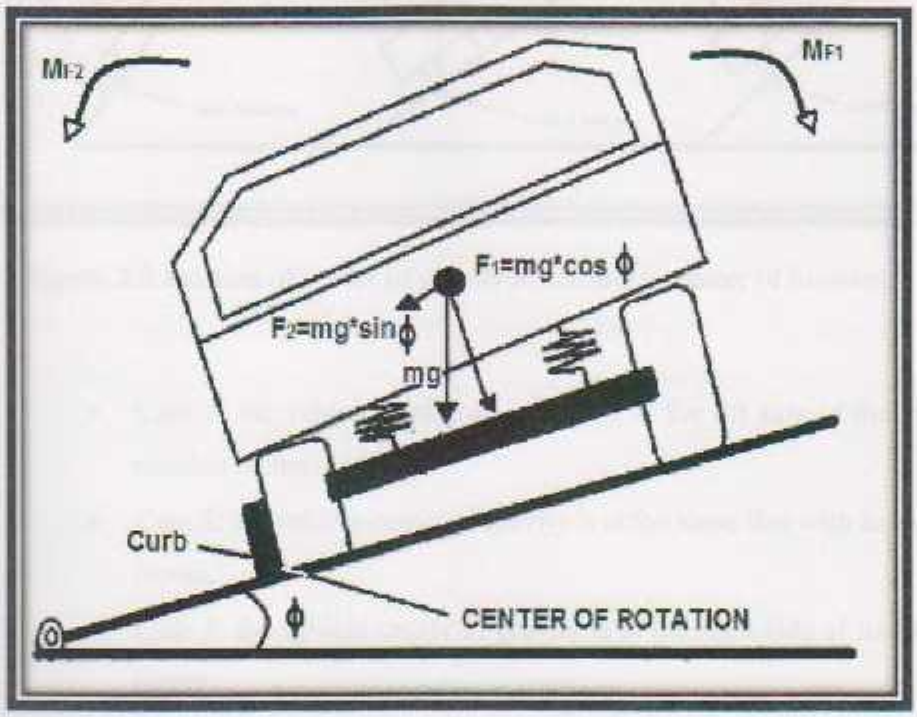


Figure 2.2 Loads on the Structure.

In fig.2.2 F_1 is the parallel component of the weight, and F_2 is the normal component of the weight, ϕ is the angle of rotation, M_{F1} is the moment caused by the F_1 component, M_{F2} is the moment caused by the F_2 component.

From the figure above it noticed that the vehicle weight is divided into two components, the first component F_2 is parallel to the table, and it will not be acted with a moment on the table, but it will cause the vehicle to rollover. As shown in figure 2.2.

The second component acts perpendicular to the table, it will increase the vehicle tendency to rolling at a large angle because at large angle the center of the gravity of the vehicle becomes at the left of center of rotation. As shown in figure 2.3.

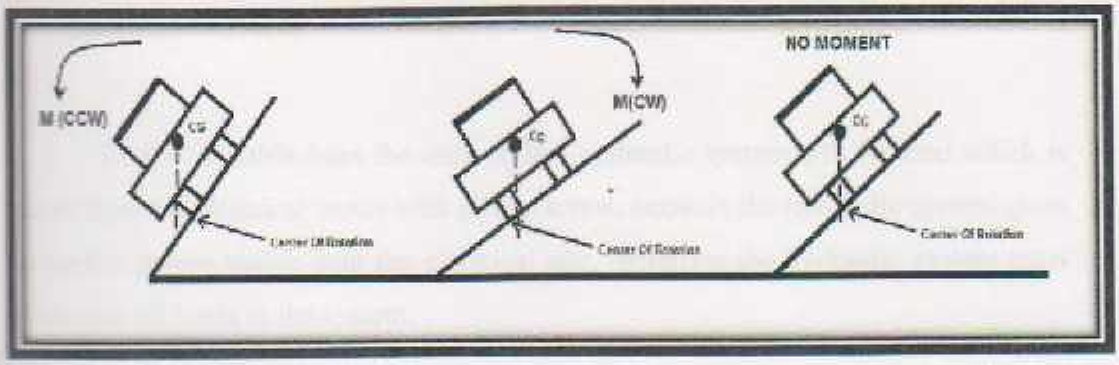


Figure 2.3 location of center of gravity according to center of location.

- Case 1: the vehicle center of gravity is at the lift side of the vehicle rotation center.
- Case 2: the vehicle center of gravity is at the same line with its rotation center.
- Case 3: the vehicle center of gravity is at the right side of its rotation center.

2.2.2 Joints

Both joints that we will use will be designed to endure against the load produced by rotation of the stand; also it should handle with the load from the vehicle weight which affects with shear force on the pin of the joint, as shown in the Figure 2.4.

Figure 2.4 the joint.

2.3 Hydraulic System

To lift the table from the outer side a hydraulic system will be used which is better than the electrical motor with power screw, because the hydraulic system gives an output power higher than the electrical one, moreover the hydraulic system must overcome all loads in the system.

The hydraulic system consists of: reservoir, hydraulic pump, pressure relief valve, 4/3 direct control valve (DCV), double acting cylinder (Cap End Trunion), and meter out flow control, oil filter, oil and pipes.

2.3.1 Reservoir

The proper design of a suitable reservoir for a hydraulic system is essential to the overall performance and life of the individual components. The reservoir serves not only as a storage space for the hydraulic fluid used by the system but also as the principal location where the fluid is conditioned. The reservoir is where sludge, water, and metal chips settle and where entrained air picked up by the oil is allowed to escape. The dissipation of heat is also accomplished by a properly designed reservoir. [1]

2.3.2 Oil Filter

Modern hydraulic systems must be dependable and provide high accuracy. This requires highly precision-machined components. The worst enemy of a precision made hydraulic component is contamination of the fluid. Essentially, contamination is any foreign material in the fluid that results in detrimental operation of any component of the system. Contamination may be in the form of a liquid, gas, or solid. [1]

2.3.3 Pump

It circulates the fluid around the system and provides the pressure necessary to overcome the load at its outlet port. All pumps used in hydrostatic systems are gear pumps.

A suitable pump is to be chosen to give enough pressure to supply the system with required power to lift the table. [1]

Selection of the pump depends on:

- Flow rate requirements.
- Operation speed.
- Pressure rating.
- Performance.

Figure 2.5 Gear pump.

2.3.4 Pressure Relief Valve (PRV)

The function of the relief valve is to limit the maximum pressure that can exist in a system. Under ideal condition the relief valve should provide an alternative bath to tank for the system oil while keeping the maximum pressure constant.

It is typically located near the pump outlet, used to protect the pump and pips from pressure overloads, as shown in figure 2.6.

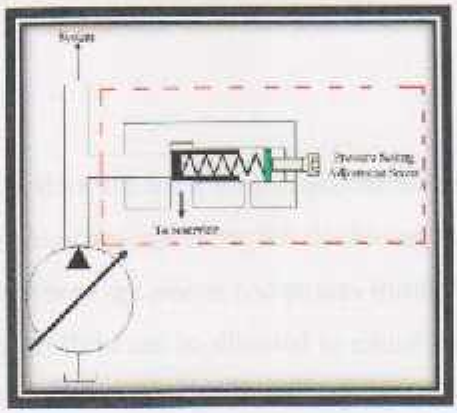


Figure 2.6 Pressure relief valve.

2.3.5 4/3 Direct Control Valve

4 – Ports and 3 – position. Used foe (stop- start- shuttle) the flow of hydraulic fluid in two ways as shown in figure 2.7. It's electrically actuated and returned using electric solenoid.

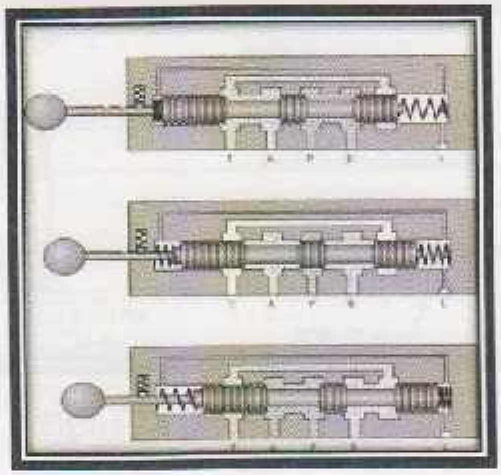


Figure 2.7 4/3 direct control valve.

2.3.6 Double Acting Cylinder

Pumps perform the function of adding energy to a hydraulic system for transmission to some remote point. Fluid power actuators do just the opposite. They extract energy from a fluid and convert it to a mechanical output to perform useful work.

Double-acting cylinders are used on equipment where force is needed in two directions. Unlike the single-acting cylinder, the double-acting cylinder contains seals at both ends of the piston where the piston rod passes through the end of the cylinder. With the use of this cylinder, fluid can be directed to either side of the piston and cause the piston rod to extend or retract under pressure. [1]

The double actuating cylinder is used to lift the table and to make sure that; the return way will be smoothly with constant speed.

Cap end Trunion type is chosen because of its rotation ability, and it's compatibility with the design.

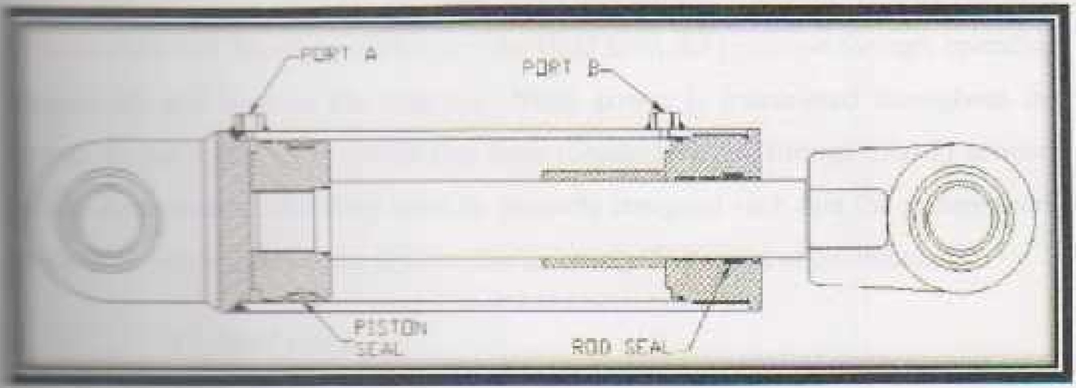


Figure 2.8 Double acting cylinder.

2.3.7 Fluid

The single most important material in a hydraulic system is the working fluid itself. Hydraulic fluid characteristics have a critical effect on equipment performance and life. It is important to use a clean, high-quality fluid in order to achieve efficient hydraulic system operation. [1]

Most modern hydraulic fluids are complex compounds that have been carefully prepared to meet their demanding tasks. In addition to having a base fluid, hydraulic fluids contain special additives to provide desired characteristics. [1]

Essentially, a hydraulic fluid has four primary functions:

- To transmit power
- To lubricate moving parts
- To seal clearances between mating parts
- To dissipate heat

2.3.8 Distribution Line

In a fluid power system, the fluid flows through a distribution system consisting of conductors and fittings, which carry the fluid from the reservoir through operating components and back to the reservoir. Since power is transmitted throughout the system, by means of these conducting lines (conductors and fittings used to connect system components), that they must be properly designed such that the system work properly. Today's fluid power systems use primarily four types of conductors:

- Steel pipes
- Steel tubing
- Plastic tubing
- Flexible hoses

The choice of which type of conductor to use depends primarily on the system's operating pressures and flow rates. In addition, the selection depends on environmental conditions such as the type of fluid, operating temperatures, vibration, and whether or not there is relative motion between connected components. [1]

2.4 Electronic System

The electronic system used in the project consists of: potentiometer, load sensor, digital to analog converter (DAC), microcontroller (Arduino), seven segment screen, and relay, on/off buttons, voltage regulator, power supply, and software.

Figure 2.10 shows block diagrams that describe the electric control system for the project.

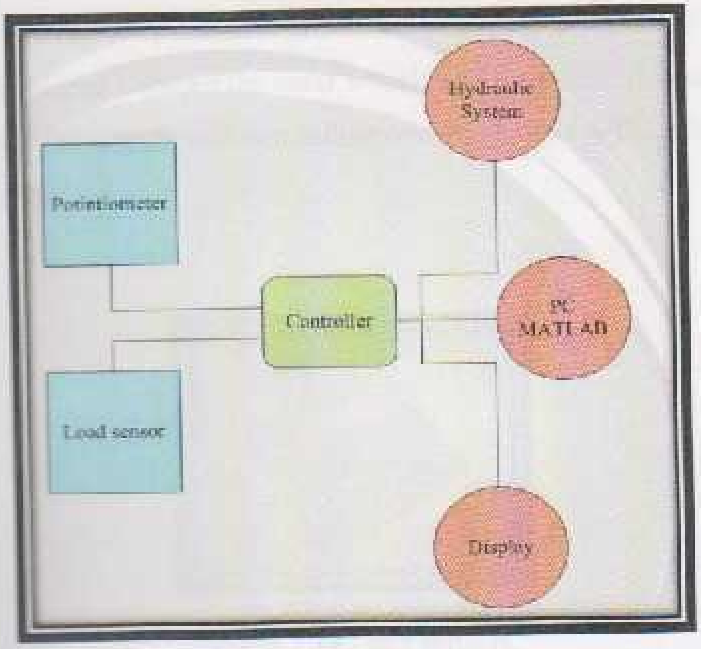


Fig 2.10 electronic system diagram

2.4.1 Potentiometer

Informally a pot, is a three-terminal resistor with a sliding contact that forms an adjustable voltage divider. If only two terminals are used, one end and the wiper.

Fig 2.11 Potentiometer

2.4.2 Load Sensors

It will be placed between the outer wheels and the frame. It is used to indicate the point at which the vehicle will start rolling over the project will use load sensor that gives analog signal.

Figure 2.12 Load sensors.

2.4.3 Microcontroller (PIC)

It's the heart of our electronic system, it receive the input signals, process it, and then order the actuators.

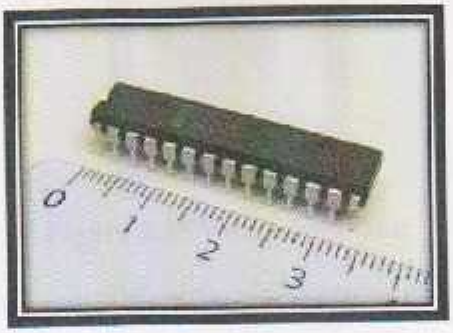


Figure 2.13 Microcontroller (PIC).

2.4.4 Seven - Segment Screen

It is used to display the reading of angle (output).

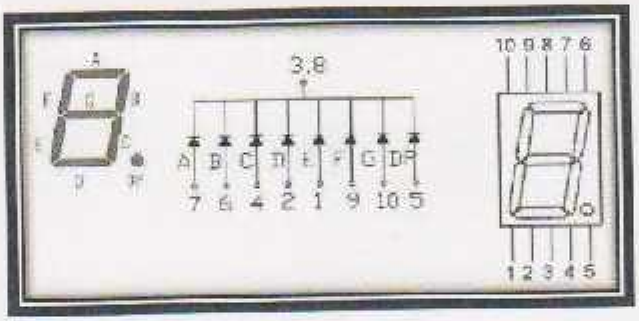


Figure 2.14 seven- segment screen.

2.4.5 ON/OFF Buttons

Connect /disconnect the electrical power to the system. Moreover we will use an emergency buttons.

2.4.6 Voltage Regulator

To make sure that the input voltage of the control circuit will not exceed the required voltage, we will use the voltage regulator.

Figure 2.15 voltage regulator.

2.4.7 Software

In our project we will use some software's, MATLAB for curve fitting and mathematical molding, Arduino program, and "PROTEUS "for circuit simulation.

CHAPTER THREE

Mechanical Design

3.1 Introduction.

3.2 Strength Calculations.

3.1 Introduction

Design is an iterative process with many interactive phases. Many resources exist to support the designer, including many sources of information and an abundance of computational design tools.

In this chapter the mechanical structure of the device is going to be designed, especially the joints and the beams based on the equations and tables from the Mechanics of Material for FERDINADD P. BEER. [2]

After visiting the Vehicle Inspection Center and scan the data base (Catalogs and PC software), collecting data from vehicles that visit the center, and taking advices from the center manager into a consideration, the dimensions of the mechanical structure assumed to be 3 meter long (L) and 2 meter width (W) as shown in figure 3.1, and assumed to carry 3000kg weight, and the table in appendix 2 show the calculation for the force acting on the mechanical structure.

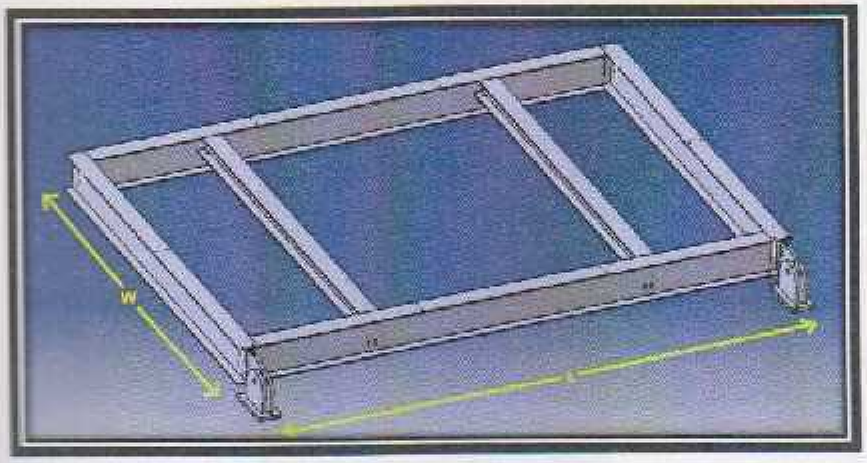


Figure 3.1 Mechanical Structure.

It is important to determine the minimum dimensions for the beams and joints to protect it from failure.

The forces that affect the structure are to be analyzed, and the suitable material (structural steel ASTM-A36) is chosen from the materials properties tables, which has yield shear stress τ_y of 240MPa, yield normal stress σ_y of 655MPa, and facture of safety n is assumed to be 1.5.

3.2 Strength Calculations

3.2.1 Joints

The joints in this structure are affected by shear and bearing stresses, which come from the load of the vehicle and the load of the structure itself. The maximum load that affects the joint is calculated by using Microsoft Excel program which comes for 11. 67KN.

The diameter (D) of the pin in the joint is assumed to be 0.03 meter, and the thickness (t) of the joint's body is 0.02 meter, as shown in figure 3.2 below.

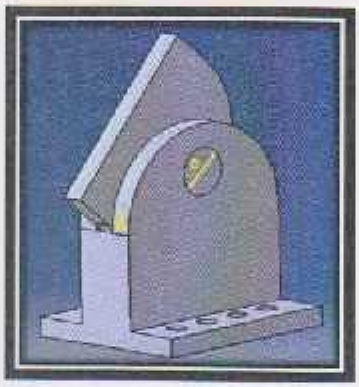


Figure 3.2 Joint.

The shear stress (τ) is obtained from equation 3.1:

$$\tau = \frac{F}{2 \times A} \qquad (3.1)$$

Where:

F: force effect on the joint.

A: cross section area of the pin.

By substituting the force and the area in the equation 3.1 the shear stress (τ) is:

$$\tau = \frac{11.67\ KN}{2 * 0.0007.6\ m^2}$$

$$= 8.34\ MPa$$

So the maximum allowable shear stress ($\tau_{max.all}$) is:

$$\tau_{max.all} = Ssy / n \qquad (3.2)$$

$$= 145\ MPa / 1.5$$

$$\tau_{max.all} = 96.67\ MPa$$

So the real factor of safety ($n^{\backslash}$) is:

$$n^{\backslash} = \frac{yield\ stress}{allwable\ stress}$$

$$= \frac{240MPa}{96.67MPa}$$

$$= 2.48$$

The bearing stress (σ_b) is obtained from equation 3.3:

$$\sigma_b = \frac{F}{t * D} \qquad (3.3)$$

Where;

F: force effect on the joint.

t: thickness of the joint body.

D: diameter of the pin.

$$\sigma_b = \frac{11.67KN}{0.02 * 0.03}$$

$$\sigma_b = 19.45MPa$$

So the maximum allowable bearing stress ($\sigma_{b_{max.all}}$) is:

$$\sigma_{b_{max.all}} = Sy\ /\ n \quad \text{.......} \quad (3.4)$$

$$= 250MPa\ /1.5$$

$$\sigma_{b_{max.all}} = 166.67MPa$$

So the real factor of safety ($n^{\backprime}$) is:

$$n^{\backprime} = \frac{yield\ stress}{allwable\ stress}$$

$$= \frac{655MPa}{166.67MPa}$$

$$= 3.93$$

As noticed from the previous calculations, the calculated shear and bearing stresses are less than the yield stresses values, which mean that our assumptions for the dimensions are valid, so the real factor of safety ($n^{\backprime}$) is taken as 19.

3.2.2 Beams

Beams in this structure are affected by shear and normal stresses, which come from the load of the vehicle. The free body diagram in fig 3.3 shows the maximum load that affects the beams.

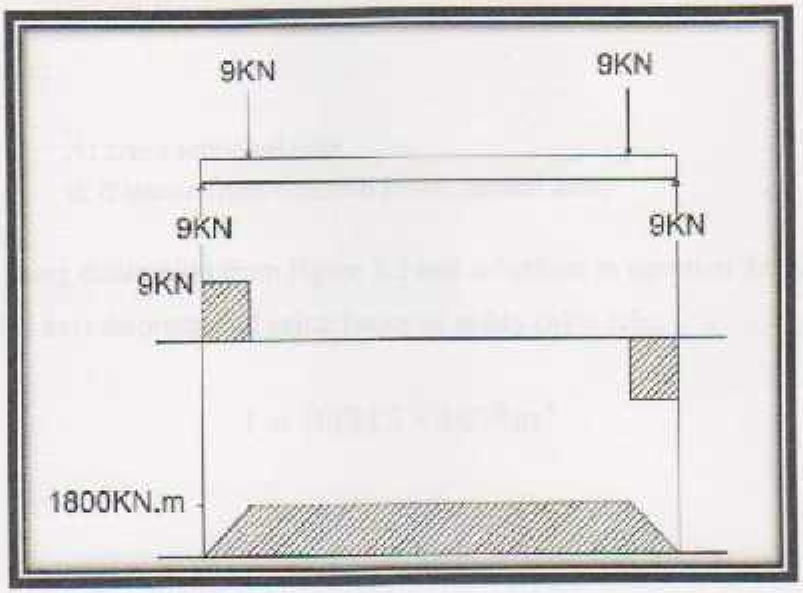


Figure 3.3 beam's free body diagram.

The beam chosen for this design is I beam (W200×19.3), from properties of rolled steel shapes table, using the same material that chosen for joints.

The critical point in the beam is shown in figure 3.2, having a shear force (V) of 9KN, and bending moment (M) of 1.8KN.m.

The shear stress Ʈ is obtained from equation 3.5:

$$Ʈ = \frac{V * Q}{t * I} \quad \text{.......} \quad (3.5)$$

Where;

V: shearing force.
Q: first moment of area.
t: width of the element at the cut.
I: moment of inertia.

Moment of inertia (I) and first moment of area (Q) are obtained from equation 3.6 and equation 3.7:

$$I = \frac{1}{12} * b * h^3 \quad \text{.......} \quad (3.6)$$

$$Q = A * d \quad \text{.......} \quad (3.7)$$

Where;

A: cross sectional area
d: distance from centroid to the neutral axis.

By using diminution from figure 3.3 and substitute in equation 3.6 and 3.7 and using parallel axis theorem, and using factor of safety (n) = 1.5:

$$I = 30315 * 10^{-6} m^4$$

$$Q = 65.14 * 10^{-6} m^3$$

By sub. (I) and (Q) in equation 3.5:

$$\tau = 6.27\ MPA$$

So the maximum allowable shear stress ($\tau_{max.all}$) is:

$$\tau_{max.all} = Ssy * n \quad \text{.......} \quad (3.8)$$

$$= 145MPa / 1.5$$

$$\tau_{max.all} = 96.67MPa / \text{n}$$

So the real factor of safety ($n^{\backslash}$) is:

$$n^{\backslash} = \frac{yield\ stress}{allwable\ stress}$$

$$= \frac{240MPa}{96.67MPa}$$

$$= 2.48$$

The normal stress (σ') is obtained from equation 3.3.:

$$\sigma_b = \frac{M*c}{I} \quad \text{.......} \quad (3.3)$$

Where;

M: moment.
c: largest distance from the neutral surface.
D: moment of inertia.

$$\sigma = \frac{1.8KN * 0.1015m}{16.12 * 10^{-6} m^4}$$

$$\sigma = 11.33MPa$$

So the maximum allowable normal stress is:

$\sigma_{max.all} = Sy/n$ .... (3.4)

$$= 250MPa * 1.5$$

$$\sigma_{b_{max.all}} = 166.67MPa$$

So the real factor of safety ($n^{\backprime}$) is:

$$n^{\backprime} = \frac{yield\ stress}{allwable\ stress}$$

$$= \frac{655MPa}{166.67MPa}$$

$$= 3.93$$

As noticed from the previous calculations, the calculated shear and normal stresses are less than the yield stresses value, which mean that our assumptions for the dimensions are valid, so the real factor of safety ($n^{\backprime}$) is taken as 2.48.

CHAPTER FOUR

Hydraulic Design

4.1 Introduction

4.2 Calculations

4.3 Buckling

4.4 Conductor Selection

4.1 Introduction

The hydraulic circuit contains a group of components such as pump, actuators, control valves and conductors arranged to perform a useful task. When designing a hydraulic circuit, the following considerations must be taken in to account: [3]

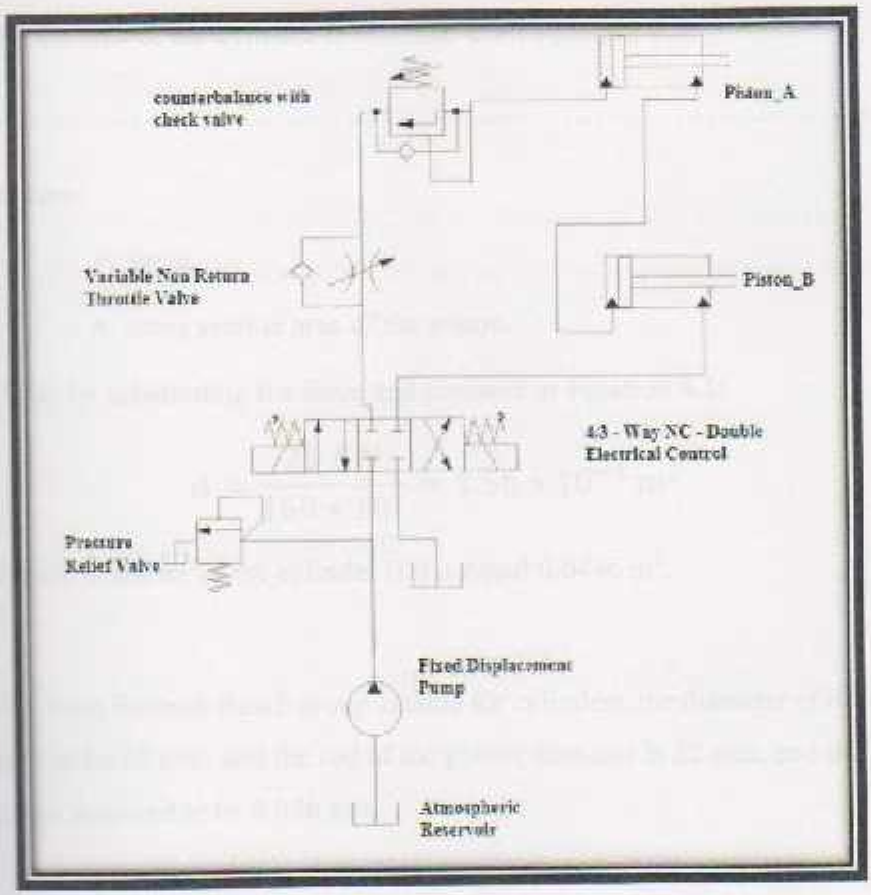


Figure 4.1 hydraulic system.

- Safety of operation.
- Performance of the desired function.
- Efficiency of operation.

In this chapter the hydraulic system will be designed to perform its task which is lifting the table in a safely.

4.2 Calculations

First of all, from the load analysis the maximum force that the hydraulic system must to overcome it is 25KN, then we assume the maximum pressure in the hydraulic system to be 160 bar ($160*10^5$ pa).

So the area of the cylinder is obtained from equation 4.1:

$P = \frac{F}{A}$ .... (4.1).

Where:

F: force.

A: cross section area of the piston.

Then by substituting the force and pressure in equation 4.1:

$$A = \frac{25\ KN}{160 * 10^5} = 1.56 * 10^{-3}\ m^2$$

So the diameter of the cylinder (D) is equal 0.0446 m^2.

So, from Rexroth Busch group catalog for cylinders, the diameter of the cylinder (D) chosen to be 50 mm, and the rod of the piston diameter is 32 mm, and the velocity of the piston assumed to be 0.026 m/s.

Actual flow rate can be obtained from equation 4.2:

$Q_a = A * V$ .... (4.2).

Where:

A: cross sectional area of the piston.

V: velocity of the fluid.

By substituting in equation 4.2:

$$Q_a = 0.00196 * 0.026 = 51 * 10^{-6}\ m^3/s$$

By assuming the volumetric efficiency to be 95%, theoretical flow rate (Q_{theo}) can be obtained from equation 4.3:

$$Q_{theo} = \frac{Q_a}{\eta_v} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4.3).$$

Where:

Q_a actual flow rate.

η_v: volumetric efficiency.

By substituting (Q_a) and η_v in equation 4.3:

$$Q_{theo} = 53.4 * 10^{-6}\ m^3/s$$

So by choosing 1400 RPM motor to drive the pump and the displacement volume (v) is chosen to be 4 cm^3/rev the actual flow rate can calculated by equation 4.4:

$$Q_a = v * n \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4.4).$$

Where;

V: displacement volume.

N: motor RPM.

$$Q_a = 4 * 10^{-6} * 1400 = 93.34 * 10^{-6}\ m^3/s$$

The velocity can be obtained from equation 4.5:

$$V = \frac{Q_a}{A} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4.5).$$

Where;

Q_a: actual flow rate.

A: cross section area of the piston.

So by substituting in equation 4.5:

$$V = 47.62 * 10^{-3} m/s$$

4.3 Buckling of the Hydraulic Piston:

The force causing buckling can be calculated from equation 4.6:

$$F_{buckling} = \frac{\pi^2 * E * I}{l_k^2 * U} \quad \text{...} (4.6).$$

Where:

E: elasticity module.

I: area moment.

L_k: free buckling length.

U: safety factor (2.5 - 3.5)

So by substituting in equation 4.6:

$$F_{buckling} = 13.56 * 10^6 \text{ N} \gg F_{load} = 25 * 10^3 \text{ N}$$

So the design is safe from buckling.

4.4 Conductor Selection

The main function of the conductors is interconnect the various components of the system, and it has many type, steel pipes, steel tubes, plastic tubes, flexible hoses.

So the choice of type depend on:

1. Operating pressure.
2. Flow rate.
3. Type of fluid.
4. Temperature.
5. Vibration and relative motion between parts

Lines must withstand pressures as high as FOUR times the working pressure so the material selected for the conductor is steel SAE 1010.

As noticed from previous calculation flow rate is equal 53.4*10^ (-6) m^3/s and velocity of the fluid is equal 47.6*10^ (-3) m^3/s so the required area for the conductor can be calculated from equation 4.2, which equal (A) 0.00121 m^2 so the diameter of the pipe is (D) equal 37 mm, the from metric tube size table the tube with outer diameter (Do=50mm), and inner diameter (Di=37mm), and thickness (t=6mm) have been selected.

The burst pressure (BP) for the selected tube can be determine from the equation 4.7:

$$BP = \frac{2 * t * S}{Di} \text{ ------------------------------------ } (4.7)\ [1]$$

Where:

t: thickness of the tube.

S: tensile strength of the tube material.

Di: inner diameter of the tube.

By substituting in equation 4.7:

$$BP = \frac{2 * 0.006 * 379 * 10^6}{0.05} = 90.96\ MPa$$

The working pressure (WP) for the selected tube can be determine from the equation 4.8:

$$WP = \frac{BP}{FS} \text{ ------------------------------------ } (4.8)\ [1]$$

By substituting in equation 4.8:

$$WP = \frac{90.96 * 10^6}{4} = 22.74\ \text{MPa}$$

So the working pressure of the tube is larger than the working pressure of the system these mean that the tube design is safe.

CHAPTER FIVE

Software Programing

5.1 Introduction.

5.2 Load Cell Reading and Calibration.

5.3 Angle Reading.

5.4 Flow Chart.

5.1 Introduction

Software is installed on the microcontroller (PIC 18F4550), and the microcontroller is connected to the hardware (Load cell, Potentiometer, Push buttons, LCD). it process data collected from the sensors, and then execute the installed instructions, and displays on LCD as shown in figure

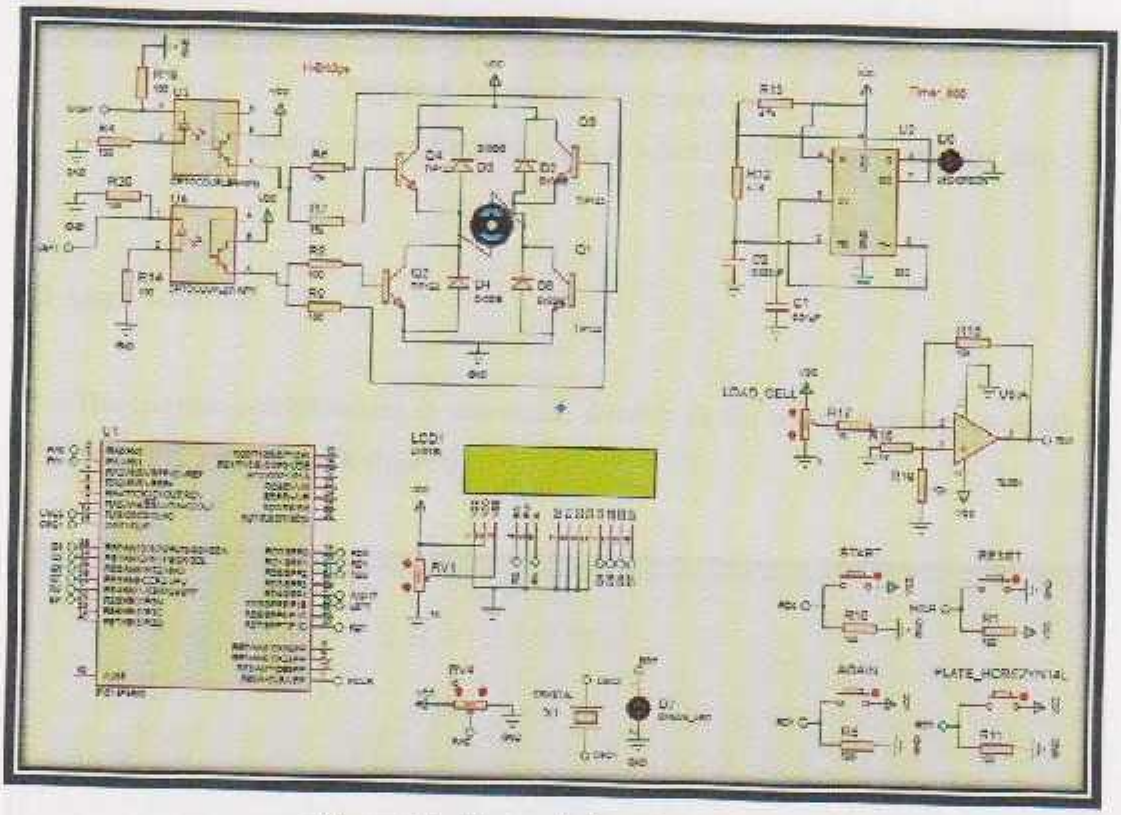


Figure 5.1: Electronic board circuit.

5.2 Load Cell Reading and Calibration.

The load cell is connected to an operational amplifier to amplified the output signal, then the amplified signal is entered to channel AN1 (Pin # 3 in PIC) as shown in figure 5.2.

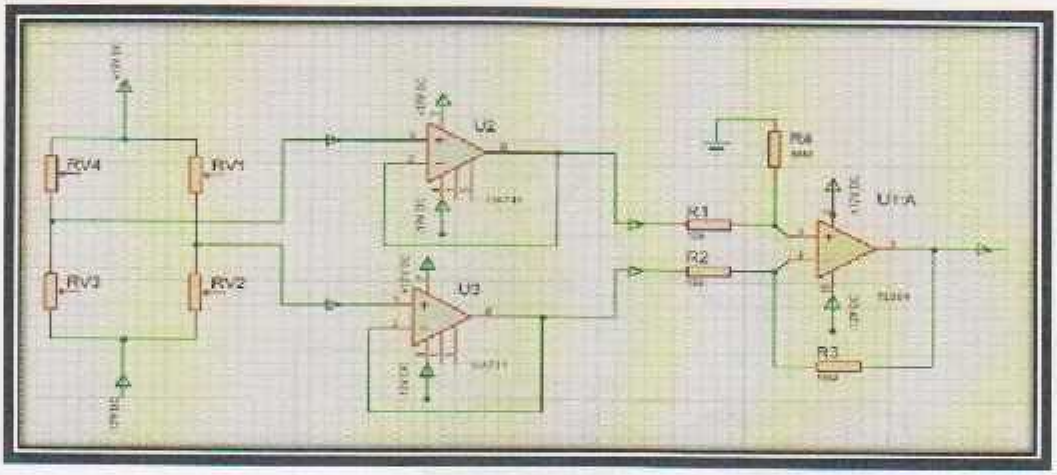


Figure 5.2: Load cell connection.

The load cell reading determines the point at which the lifting system must stop.

5.3 Angle Reading.

The angular potentiometer is connected directly to the microcontroller in ANO (Pin # 2 in PIC) as shown in figure 2.3.

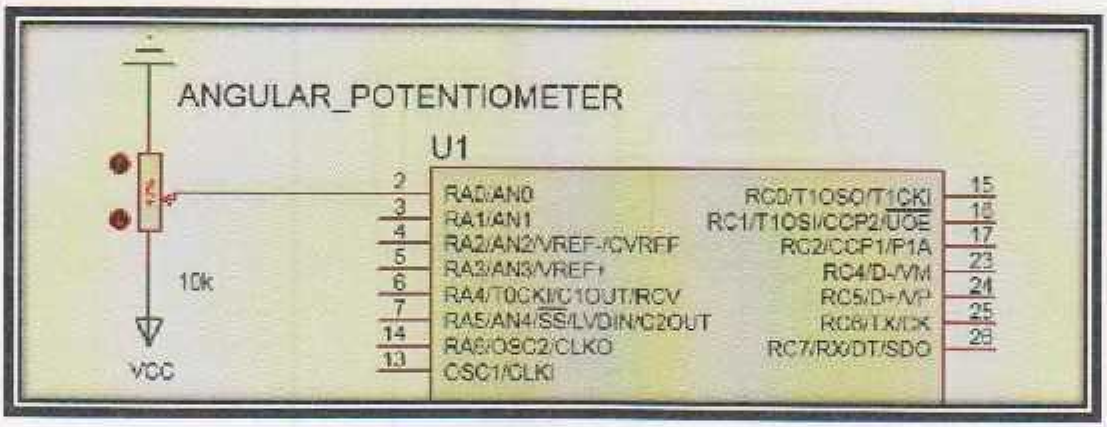
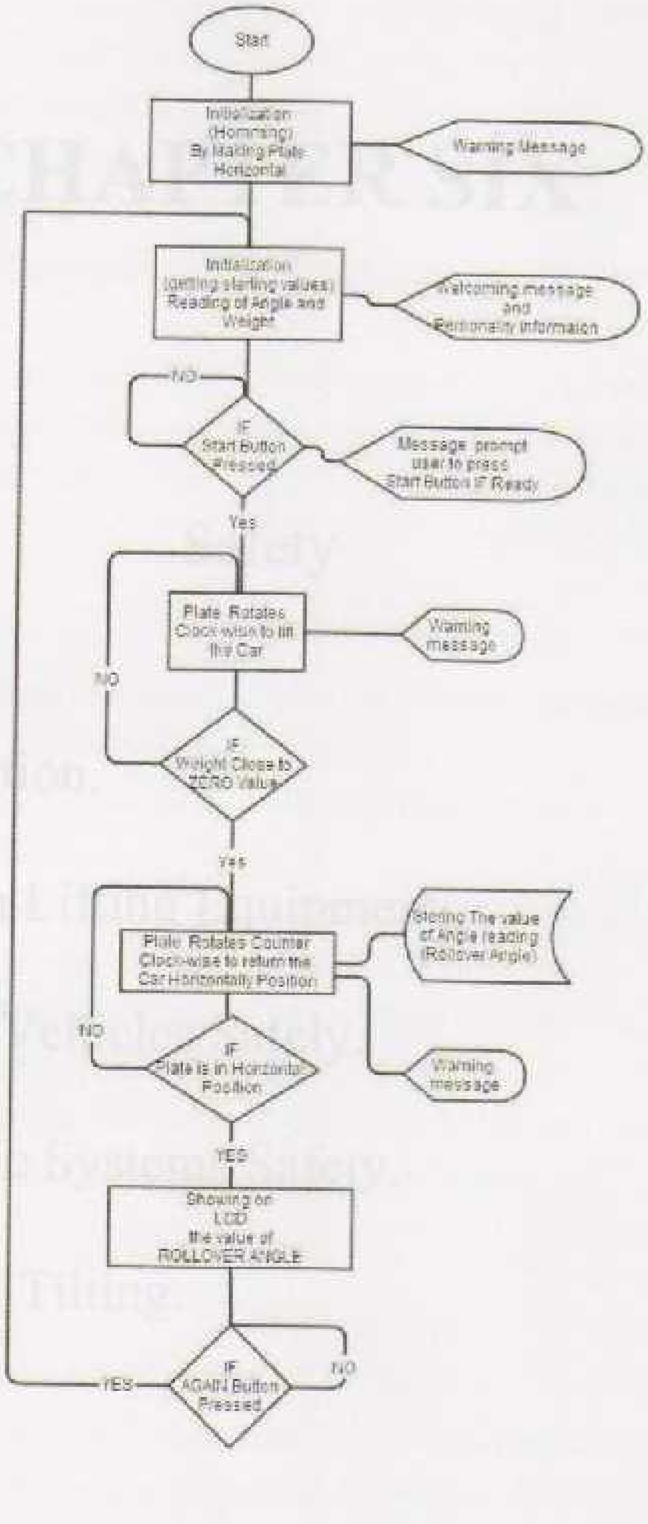


Figure 5.3: potentiometer connection.

When the microcontroller decides that the lifting option must stop, it takes the reading of the potentiometer, and process it then displays it on the LCD as the rollover angle.

5.4 Flow Chart.



CHAPTER SIX

Safety

6.1 Introduction.

6.2 Safety in Lifting Equipment.

6.3 Moving Vehicles Safely.

6.4 Hydraulic Systems Safety.

6.5 Safety in Tilting.

1.1 Introduction

Successful health and safety management in small engineering workshops is about identifying the most frequent and possible risks and adopting the right precautions, taking into account time, money, and resources.

6.2 Safety in Lifting Equipment.

Although lifting, supporting and handling equipment can lighten the load of manual handling when properly used, many accidents happen when loads are dropped from lifting equipment, either because of poor slinging, or equipment failure or overloading. [6]

Always:

1. Maintain all lifting equipment, including that used only occasionally, such as attachments to fork lift trucks.
2. Train all users, particularly in the use of slings where necessary.
3. Plan lifts in advance.
4. Ensure that the weight and the distribution of any load is not beyond the capacity of the equipment being used.
5. Provide safe places of work from which to maintain hoists and lifts, particularly at heights.
6. Check the condition, type and size of any eyebolts used and ensure that the thread type matches the hole into which it is to be screwed.

6.3 Moving vehicles safely.

Lorries, vans, cars and other vehicles and mobile plant are involved in many accidents, when reversing and maneuvering in or around small workshops. These accidents cause injuries and occasionally deaths when victims are run over or crushed. [6]

To reduce risks:

1. Identify and clearly mark safe routes and locations for deliveries and dispatches which are:
    - Away from pedestrians as much as possible.
    - In good condition.
    - Well lit at all times when being used.
    - Away from vulnerable plant.
    - Marked clearly with suitably low speed limits.
2. Provide loading bays with an exit from low level or a refuge to prevent crushing.
3. Do not allow untrained drivers to drive vehicles.
4. Avoid reversing (eg by suitable traffic routing for example) or provide help for reversing drivers if possible (eg a guide).
5. Use speed bumps to limit traffic speeds where necessary and make sure there are gaps for any lift trucks which have to cross them.
6. Select and train your own drivers with care.

6.4 Hydraulic Systems Safety.

Hydraulic systems are popular on many types of equipment because they reduce the need for complex mechanical linkages and allow remote control of numerous operations. Hydraulic systems are used to lift implements; to change the position of implement components; to operate remote hydraulic motors; and to assist steering and braking. [7]

Many systems store hydraulic energy in accumulators. These accumulators are designed to store oil under pressure when the hydraulic pump cannot keep up with demand, when the engine is shut down, or when the hydraulic pump malfunctions. Even though the pump may be stopped or an implement disconnected, the system is still under pressure. To work on the system safely, relieve the pressure first. [7]

6.4.1 Pinhole Leak Injuries

Probably the most common injury associated with hydraulic systems is the result of pinhole leaks in hoses. These leaks are difficult to locate. A person may notice a damp, oily, dirty place near a hydraulic line. Not seeing the leak, the person runs a hand or finger along the line to find it. When the pinhole is reached, the fluid can be injected into the skin as if from a hypodermic syringe. [7]

Immediately after the injection, the person experiences only a slight stinging sensation and may not think much about it. Several hours later, however, the wound begins to throb and severe pain begins. By the time a doctor is seen, it is often too late, and the individual loses a finger or entire arm.
Unfortunately, this kind of accident is not uncommon. To reduce the chances of this type of injury, run a piece of wood or cardboard along the hose (rather than fingers) to detect the leak (see Figure 6.1). [7]

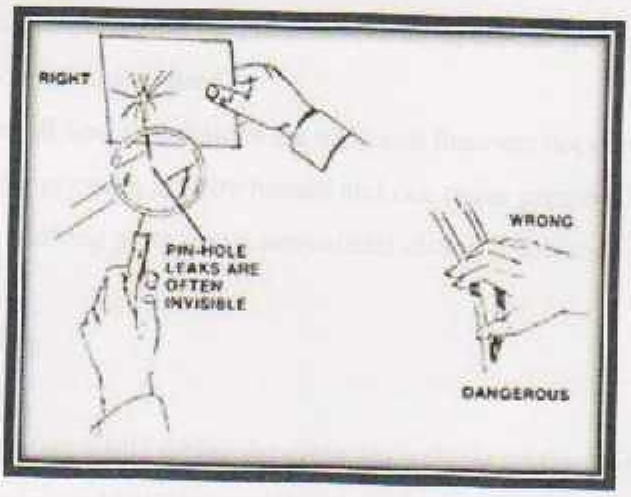


Figure 6.1 Pinhole Leak. [7]

6.4.2 Improper Coupling

An improperly maintained hydraulic system can lead to component failures. Safe hydraulic system performance requires general maintenance. [7]

- Periodically check for oil leaks and worn hoses.
- Keep contaminants from hydraulic oil and replace filters periodically.
- Coat cylinder rods with protective lubricants to avoid rusting.

6.4.3 Tips for Safe Operation

Follow these rules for safe hydraulics operation:

- Always lower the hydraulic working units to the ground before leaving the machine.
- Block up the working units when you must work on the system while raised; do not rely on the hydraulic lift.
- Never service the hydraulic system while the machine engine is running unless absolutely necessary (bleeding the system).
- Do not remove cylinders until the working units are resting on the ground or securely on safety stands or blocks; shut off the engine.
- Before disconnecting oil lines, relieve all hydraulic pressure and discharge the accumulator (if used).
- Be sure all line connections are tight and lines are not damaged; escaping oil under pressure is a fire hazard and can cause personal injury.
- When washing parts, use a nonvolatile cleaning solvent.

6.5 Safety in Tilting

To insure the safety while tilting the table, the vehicle on the table is going to be connected with the ground to make sure that the vehicle will not rollover.

CHAPTER SEVEN

Prototype

7.1 Introduction.

7.2 Hardwar Change.

7.1 Introduction

A prototype is an early sample, model or release of a product built to test a concept or process or to act as a thing to be replicated or learned from. It is a term used in a variety of contexts, including semantics, design, electronics, and software programming. A prototype is designed to test and trial a new design to enhance precision by system analysts and users. Prototyping serves to provide specifications for a real, working system rather than a theoretical one. [8]

7.2 Hardware Change.

Prototyping in this project is done on the hardware only, and the software remains almost the same.

First the body of the prototype is made of steel structure with smaller scale, as shown in figure 7.1.

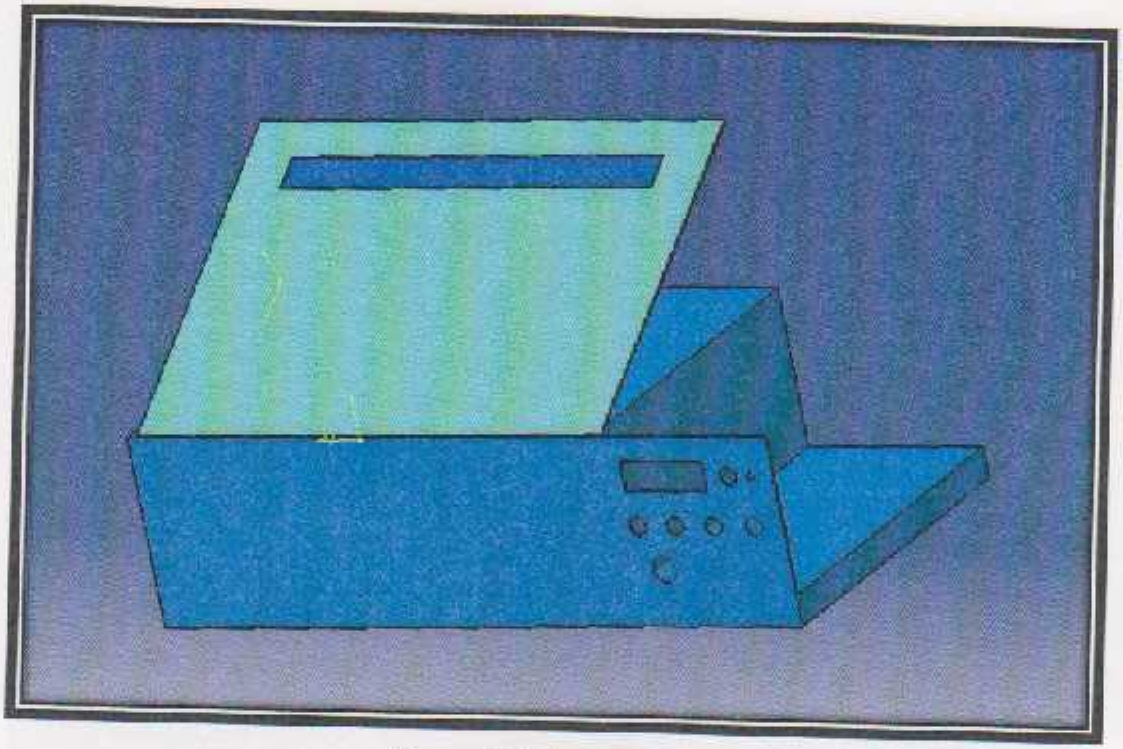
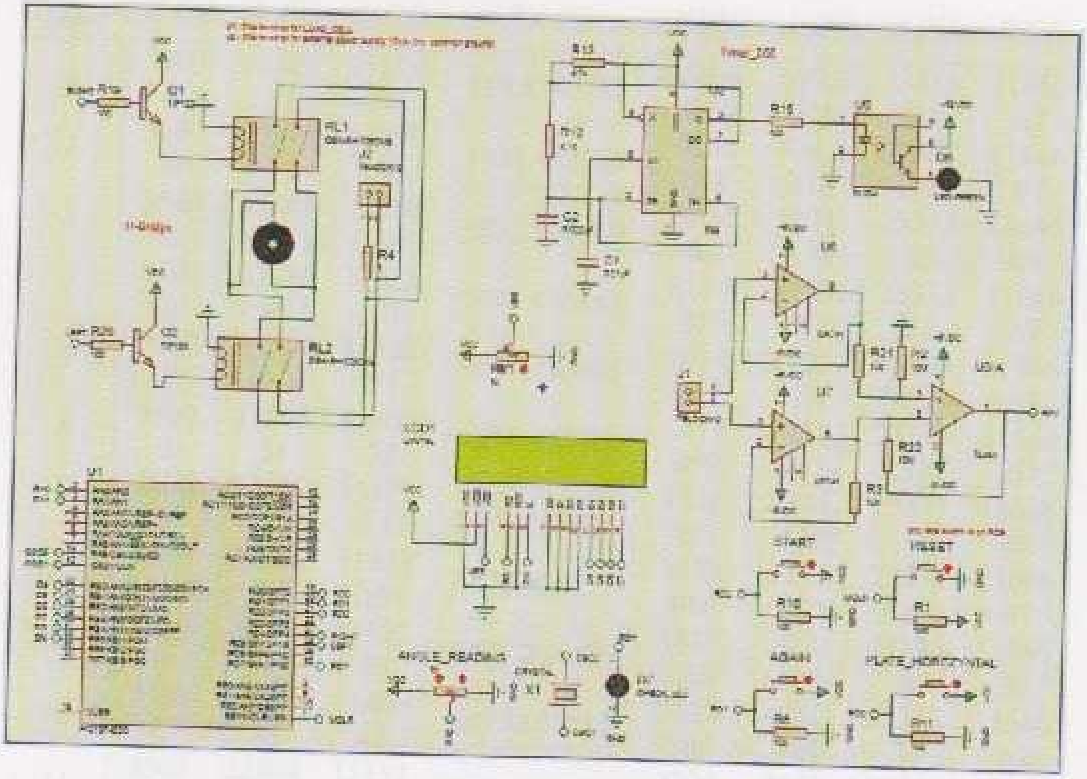


Figure 7.1: Prototype.

Second, lifting system used in the prototype is electrical system instead of hydraulic system, because it's more suitable for the prototype in size and cost.

Finally the software remains almost the same, with small change in the output signal and the number of load cells.

Appendix 1: Project CCT



Appendix 2: Load Analysis Table

φ (deg)	W (N)	Jy (N)	Ry(N)	Wx (N)	Rx(N)	Jx(N)	J (N)	R (N)
1	35000	23329.78	11664.89	610.8342253	203.6114	407.2228	23333.33	11666.67
2	35000	23319.12	11659.56	1221.482385	407.1608	814.3216	23333.33	11666.67
3	35000	23301.36	11650.68	1831.758469	610.5862	1221.172	23333.33	11666.67
4	35000	23276.49	11638.25	2441.476581	813.8255	1627.651	23333.33	11666.67
5	35000	23244.54	11622.27	3050.450996	1016.817	2033.634	23333.33	11666.67
6	35000	23205.51	11602.76	3658.496214	1219.499	2438.997	23333.33	11666.67
7	35000	23159.41	11579.71	4265.427019	1421.809	2843.618	23333.33	11666.67
8	35000	23106.25	11553.13	4871.058534	1623.686	3247.372	23333.33	11666.67
9	35000	23046.06	11523.03	5475.206276	1825.069	3650.138	23333.33	11666.67
10	35000	22978.85	11489.42	6077.686218	2025.895	4051.791	23333.33	11666.67
11	35000	22904.63	11452.32	6678.314838	2226.105	4452.21	23333.33	11666.67
12	35000	22823.44	11411.72	7276.909179	2425.636	4851.273	23333.33	11666.67
13	35000	22735.3	11367.65	7873.286902	2624.429	5248.858	23333.33	11666.67
14	35000	22640.23	11320.12	8467.266346	2822.422	5644.844	23333.33	11666.67
15	35000	22538.27	11269.13	9058.666579	3019.556	6039.111	23333.33	11666.67
16	35000	22429.44	11214.72	9647.307454	3215.769	6431.538	23333.33	11666.67
17	35000	22313.78	11156.89	10233.00967	3411.003	6822.006	23333.33	11666.67
18	35000	22191.32	11095.66	10815.5948	3605.198	7210.397	23333.33	11666.67
19	35000	22062.1	11031.05	11394.88541	3798.295	7596.59	23333.33	11666.67
20	35000	21926.16	10963.08	11970.70502	3990.235	7980.47	23333.33	11666.67
21	35000	21783.54	10891.77	12542.87823	4180.959	8361.919	23333.33	11666.67
22	35000	21634.29	10817.14	13111.23077	4370.41	8740.821	23333.33	11666.67
23	35000	21478.45	10739.22	13675.5895	4558.53	9117.06	23333.33	11666.67

24	35000	21316.06	10658.03	14235.78251	4745.261	9490.522	23333.33	11666.67
25	35000	21147.18	10573.59	14791.63916	4930.546	9861.093	23333.33	11666.67
26	35000	20971.86	10485.93	15342.99014	5114.33	10228.66	23333.33	11666.67
27	35000	20790.15	10395.08	15889.66749	5296.556	10593.11	23333.33	11666.67
28	35000	20602.11	10301.06	16431.5047	5477.168	10954.34	23333.33	11666.67
29	35000	20407.79	10203.9	16968.33671	5656.112	11312.22	23333.33	11666.67
30	35000	20207.26	10103.63	17500	5833.333	11666.67	23333.33	11666.67
31	35000	20000.57	10000.29	18026.33262	6008.778	12017.56	23333.33	11666.67
32	35000	19787.79	9893.894	18547.17425	6182.391	12364.78	23333.33	11666.67
33	35000	19568.98	9784.49	19062.36623	6354.122	12708.24	23333.33	11666.67
34	35000	19344.21	9672.105	19571.75162	6523.917	13047.83	23333.33	11666.67
35	35000	19113.55	9556.774	20075.17527	6691.725	13383.45	23333.33	11666.67
36	35000	18877.06	9438.532	20572.48383	6857.495	13714.99	23333.33	11666.67
37	35000	18634.83	9317.414	21063.52581	7021.175	14042.35	23333.33	11666.67
38	35000	18386.92	9193.459	21548.15164	7182.717	14365.43	23333.33	11666.67
39	35000	18133.41	9066.703	22026.21369	7342.071	14684.14	23333.33	11666.67
40	35000	17874.37	8937.185	22497.56634	7499.189	14998.38	23333.33	11666.67
41	35000	17609.89	8804.945	22962.06601	7654.022	15308.04	23333.33	11666.67
42	35000	17340.05	8670.023	23419.57122	7806.524	15613.05	23333.33	11666.67
43	35000	17064.92	8532.46	23869.9426	7956.648	15913.3	23333.33	11666.67
44	35000	16784.6	8392.298	24313.04297	8104.348	16208.7	23333.33	11666.67
45	35000	16499.16	8249.579	24748.73734	8249.579	16499.16	23333.33	11666.67
46	35000	16208.7	8104.348	25176.89301	8392.298	16784.6	23333.33	11666.67
47	35000	15913.3	7956.648	25597.37956	8532.46	17064.92	23333.33	11666.67
48	35000	15613.05	7806.524	26010.06889	8670.023	17340.05	23333.33	11666.67

49	35000	15308.04	7654.022	26414.83531	8804.945	17609.89	23333.33	11666.67
50	35000	14998.38	7499.189	26811.55551	8937.185	17874.37	23333.33	11666.67
51	35000	14684.14	7342.071	27200.10865	9066.703	18133.41	23333.33	11666.67
52	35000	14365.43	7182.717	27580.37638	9193.459	18386.92	23333.33	11666.67
53	35000	14042.35	7021.175	27952.24285	9317.414	18634.83	23333.33	11666.67
54	35000	13714.99	6857.495	28315.5948	9438.532	18877.06	23333.33	11666.67
55	35000	13383.45	6691.725	28670.32155	9556.774	19113.55	23333.33	11666.67
56	35000	13047.83	6523.917	29016.31504	9672.105	19344.21	23333.33	11666.67
57	35000	12708.24	6354.122	29353.46988	9784.49	19568.98	23333.33	11666.67
58	35000	12364.78	6182.391	29681.68337	9893.894	19787.79	23333.33	11666.67
59	35000	12017.56	6008.778	30000.85552	10000.29	20000.57	23333.33	11666.67
60	35000	11666.67	5833.333	30310.88913	10103.63	20207.26	23333.33	11666.67

Where φ is tilting angle, W: weight, J: reaction on the piston, R: reaction on joint,

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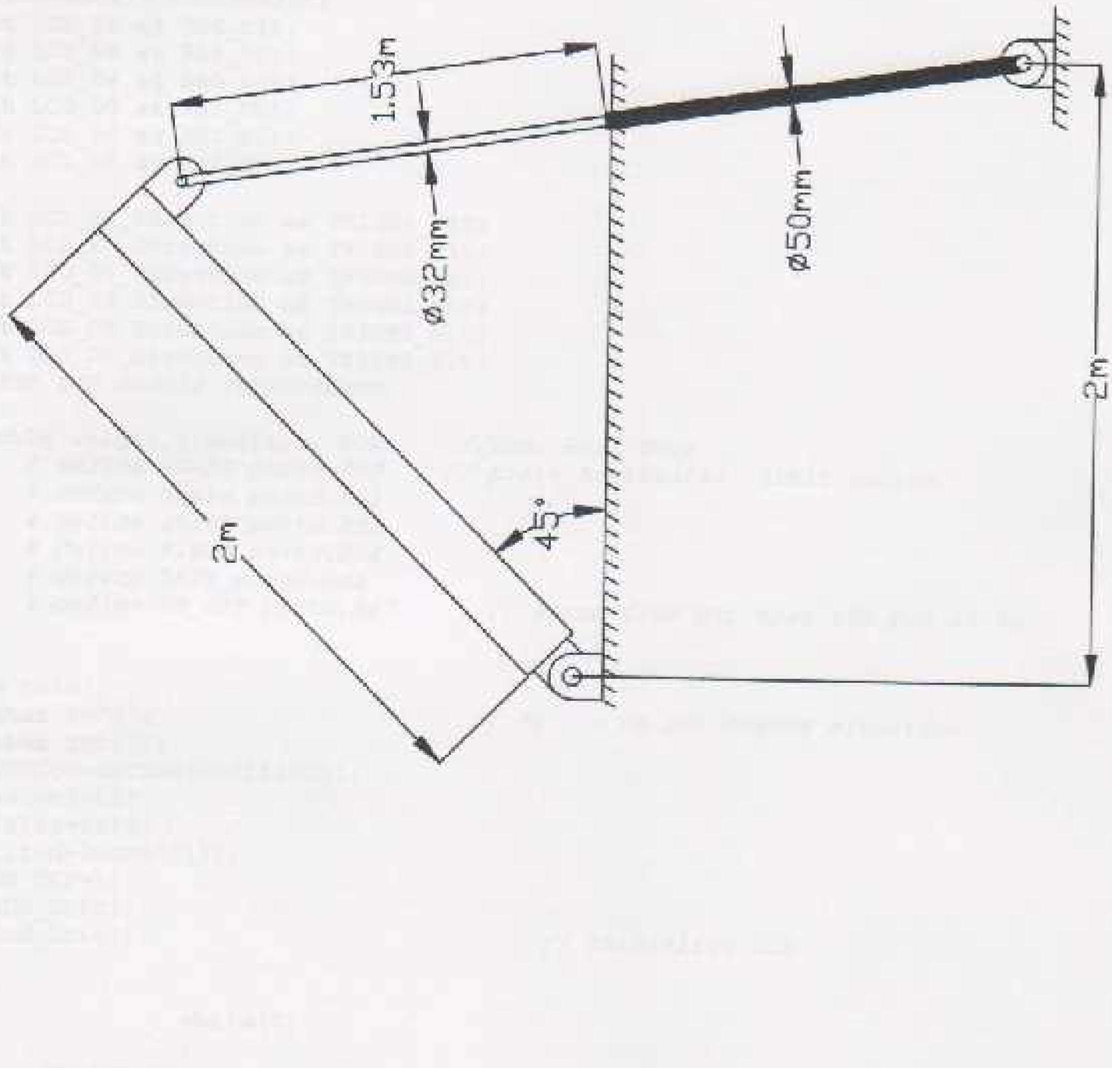

1.53m
Ø32mm
Ø50mm
2m
2m
45°

```
//////////////////////////////////////////////////////////////////////////////////////
/**********            TILT TABLE RATIO                  ***********************/
/**********  Palestine Polytechnich University           ***********************/
/**********   supervisoir : Eng. zuhair wazwaz          ***********************/
/**********    Project team:-                            ***********************/
/**********    Eng. Alqassam Awawdwh                     ***********************/
/**********    Eng. Muath Bassar                         ***********************/
/**********    Eng. Ashraf Alsahroof                     ***********************/
/******************************************************************************/
//////////////////////////////////////////////////////////////////////////////////////


// LCD module connections
sbit LCD_RS at RB4_bit;
sbit LCD_EN at RB5_bit;
sbit LCD_D4 at RB0_bit;
sbit LCD_D5 at RB1_bit;
sbit LCD_D6 at RB2_bit;
sbit LCD_D7 at RB3_bit;

sbit LCD_RS_Direction at TRISB4_bit;
sbit LCD_EN_Direction at TRISB5_bit;
sbit LCD_D4_Direction at TRISB0_bit;
sbit LCD_D5_Direction at TRISB1_bit;
sbit LCD_D6_Direction at TRISB2_bit;
sbit LCD_D7_Direction at TRISB3_bit;
// End LCD module connections

 double weight,j,angle,k, ROA;      //ROA: Roll Over
     # define PL_HZ portd.Rd0      // plate horizental  limit switch
     # define again portd.Rd1
     # define start portd.Rd2
     # define RIGHT portd.Rd4
     # define LEFT portd.Rd5
     # define ON_OFF portd.Rd7          // signe from pic that the pic is on


void main() {
   char c='H';                         // 'H' :- to set homing situation
   char txt[7];
   OSCCON=OSCCON|0b01110011;
   adcon1=13;
   trisa=0xff;
   trisd=0b00001111;
   ON_OFF=1;
   ADC_Init();
   Lcd_Init();                              // Initialize LCD


               while(1)
               {
       switch(c){

   case 'H':
   {
  Lcd_Cmd(_LCD_CLEAR);                 // Clear display
  Lcd_Cmd(_LCD_CURSOR_OFF);            // Cursor off
  Lcd_Out(1,5,"Warnning ");
```

```
   Delay_ms(10);

   Lcd_Out(2,2,"HOMMING");
     Delay_ms(1000);
       LEFT=1;
       while(!PB_R2);
       LEFT=0;
        Lcd_Cmd(_LCD_CLEAR);                 // Clear display
   Lcd_Cmd(_LCD_CURSOR_OFF);            // Cursor off
   Lcd_Out(1,2,"READY:HOMMING");
   Delay_ms(10);

   Lcd_Out(2,5,"has Done");
     Delay_ms(1000);
       }
    case 0:
   {
  Lcd_Cmd(_LCD_CLEAR);                 // Clear display
   Lcd_Cmd(_LCD_CURSOR_OFF);             // Cursor off
   Lcd_Out(1,1,"palestine poly.");
   Delay_ms(10);

   Lcd_Out(2,1," university");
     Delay_ms(1000);
     Lcd_Cmd(_LCD_CLEAR);               // Clear display

   Lcd_Out(1,1,"TILT TABLE");
   Delay_ms(10);

   Lcd_Out(2,1,"Ratio TEST ");
     Delay_ms(2000);
     Lcd_Cmd(_LCD_CLEAR);             // Clear display

     Lcd_Out(1,1,"  supervisoir ");
   Delay_ms(2000);

      Lcd_Cmd(_LCD_CLEAR);            // Clear display

     Lcd_Out(1,1,"Eng.");
   Delay_ms(10);

   Lcd_Out(2,1," Zuhair Wazwaz");
     Delay_ms(2000);


      Lcd_Cmd(_LCD_CLEAR);            // Clear display

     Lcd_Out(1,1,"student's names");
   Delay_ms(2000);

      Lcd_Cmd(_LCD_CLEAR);            // Clear display

     Lcd_Out(1,1,"Eng. Alqassam ");
   Delay_ms(10);

   Lcd_Out(2,6,"Awwawdeh");
     Delay_ms(2000);
```

```
   Lcd_Cmd(_LCD_CLEAR);            // Clear display

  Lcd_Out(1,1,"Eng.");
Delay_ms(10);

Lcd_Out(2,4," Muath Nassar");
  Delay_ms(2000);

               Lcd_Cmd(_LCD_CLEAR);            // Clear display

  Lcd_Out(1,1,"Eng.  ");
Delay_ms(10);

Lcd_Out(2,1,"Ashraf Alshareef");
  Delay_ms(2000);

   Lcd_Cmd(_LCD_CLEAR);            // Clear display
       c=1;
       }

       case 1:
       {
  Lcd_Out(1,1," First step ");
Delay_ms(10);

Lcd_Out(2,1,"Put Car on Table");
  Delay_ms(2000);

   Lcd_Cmd(_LCD_CLEAR);            // Clear display

  Lcd_Out(1,3," IF Ready ");
Delay_ms(10);

Lcd_Out(2,3,"Press Start");
  Delay_ms(1000);
  while(!start);
  c=2;
  }
  break;

     //  !while(!start);
       case 2:
       {
          Lcd_Cmd(_LCD_CLEAR);            // Clear display

  Lcd_Out(1,3," Now Be  ");
Delay_ms(10);

Lcd_Out(2,3," Careful");
  Delay_ms(500);
          Lcd_Cmd(_LCD_CLEAR);            // Clear display
  Lcd_Out(1,3," Now Be  ");
Delay_ms(10);

Lcd_Out(2,3," Careful");
  Delay_ms(500);
          Lcd_Cmd(_LCD_CLEAR);            // Clear display
  Lcd_Out(1,3," Now Be  ");
```

```
Delay_ms(10);

Lcd_Out(2,3," Careful");
  Delay_ms(500);
        c=3;}
        break;
        case 3:
        {
   j=0;k=0;
  j = ADC_Read(0);
           angle=(j/3.3);

           k= ADC_Read(1);
           weight=(k/0.54)-260;

   IntToStr(angle, txt);

         Lcd_Cmd(_LCD_CLEAR);            // Clear display
   Lcd_Out(1, 1,"angle");
   Lcd_Out(1, 8,txt);
  /*IntToStr(weight, txt);
   Lcd_Out(2, 1,"weight ");
   Lcd_Out(2, 8,txt);*/
         c=4;
         }
         break;
         case 4:   // move as Lift / Rising
         {
   RIGHT=1;
  while(k > 140)
  {
 //  j=0;k=0;

          j = ADC_Read(0);
          angle=(j/3.3);

          k= ADC_Read(1);
          weight=(k/0.54)-180;
          weight=k;


   IntToStr(angle, txt);
   Lcd_Out(1, 8,txt);
   IntToStr(weight, txt);
   Lcd_Out(2, 8,txt);
   }
   RIGHT=0;
         c=5;
         }
         break;
         case 5:
         {                          // returnning to home position
  RIGHT=0;
  ROA=angle;
         Lcd_Cmd(_LCD_CLEAR);           // Clear display

 Lcd_Out(1,3," Now Be  ");
Delay_ms(10);
```

```
Lcd_Out(2,3," Careful");
  Delay_ms(800);

          Lcd_Cmd(_LCD_CLEAR);          // Clear display

  Lcd_Out(1,1," The plate  ");
Delay_ms(10);

Lcd_Out(2,3," Will Return");
  Delay_ms(500);

          Lcd_Cmd(_LCD_CLEAR);          // Clear display

  Lcd_Out(1,1," The plate  ");
Delay_ms(10);

Lcd_Out(2,3," Will Return");
  Delay_ms(500);

    LEFT=1;
    while(!PL_HZ);
    LEFT=0;
             Lcd_Cmd(_LCD_CLEAR);          // Clear display
            c= 6;}
                 break;
                 case 6:
                 {
    IntToStr(ROA, txt);
    Lcd_Out(1, 1,"THE ROLLOVER angle");
    Lcd_Out(2, 0,txt);
    Lcd_Out(2, 8,"degree");
    c=7;
    }
    break;
    case 7:
     {while(!again);
     c=1;
     }
     break;
     }
                 }
}
```