Palestine Polytechnic University

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Graduation Project

Smart Conveyor

Project Team

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Abstract

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This project is a complete design of a conveyor system which used usually in material handling, this system works depending on AC motor and gears for moving the belt and the materials on it, also it depends on a DC motor for controlling the variable angle to transmit the material to the needed position.

Mostly, the conveyors that used for material handling in the market although it is expensive it is manually position control which need time and power, so it is important to built this system in order to save the time and the power also.

This project is arranged in four chapters , the first one contains the most kinds of conveyors are used and introduction of all over the ideas in brief description to the project .

The second chapter provides ideas of mechanical design and analysis of the mechanical component in the project such as column, and beams.

The third chapter contains the electrical system and it is main component that will be used in this system such as DC motor, AC motor, and PLC device.

The last chapter will provide some information about the control system in the project such as the position control, and programmable logic control

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Chapter One
Introduction

1.1 Overview

Conveyors are used when material must be moved in relatively large quantities between specific locations over a fixed path. The fixed path is implemented by a tack system, which may be in-the-floor, above-the-floor. conveyors divided into two basic categories (1) powered and (2) non-powered. In powered conveyors, the power mechanism is contained in the fixed path, using chains, belt, rotating rolls, or other device to load along the path. Powered conveyors are commonly used in automated material transport systems in manufacturing plants, and distribution center. In non-powered conveyors, materials are moved either manually by human workers who push the loads along the fixed path or by gravity from one elevation to a lower elevation [1].

1.2 Types of conveyors

A variety of conveyor equipment is commercially available. In the following paragraphs, we will describe the major types of powered conveyors, organized according to the type of mechanical power provided in the fixed path [1].

1-roller and Skate wheel conveyor: these conveyors have rolls or wheels on which the loads ride. Loads must possess a flat bottom surface of sufficient area to span several adjacent rollers. Pallets, tote pans, or carton serve this purpose well.

In roller conveyors, the pathway consists of a series of tubes (rollers) that are perpendicular to the direction of travel, as in figure1.1 (a). The rollers are contained in a fixed frame that elevates the path above floor level from several inches to several feet. Flat pallets or tote carrying unit loads are moved forward as the rollers rotate. Roller conveyors can either be powered or non-powered. Powered roller conveyors are driven by belts or chains. Non-powered conveyors are often driven by gravity so that the pathways has downward slope sufficient to overcome rolling friction. Roller conveyors are used in a wide variety of applications, including manufacturing, assembly, packaging, sortation, and distribution [1].

Skate-wheel conveyors are similar in operation to roller conveyors. Insted of rollers, they use skate wheels rotating on shafts connected to a frame to roll pallets or tote pans or other containers along the pathway, as in figure1.1 (b).This provides the skate wheel conveyor with a lighter weight construction than the roller conveyor. Application of skate-wheel conveyors are similar to those of roller conveyors, expect that the loads must generally be lighter since the contacts between the load and the conveyor are much more concentared. Because of their light weight, skate wheel conveyors are some times built as portable equipment that can be used for loading and unloading [1].

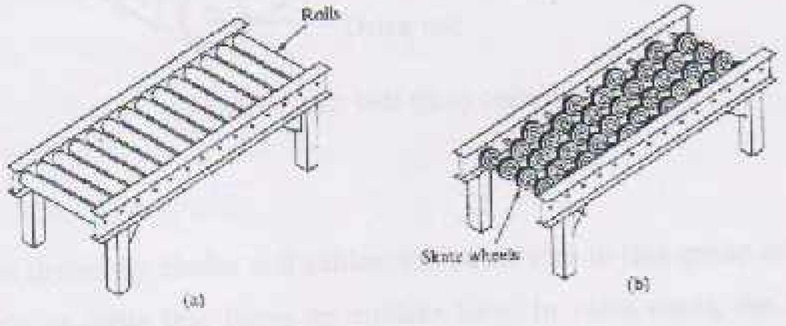


Figure (1.1): (a) roller (b) skate wheel conveyor

2-belt conveyors: belt conveyors consist of a continuous loop: half its length is used or delivering materials, and the other half is the return run, as in figure1.2.The belt is made of reinforced elastomer (rubber), so that it possesses high flexibility but low extensibility. At one end of the conveyor is a drive roll that powers the belt. The flexible belt is supported by a frame that has rollers or support sliders along its forward loop.

Belt conveyors are available in two common forms: (1) flat belts for pallets, individual parts, or even certain types of bulk materials; and (2) troughed belts for bulk materials. Materials placed on the belt surface travel along the moving pathway [1].

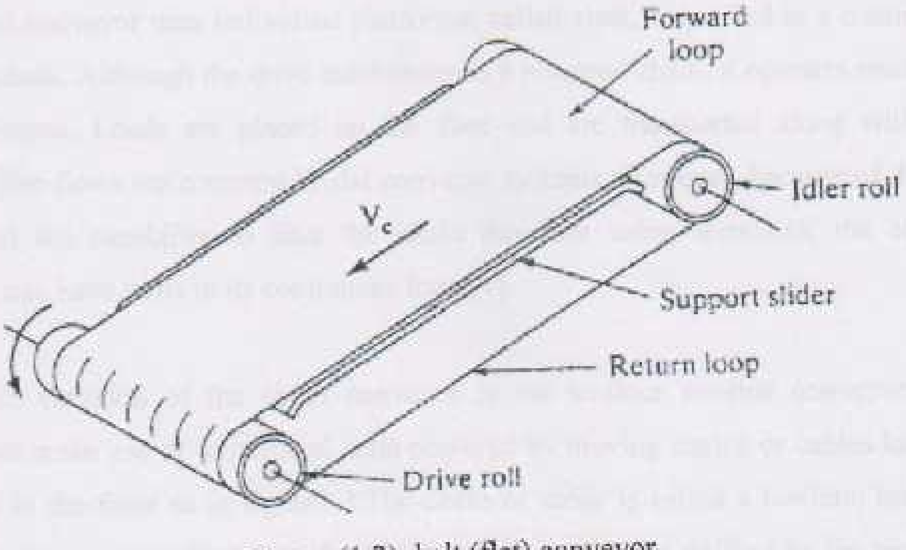


Figure (1.2): belt (flat) conveyor

3-conveyors driven by chains and cables: the conveyors in this group are driven by a powered chain or cable that forms an endless loop. In some cases, the loop forms a straight line, which a pulley at each end. This is usually in an over-and-under configuration. In other conveyors, the loop has a more-complex path, with more than tow pulleys needed to define the shape of the path. Also it has the following conveyors in this category:

Chain conveyors consist of chain loops in an over-and-under configuration around powered sprockets at the ends of the pathway. One or more chains operating in parallel may be used to form the conveyor. The chains travel along channels in the floor that provide support for the flexible chain sections. Either the chains slide along the channel or they ride on rollers in the channel. The loads are generally dragged along the pathway using bars that project up from the moving chain.

The slat conveyor uses individual platforms, called slats, connected to a continuously moving chain. Although the drive mechanism is a powered chain, it operates much like a belt conveyor. Loads are placed on the slats and are transported along with them. Straight line flows are common in slat conveyor systems. However, because of the chain drive and the capability to alter the chain direction using sprockets, the conveyor pathway can have turns in its continuous loop [1].

Another variation of the chain conveyor is the in-floor towline conveyor. These conveyors make use of four-wheel carts powered by moving chains or cables located in trenches in the floor as in figure1.*3*.The chain or cable is called a towline; hence, the name of the conveyor. Pathways for the conveyor system are defined by the trench and cable, and the cable is driven as a powered pulley system. Switching between powered pathways is possible in a towline system to achieve flexibility in routing. The carts use steel pins that project below floor level into the trench to engage the chain for towing. (Gripper devices are substituted for pins when cable is used as the pulley system).The pin can be pulled out of the chain (or the gripper releases the cable) to disengage the cart for loading, unloading, switching, accumulating of parts, and manually pushing a cart off the main pathway. Towline conveyor systems are used in manufacturing plants.

All of the preceding chain and cable drive conveyors operate at floor level or slightly above. Chain –drive conveyors can also be designed to operate overhead, suspended from the ceiling of the facility so as not to consume floor space. The most common types are overhead trolley conveyors. These are available either as constant speed (synchronous) or as power-and-free (asynchronous) systems.

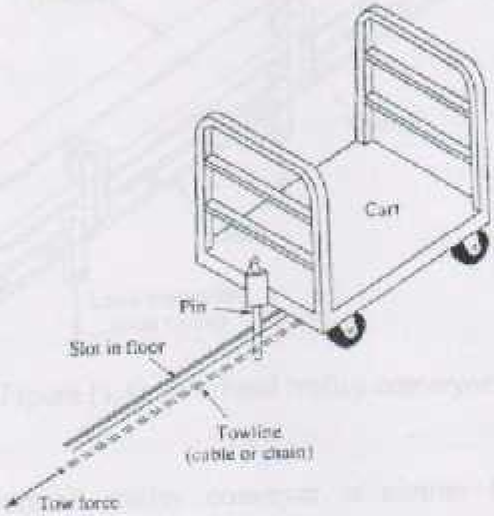


Figure (1.3): in-floor towline conveyor

A trolley in material handling is a wheeled carriage running on an overhead rail from which loads can be suspended. *An* overhead trolley conveyor as in *figure1.4* consists of multiple trolleys, usually equally space along fixed track. The trolleys are connected together and moved along the track by means of a chain or a cable that forms a complete loop that suspended from the trolleys are hooks, baskets, or other receptacles to carry loads. The chain or cable is attached to drive wheel that supplies power to move the chain at a constant velocity. The conveyor path is determined by the configuration of the track system, which has turns and possible changes in elevation. Overhead trolley conveyors are often used in factories to move parts and assemblies between major production departments. They can be used for both delivery and storage.

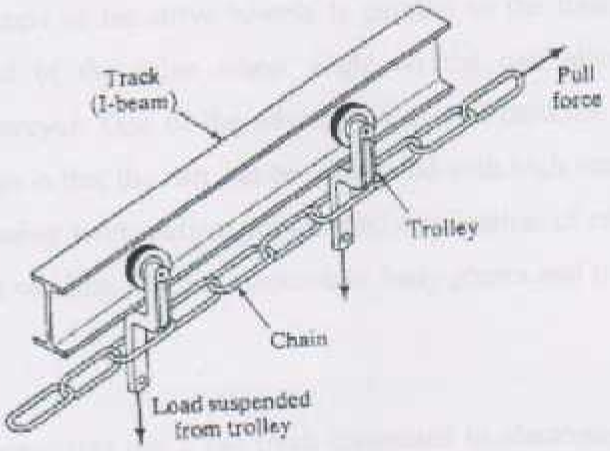


Figure (1.4): overhead trolley conveyor

A power-and-free overhead trolley conveyor is similar to the overhead trolley conveyor; expect that the trolleys are capable of being disconnected from the drive chain, providing this conveyor with an asynchronous capability. This is usually accomplished by using two tracks, one just above the other .The upper track contains the continuously moving endless chain, and the trolley that carry loads ride on the lower track. Each trolley includes mechanism by which it can be connected to the drive chain and disconnected from it. When connected, the trolley is pulled along its track by the moving chain in the upper track. When disconnected, the trolley is idle [1].

Other conveyor types: other powered conveyors include cart-on-track, screw, vibration-based systems, and vertical lift conveyors. Cart–on-track conveyors consist of individual carts riding on a track a few feet above floor level. The carts are driven by means of a rotating shaft as in *figure1.5*. A drive wheel, attached to the bottom of the cart and set at an angle to the rotating tube, rests against it and drive the cart forward. The cart speeds is controlled by regulating the angle of contact between the drive wheel and the spinning tube. When the axis of the drive wheel is 45°, the cart is propelled forward. When the axis of the drive wheels is parallel to the tube, the cart does not move. Thus, control of the drive wheel angle on the cart allows power-and-free operation of the conveyor. One of the advantages of cart-on-track systems relative to many other conveyors is that the cart can be positioned with high accuracy. This permits their use for positioning work during production. Application of cart-on-track-systems include robotic spot welding lines in automobile body plants and mechanical assembly systems [1].

Vibration-based conveyors use a flat track connected to electromagnet that impart an angular vibratory motion to the track to propel items in the desired direction. *Vertical lift conveyors* include a variety of mechanical elevators designed to provide vertical motion, such as between floors or to link floor-based conveyors with over head conveyors. Other conveyor types include a non-powered *chutes, ramps, and tubes,* which are driven by gravity.

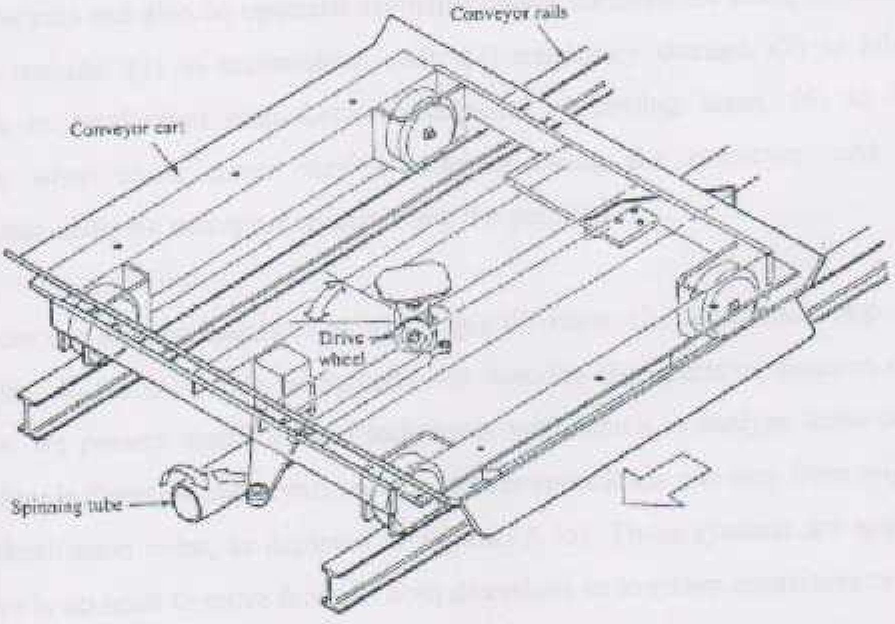


Figure (1.5): cart-on-track conveyor

1.3 Conveyor Operation and Features

As indicated by our preceding discussion, conveyor equipment covers a wide variety of operations and features. Let us restrict our discussion here to powered conveyors, excluding non-powered types. Conveyor systems divide into two basic types in terms of the characteristic motion of the materials moved by the system:
(1) Continuous and (2) asynchronous.

Continuous motion conveyors move at a constant velocity (Vc) along the path. They include belt, roller, skate-wheel, overhead trolley, and slat conveyors. Asynchronous conveyors operate with a stop-and-go motion in which loads, usually contained in carriers (e.g., hooks, baskets, and carts), move between stations and then stop and remain at the station until released. Asynchronous handling allows independent movement of each carrier in the system. Examples of this type include overhead power-and-free trolley, in-floor towline, and cart-on-track conveyors. Some roller and skate-wheel conveyors can also be operated asynchronously. Reasons for using asynchronous conveyors include: (1) to accumulate loads, (2) temporary storage, (3) to allow for differences in production rates between adjacent processing areas, (4) to smooth production when cycle times vary at stations along the conveyor, and (5) to accommodate different conveyor speeds along the pathway.

Conveyors can also be classified as: (1) single direction, (2) continuous loop, and (3) recirculating. In the following paragraphs, we describe the operating features of these categories. We present equations and techniques with which to analyze these conveyor systems. Single direction conveyors are used to transport loads one way from origination point to destination point, as depicted in *Figure1.6 (a)*. These systems are appropriate when there is no need to move loads in both directions or to return containers or carriers from the unloading stations back to the loading stations. Single direction powered conveyors include roller, skate wheel, belt, and chain-in-floor types. In addition, all gravity conveyors operate in one direction.

Continuous loop conveyors form a complete circuit, as in *Figure1.6 (b)*. An overhead trolley conveyor is an example of this conveyor type. However, any conveyor type can be configured as a loop, even those previously defined as single direction conveyors, simply by connecting several single direction conveyor sections into a closed loop. A continuous loop system allows materials to be moved between any two stations along the pathway. Continuous loop conveyors are used when loads are moved in carriers (e.g., hooks, baskets) between loads and unload stations and the carriers are affixed to the conveyor loop. In this design, the empty carriers are automatically returned from the unload station back to the load station.

The preceding description of a continuous loop conveyor assumes that items loaded at the load station are unloaded at the unload station. There are no loads in the return loop; the purpose of the return loop is simply to send the empty carriers back for reloading. This method of operation overlooks an important opportunity offered by a closed loop conveyor; to store as well as deliver parts. Conveyor systems that allow parts to remain on the return loop for one or more revolutions are called recalculating conveyors. In providing a storage function, the conveyor system can be used to accumulate parts to smooth out effects of loading and unloading variations at stations in the conveyor. There are two problems that can plague the operation of a recirculating conveyor system. One is that there may be times during the operation of the conveyor that no empty carriers are immediately available at the loading station when needed. The other problem is that no loaded carriers are immediately available at the unloading station when needed. It is possible to construct branching and merging points into a conveyor track to permit different routings for different loads moving in the system. In nearly all conveyor systems, it is possible to build switches, shuttles, or other mechanisms to achieve these alternate routings. In some systems, a push-pull mechanism or lift-and-carry device is required to actively move the load from the current pathway onto the new pathway [1].

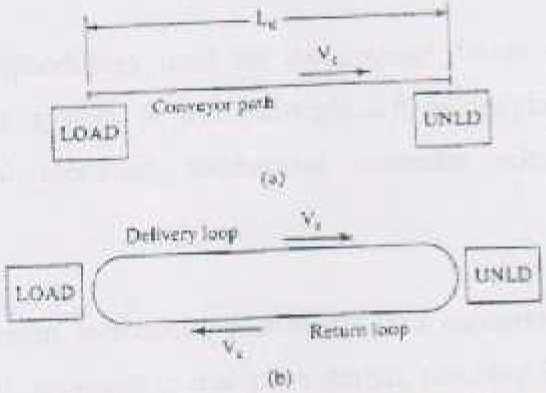


Figure (1.6): (a) single direction conveyor and (b) continuous loop conveyor

1.4 Aims of the project

This project aims to:

1- Design of the system and achieve optimization.
   Optimization can be achieved with best design and lowing cost.
2- The need of the market.
   We as a group did a visit to industrial placement in Hebron ,and we asked their a bout the project ,we also saw it is a very usefully project because they are need it for stone industrial ,and for another material handling like sugar, rise,…….etc
3- This project will be a basic stone in conveyor system manufacturing in Palestine.
   All of conveyor which used in local industrials it depends on importing from Israel or outside which it is a very expensive one ,and in our project we will give a a good manufacturing with acceptable cost.

1.5 The mechatronics design Approach

Mechatronics is a methodology used for the optimal design of electromechanical products; Mechatronics system is multi-disciplinary embodying four fundamental disciplines: electronical, electrical, mechanical, computer science and information technology.

The mechatronics design methodology is based in a concurrent design, instead of traditional or sequential, approach to discipline design, resulting in products with more synergy, this synergy is generated by the right combination of parameters so that this system design offers solutions to all problems in design.

1.5.1 The mechatronics design process

The process of mechatronics design starts with modeling, prototyping and deployment.

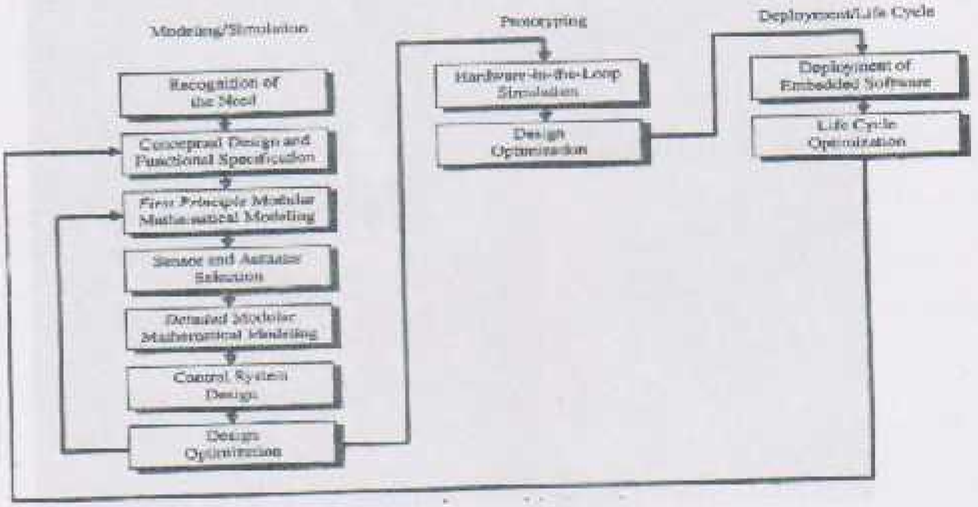


Figure (1.7): mechatronics design process

1.6 Conceptual design

Figure (1.8): conceptual design at $\theta = 0°$

Figure (1.9): conceptual design at $\theta = 40°$

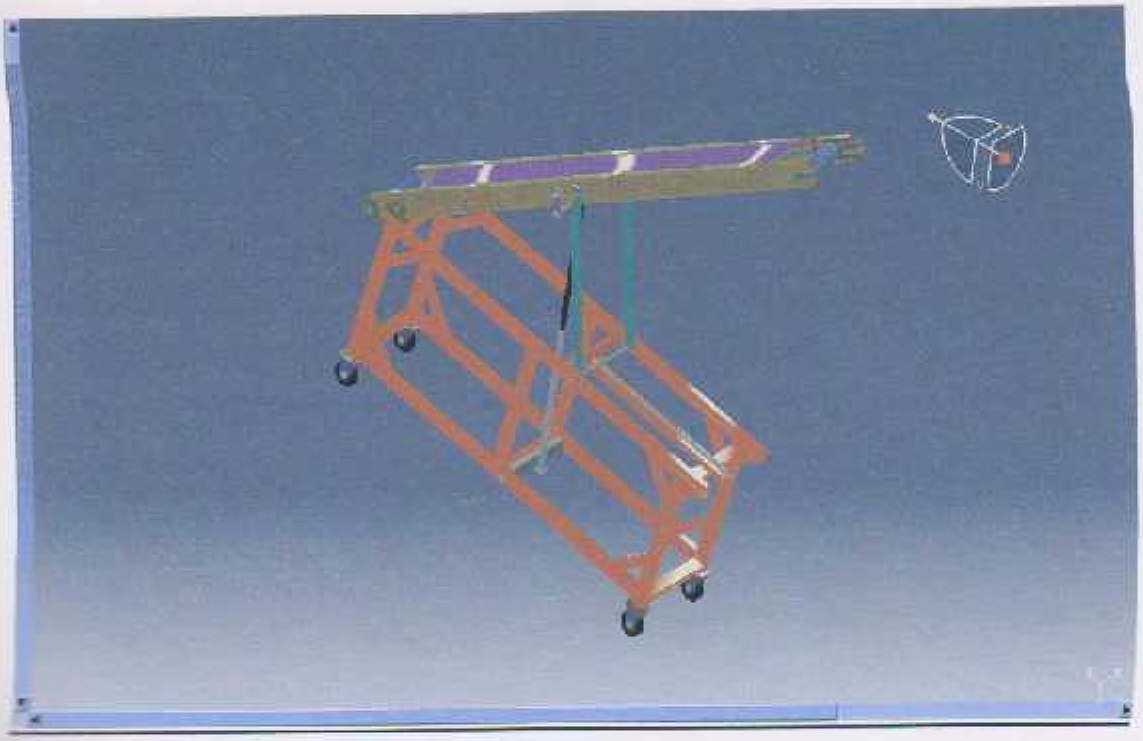


Figure (1.10): top view at $\theta = 40^\circ$

According to the introduction of the conveyor types, needs of the market, the conveyor will build of 3m length, and with controllable variable angles (θ) from 0 to 40°, by this length and the variable angles that will give a variety of moving materials, which means moving material from the ground to the truck, or from the ground to the first, and second floor, and that the market which needs exactly. Also the conveyor will be a belt conveyor type and that because the belt has good coefficient friction which help of no materials slipping also the belt has low cost. Also the conveyor will be a continuous motion conveyor type and has a constant velocity when traveling materials from one place to another. The conveyor will move vertically using screw mechanism, uses this mechanism because it has low cost compared with hydraulic system.

1.7 Scope of the project

This project includes the following chapters:

1- Chapter 1 includes the introduction of the project; the overview of the project, the conceptual design, and the mechanical elements.

2- Chapter 2 includes the mechanical design of the project, mathematical modeling and the reasons for choosing each of the elements specifications.

3- Chapters 3 & 4 include the motors AC and DC and it is specifications and the design of closed loop control circuit for angle controlling.

Chapter Two

System Analysis and Design

2.1 Introduction

This chapter explains the analysis of the system that includes the mechanical analysis which gives us the maximum load that acts on every column and beam, and this data will help for determining the cross section of every column and beams with help of the ANSYS program.

2.2 The physical laws that need in the analysis

2.2.1 Static laws

The static laws that needs for calculating the loads which acts on each beam or column which a special case of Newton second law (the acceleration = 0)

Newton second low $F = M.\ddot{X}$

1) Summation of the force in any direction equal zero

$\sum Fy = 0$

$\sum Fx = 0$

2) Summation of the moment at any point (x) equal zero

$\sum Mx = 0$

this distributed load for a 3m of length will be a single load in the middle with 4.5KN of it is magnitude.

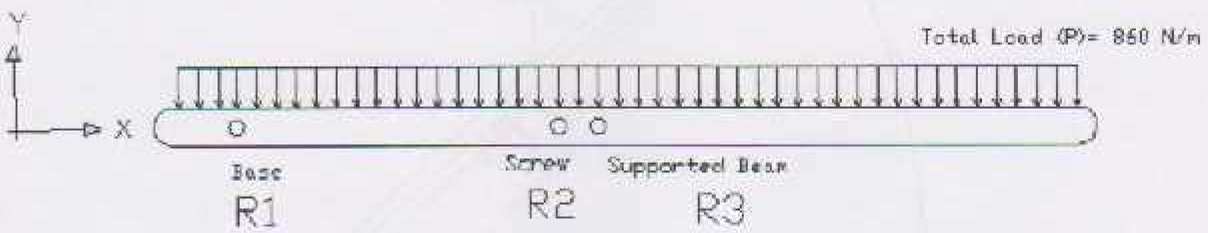


Figure (2.2): the distributed load and the reactions

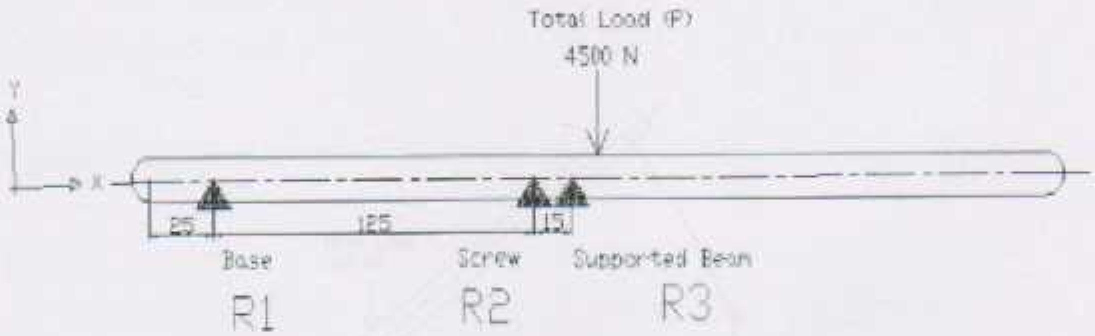


Figure (2.3): free body diagram at angle 0°

2.3.1 Analysis at maximum angle (θ=40)

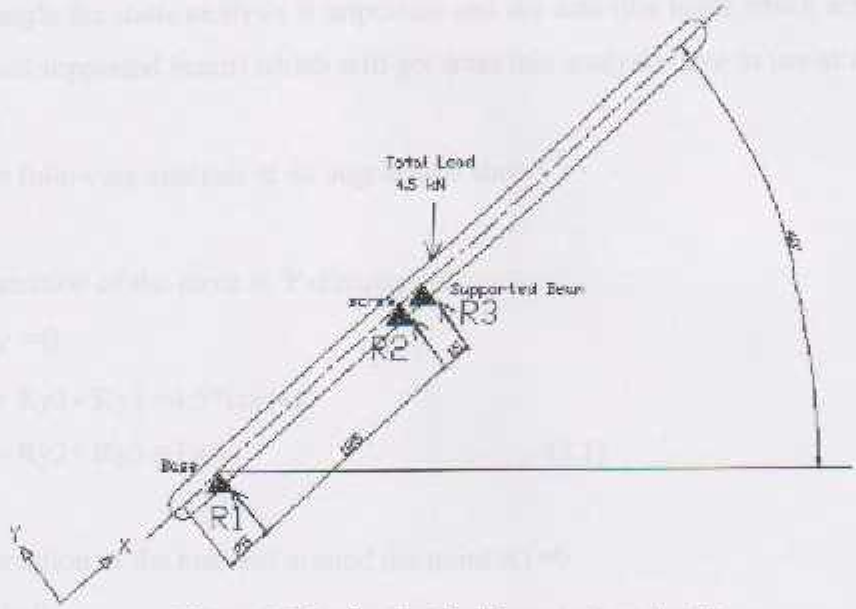


Figure (2.4): free body diagram at angle 40

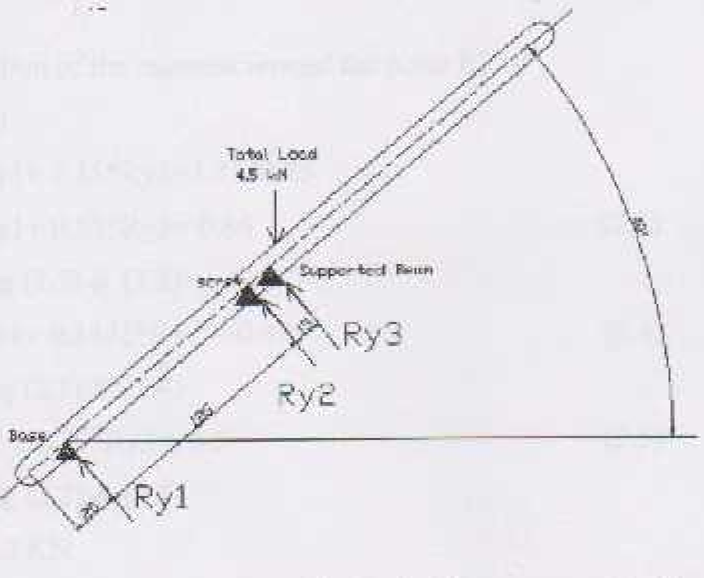


Figure (2.5): free body diagram at angle 40

From figure (2.5) the maximum angle that the conveyor can be raised is 40 degree, so for this angle the static analysis is important and the data (the loads which acts at base, screw, and supported beam) which will get from this analysis have to use at ANSYS analysis.

So, the following analysis at 40 degree will show:

The summation of the force in Y direction=0.

$\sum Fy = 0$

Ry1+ Ry2+ Ry3 =4.5*cos(40)

Ry1+ Ry2+ Ry3 =3.45 (2.1)

The summation of the moment around the point R1=0

$\sum M1 = 0$

1.25*Ry2+ 1.4*Ry3- 3.45*1.5 =0

1.25*Ry2+ 1.4*Ry3 =5.2 (2.2)

The summation of the moment around the point R2=0

$\sum M2 = 0$

-1.25*Ry1+ 0.15*Ry3=3.45*0.25

-1.25*Ry1+ 0.15*Ry3= 0.86 (2.3)

By summing (2.2) & (2.3)

1.75*Ry1+ 0.1875*Ry2= -0.42 (2.4)

By summing (2.1) & (2.4)

1.5*Ry2 + 1.75*Ry3 = 6.5 (2.5)

By summing (2.2) & (2.5)

Ry3 = 3.3 KN

Then,

Ry2 = 0.464 KN

Ry1= -0.314 K

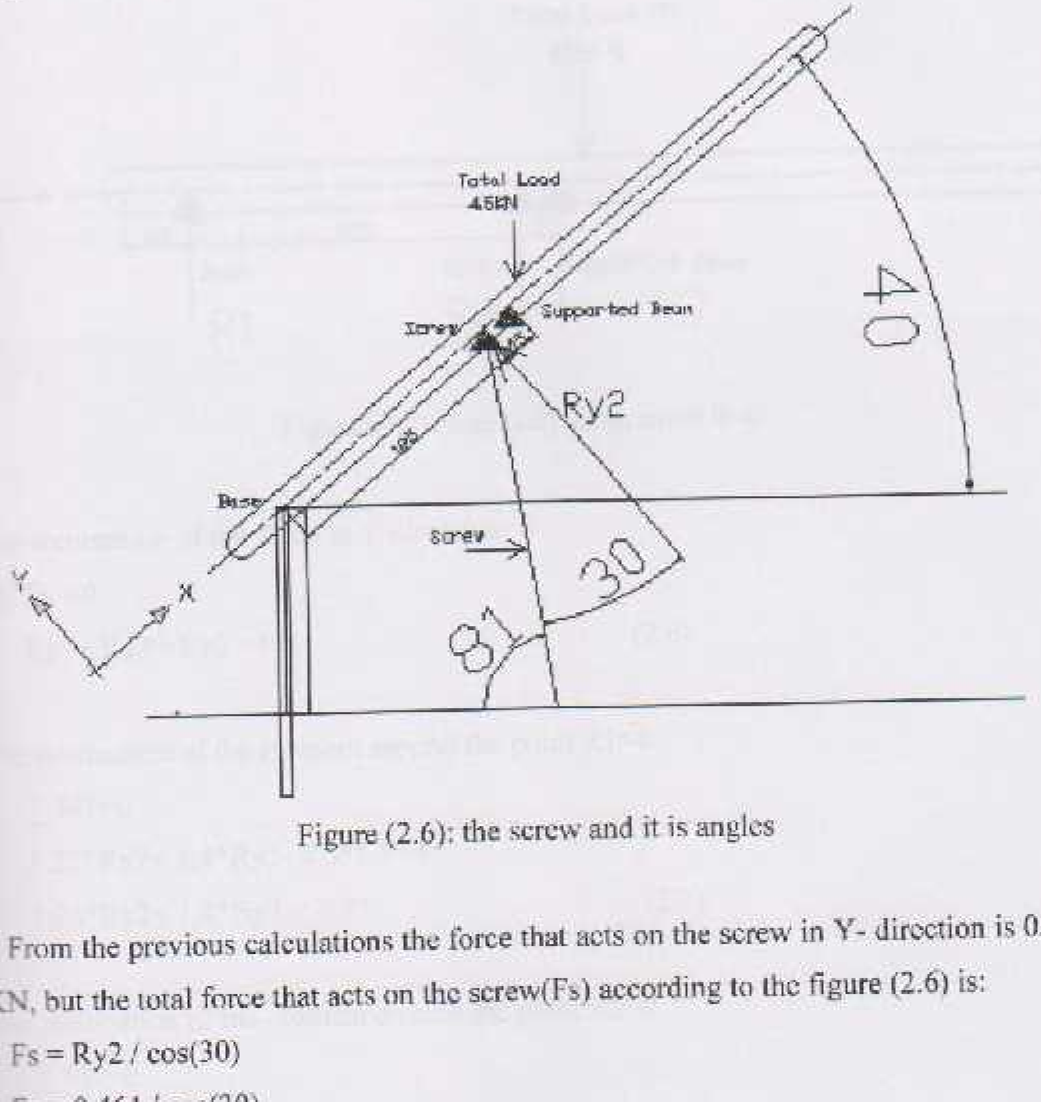


Figure (2.6): the screw and it is angles

From the previous calculations the force that acts on the screw in Y- direction is 0.464 KN, but the total force that acts on the screw(Fs) according to the figure (2.6) is:

Fs = Ry2 / cos(30)

Fs = 0.464 / cos(30)

Fs = 0.54 kN

2.3.2 Analysis at minimum angle ($\theta=0^\circ$)

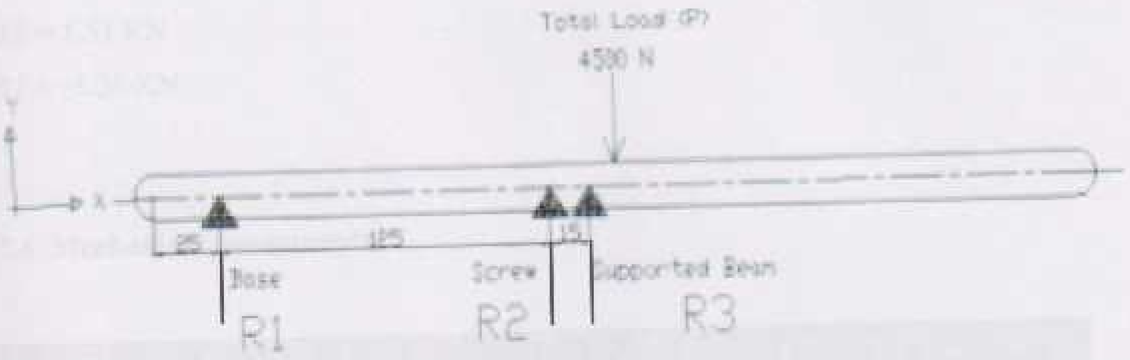


Figure (2.7): free body diagram at $\theta=0^\circ$

The summation of the force in Y direction=0

$\sum Fy=0$

$Ry1+Ry2+Ry3=4.5$ (2.6)

The summation of the moment around the point R1=0

$\sum M1=0$

$1.25*Ry2+1.4*Ry3-4.5*1.5=0$

$1.25*Ry2+1.4*Ry3=6.75$ (2.7)

The summation of the moment around the point R2=0

$\sum M2=0$

$-1.25*Ry1+0.15*Ry3=4.5*0.25$

$-1.25*Ry1+0.15*Ry3=1.125$ (2.8)

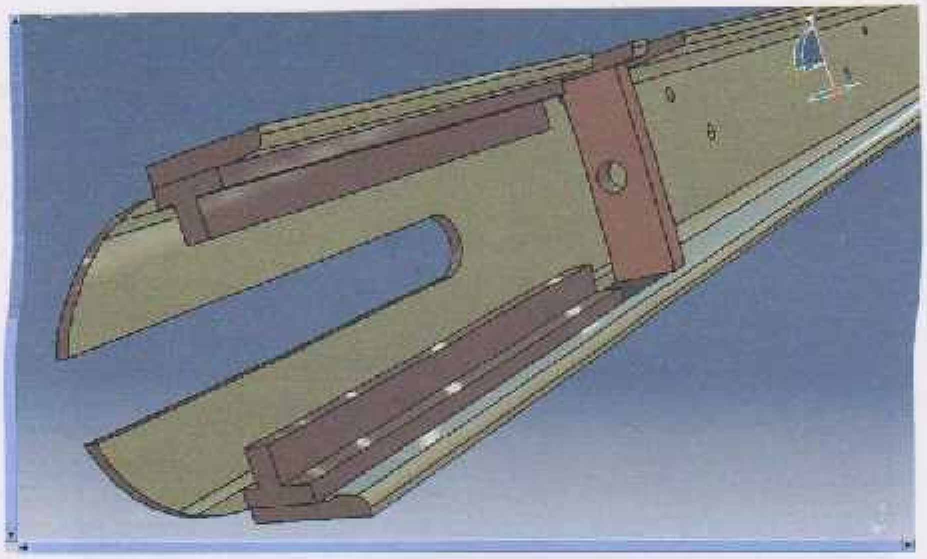


Figure (2.10): the slot of the conveyor side

2.4.1.1.2 Driving shaft

This component uses for connecting the AC motor on it to drive the belt which a rounded the driving shaft to handle the materials from one place to another .

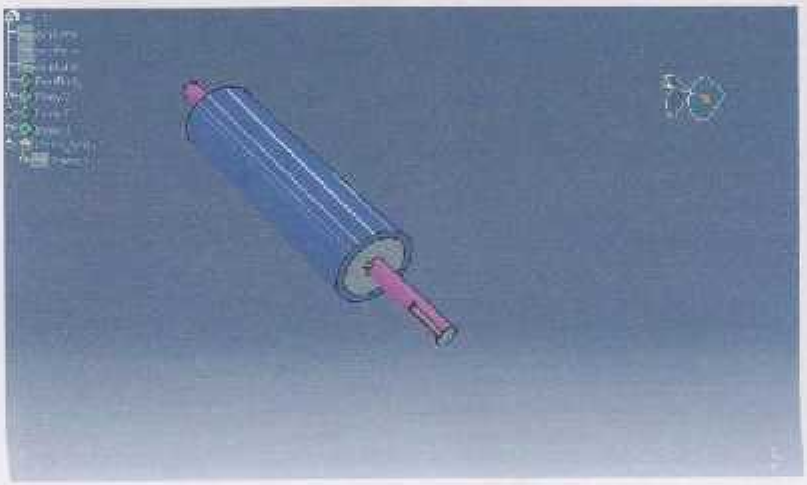


Figure (2.11): driving shaft

Also the driving shaft has the following components:

1- Outer cylinder

2- Two inner cylinders.

3- Rod.

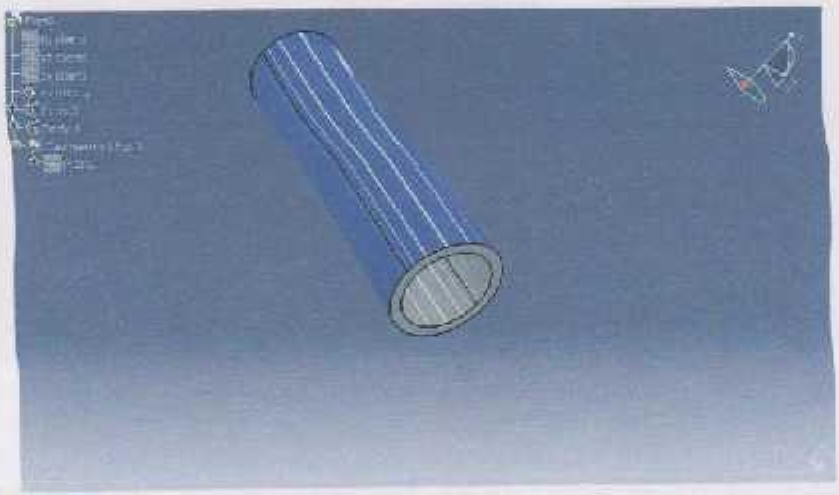


Figure (2.12): outer cylinder

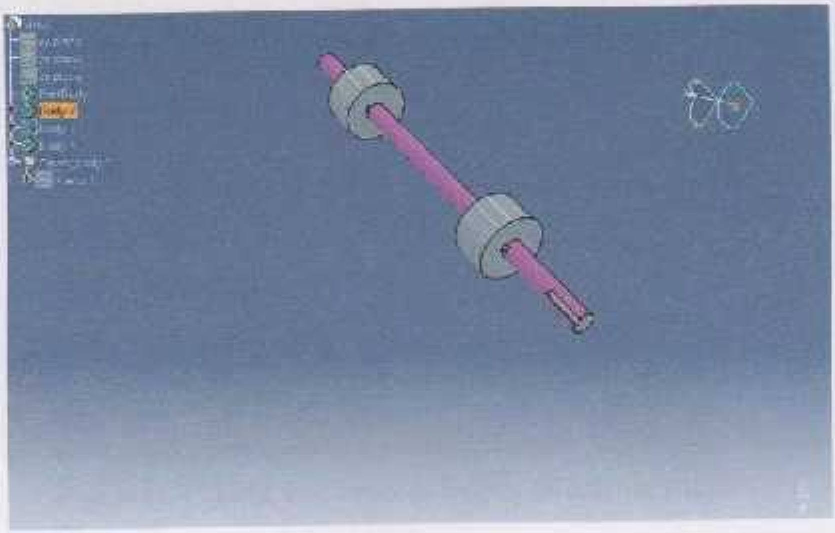


Figure (2.13): rod and the two inner cylinders of driving shaft

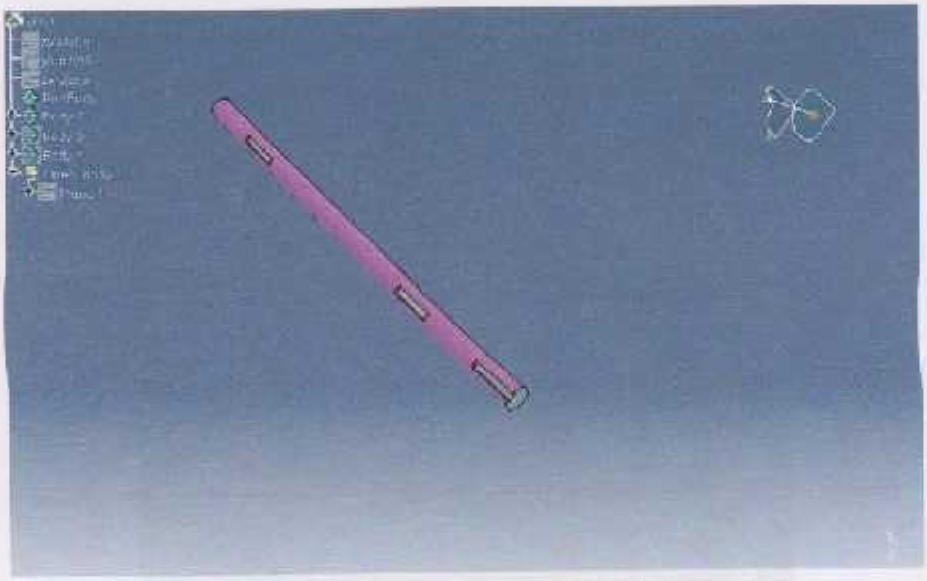


Figure (2.14): rod of driving shaft

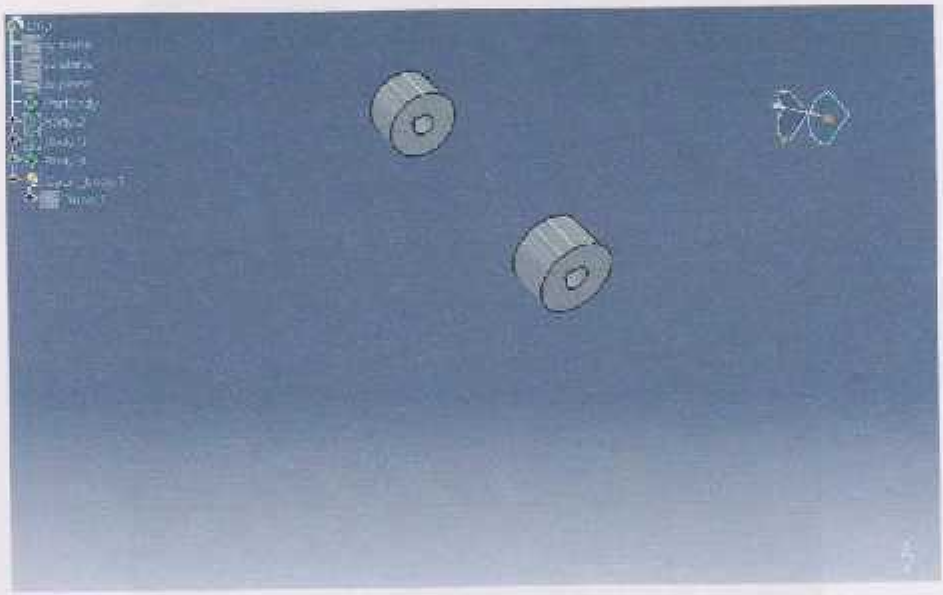


Figure (2.15): the two inner cylinders of driving shaft

2.4.1.1.3 Ball bearing units

Three kinds of ball bearing which used at the upper part of the conveyor

1- UCF2 ball bearing.

2- UCP2 ball bearing.

3- UCT2 ball bearing.

All the information about those kinds of bearing explained in details at appendix (A).

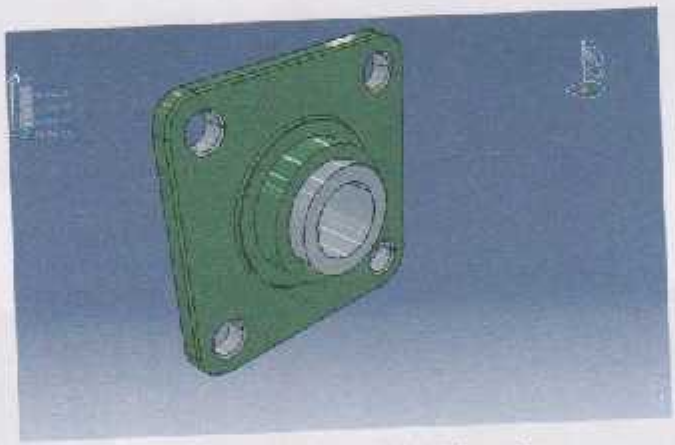


Figure (2.16): UCF2 ball bearing

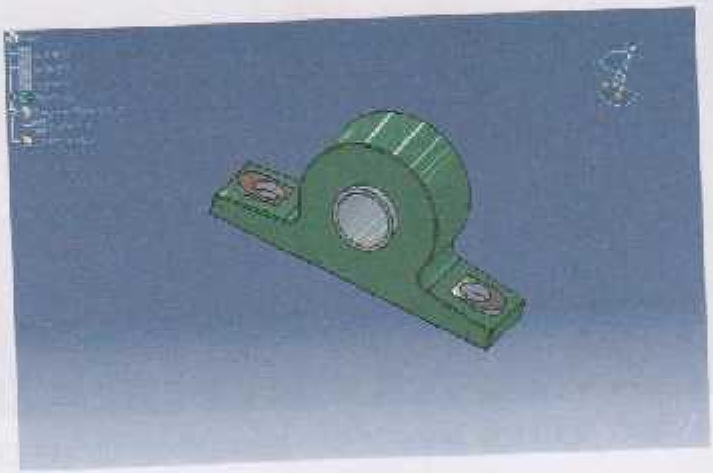


Figure (2.17): UCP2 ball bearing

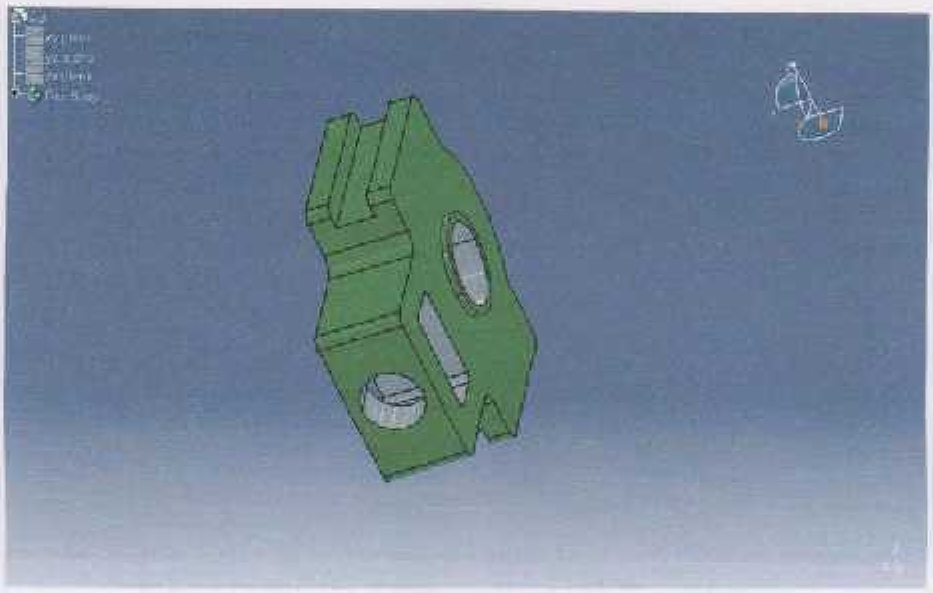


Figure (2.18): UCT2 ball bearing

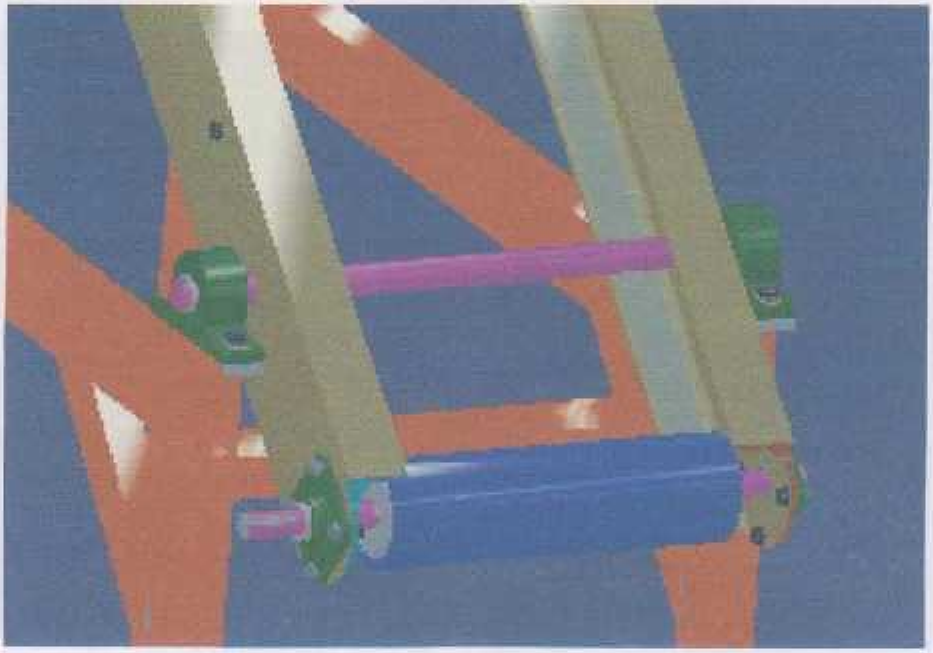


Figure (2.19): the driving shaft with U-beam, and UCF, UCP ball bearing

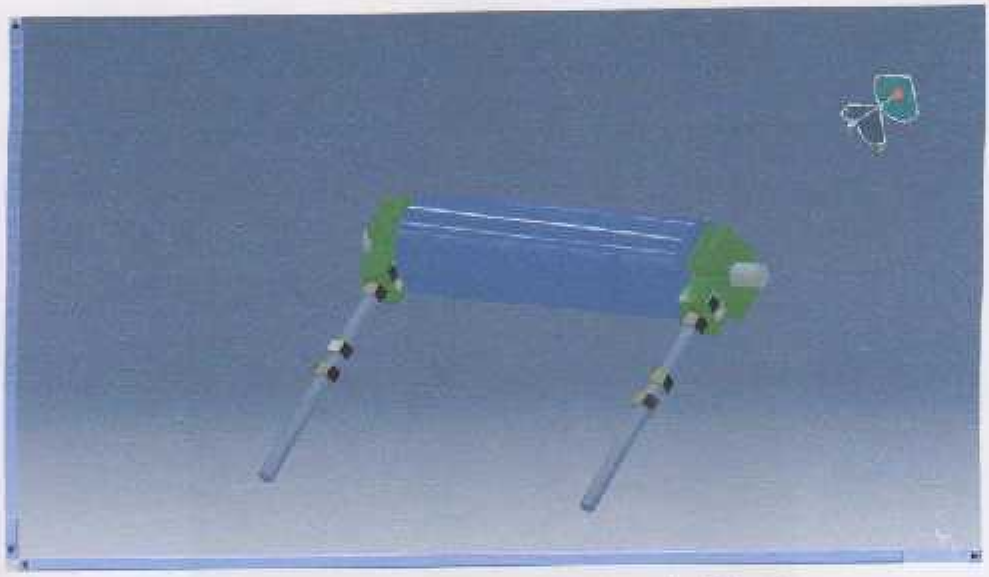


Figure (2.20): the driven shaft, and UCT ball bearing

Figure (2.21): the driven shaft with U-beam, and UCT ball bearing

2.4.1.1.4 The sheet of the conveyor body

This component uses for joining the two I-beams together, in addition to carry the belt which the materials carries on it.

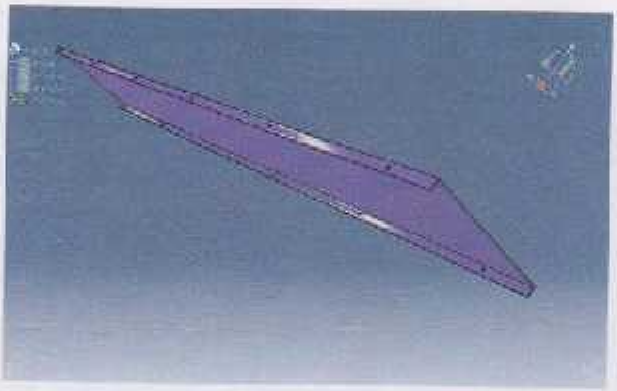


Figure (2.22): the sheet of the conveyor body

2.4.1.1.5 The connecting shaft

The function of this mechanical component is to connect the conveyor sides.

Figure (2.23): the connecting shaft

2.4.1.1.6 The base shaft

The function of this mechanical component is to connect the base of the conveyor to the conveyor body also the conveyor body is rotating about it to get the desired angle, and it is from stainless steel.

Figure (2.24): the base shaft

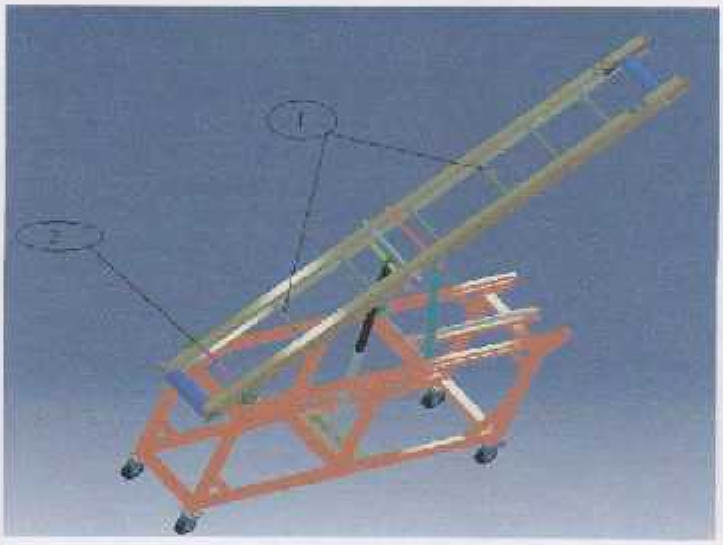


Figure (2.25): the conveyor with connecting shaft(1), and base shaft(2)

2.4.1.1.7 Nuts and Bolts

According to the standard of this components the dimensions of nuts are M10, M12, and M16 are used.

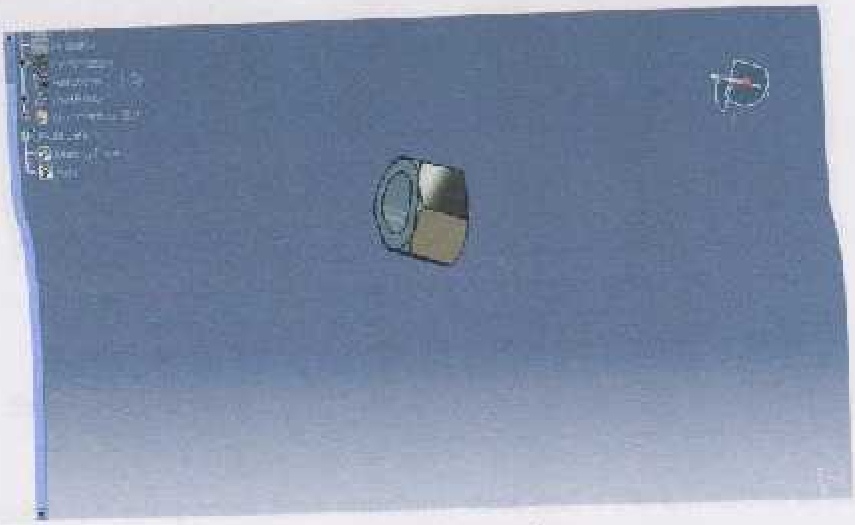


Figure (2.26): M10 nut

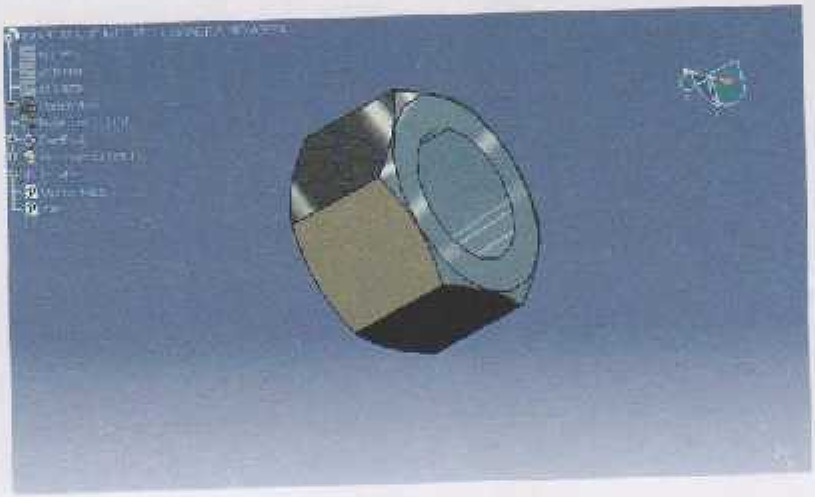


Figure (2.27): M16 nut

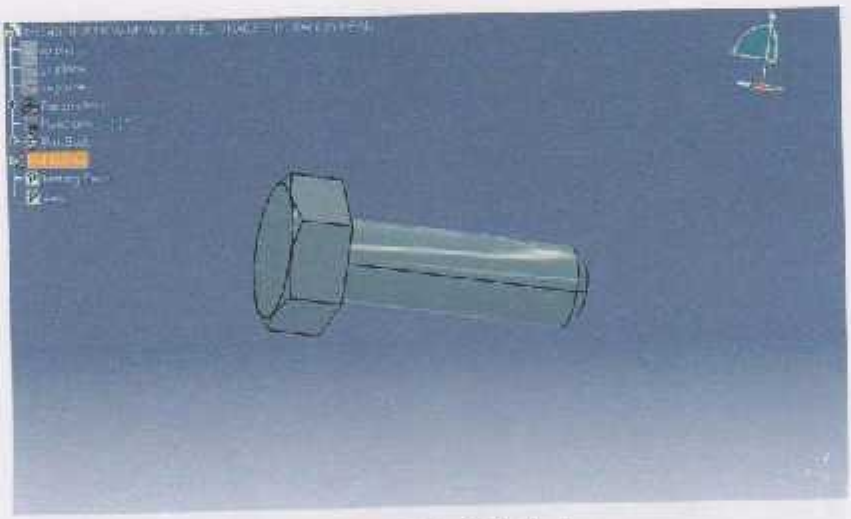


Figure (2.28): M12 bolt

2.4.1.2 Supported beams

This mechanical component from structural steel, and it has a function as assistance in carrying the load when the conveyor angle more than 0°.

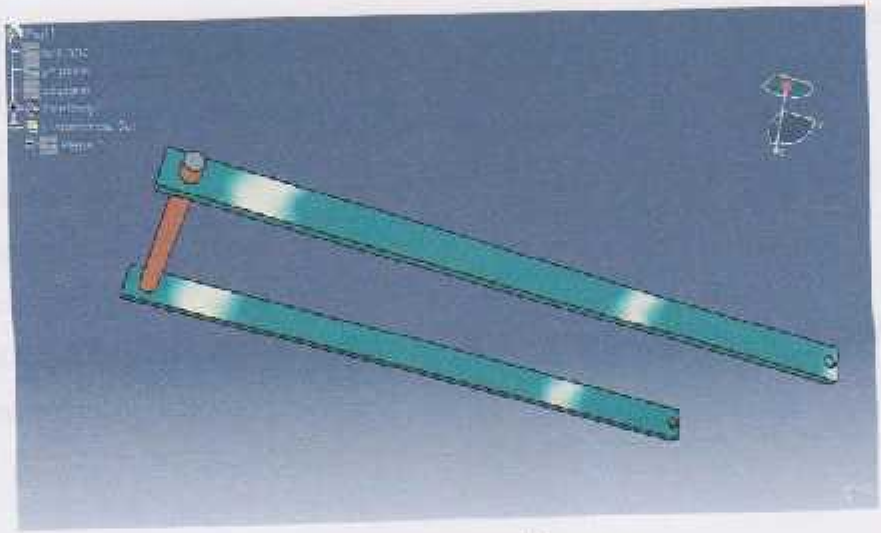


Figure (2.29):supported beams

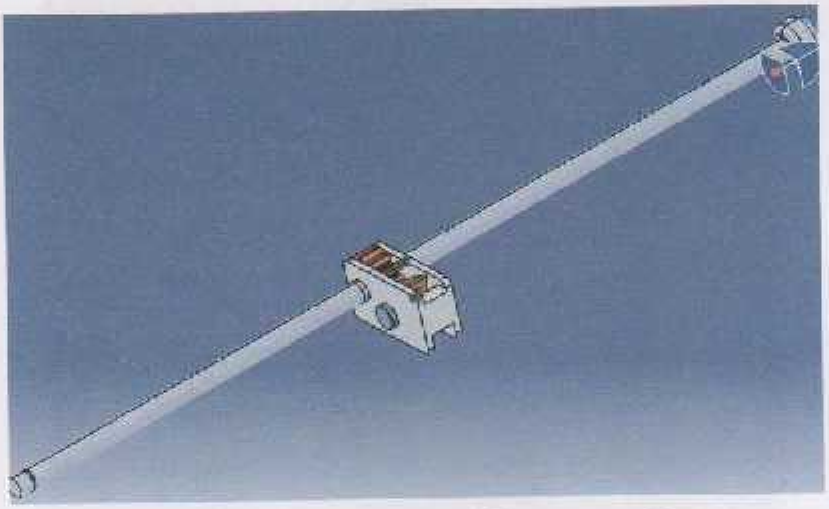


Figure (2.30): breaking part of the supported beam

2.4.1.3 Power screw

An important mechanical element from structural steel which has a basic function in moving the conveyor body at different angles; from 0° to 40°, and it has the following components:

1- The connection part between the screw and the conveyor body, figure (2.29).

2- The inner and outer cylinders, figure (2.30).

3- Power screw base, figure (2.31).

4- Compression bearing.

5- Nut that fixed in inner cylinder with 50mm of width, and 44mm of outer diameter, also a 30mm of inner diameter

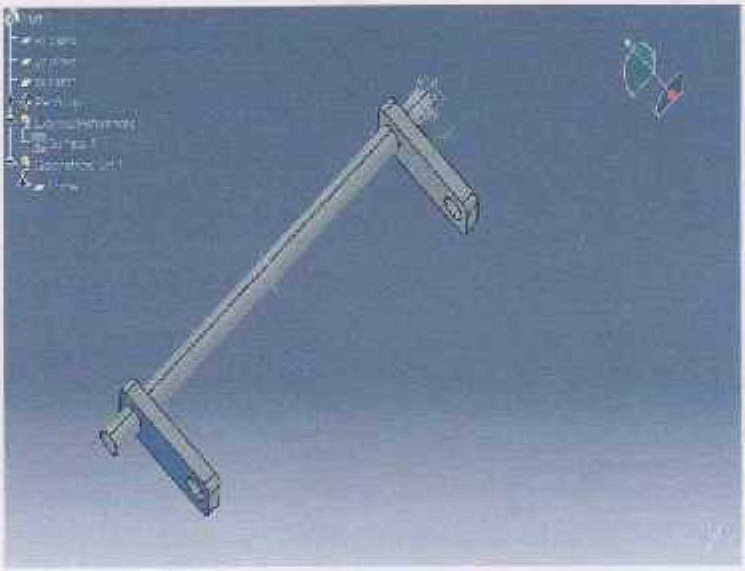


Figure (2.31): The connection part between the screw and the conveyor body

Figure (2.32): the inner and outer cylinders

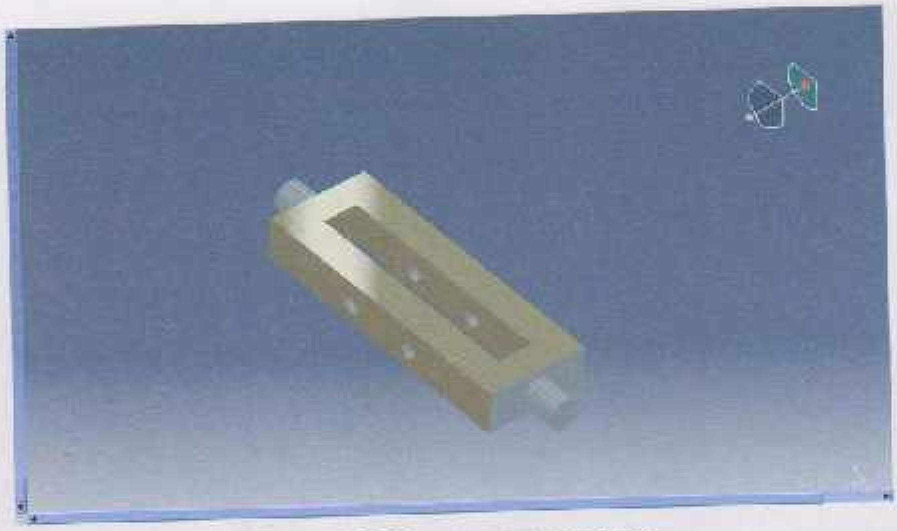


Figure (2.33): power screw base

Figure (2.34): power screw with all components

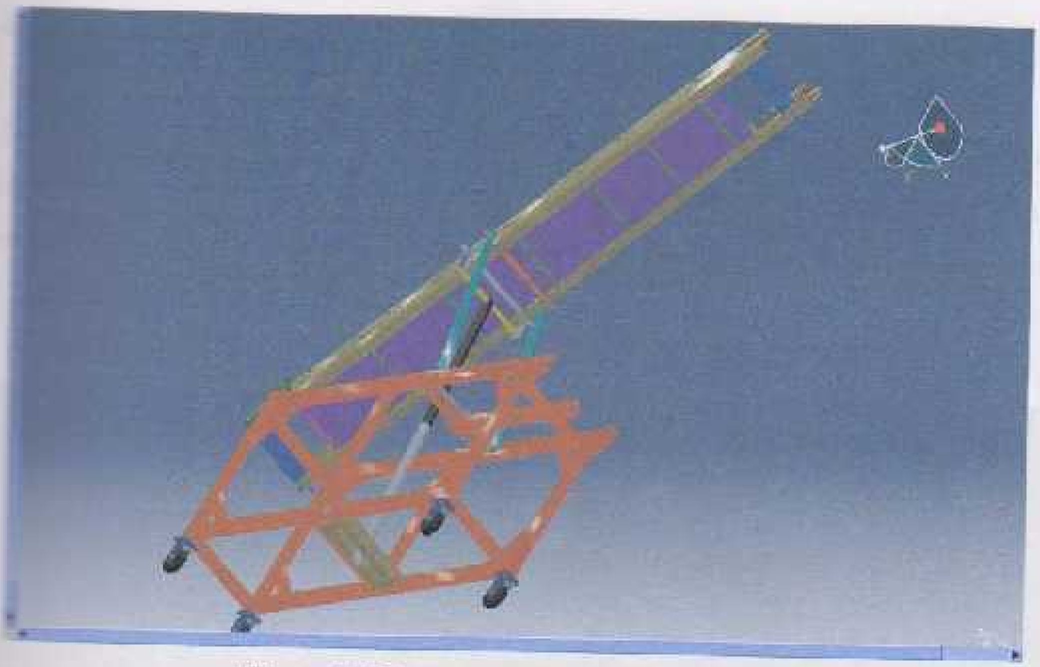


Figure (2.35): power screw at the conveyor

2.4.1.4 Conveyor base

The base of the conveyor designed to carry the conveyor body from structural steel, also to give a height from the ground for putting the motors, in addition to get more normal height and this help for carrying materials from ground to first and second floors.

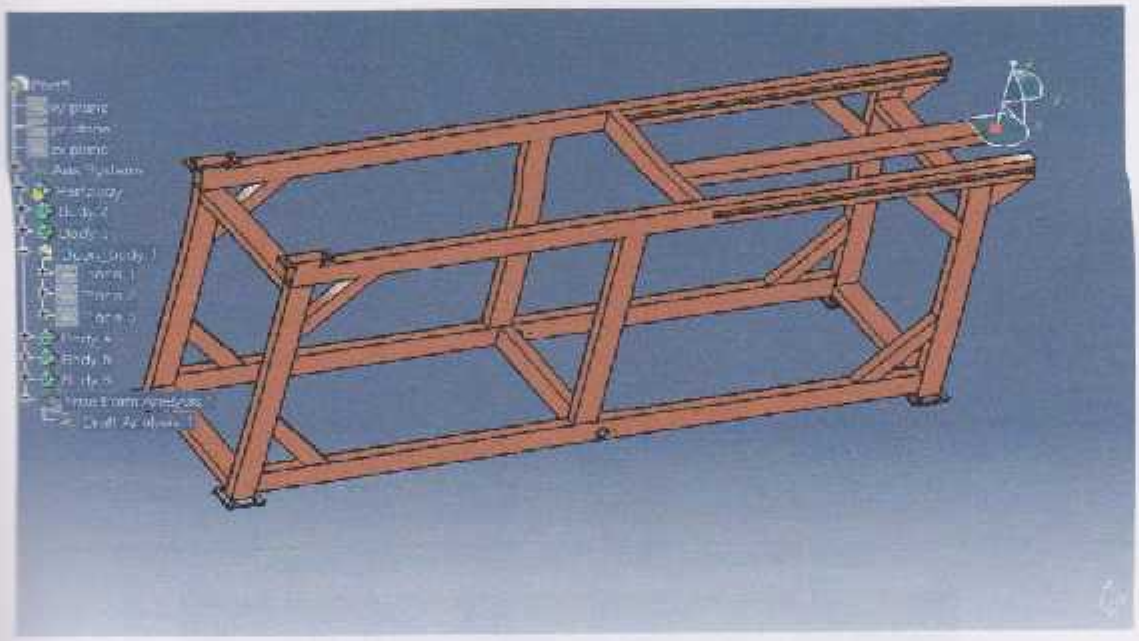


Figure (2.36):the base of the conveyor

2.4.1.5 Rack and pinion

Another mechanical component from structural steel at the base of the conveyor which make the supported beam flexibility to move when the conveyor body moving vertically. also for fixing the supported beam when the conveyor body stop it is move, the pinion can be rotated easily when the conveyor body moving up , the pin fix it to move down , so the magnetic coil are used to move the pin in the moving down process

Figure (2.37.a): the rack (1) with supported beam

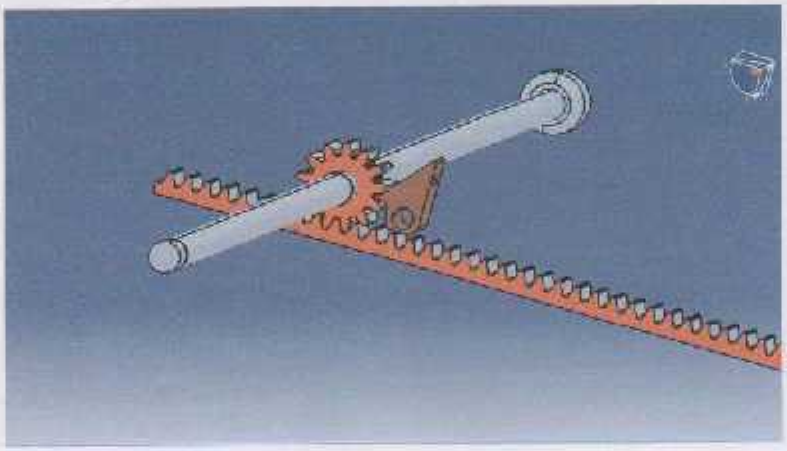


Figure (2.37.b): rack and pinion with the pin

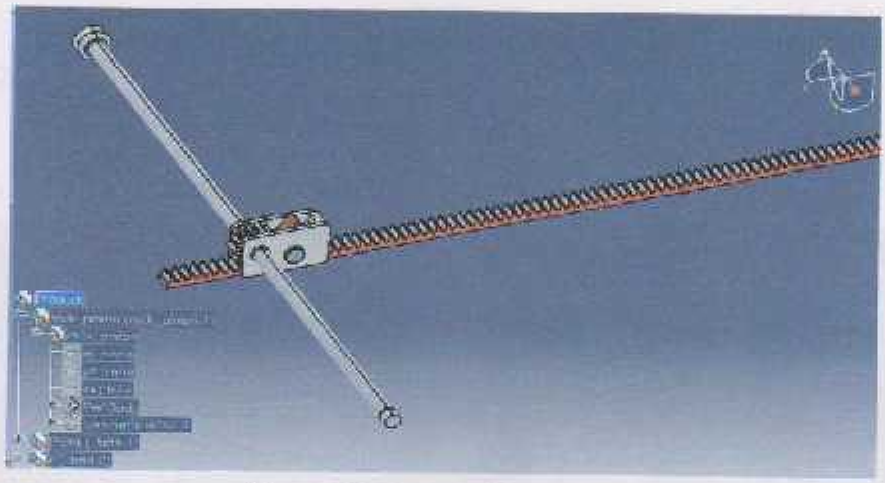


Figure (2.37.c): rack and pinion

2.4.1.6 The wheels

The wheels, an important mechanical component because it give flexibility to move the conveyor from one place to another, also it designed according to the standard with diameter of 12.5 cm and braking unit, and every wheel can carry about 2.5 KN .

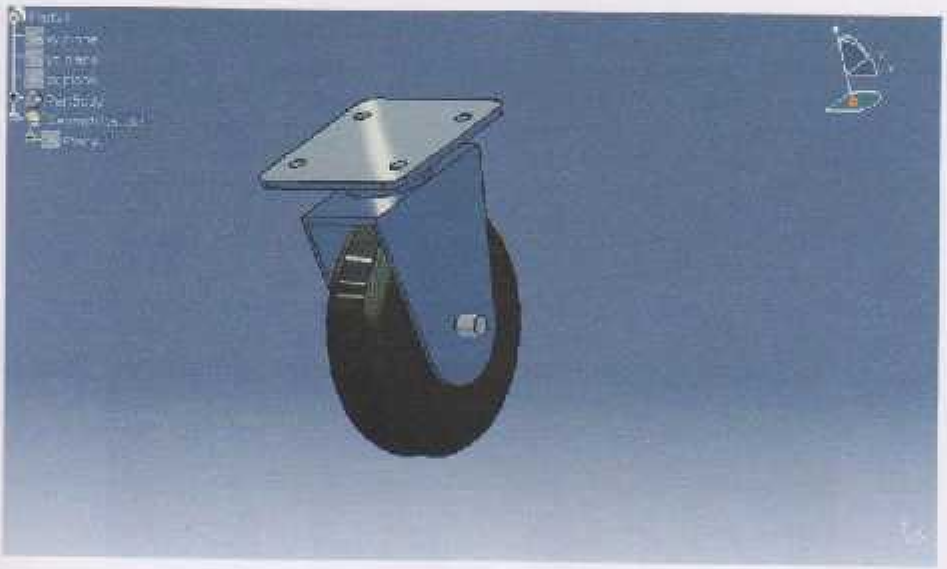


Figure (2.38): the wheel of the conveyor

2.4.1.7 Gear box

1- A warm gear used fro DC motors

Figure (2.39):warm gear

2- Friction gear

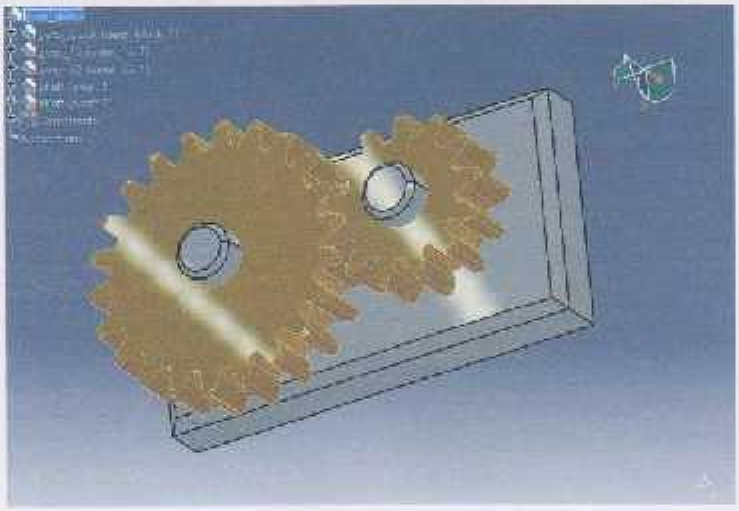


Figure (2.40):friction gear

2.4.1.8 The belt

This mechanical component between divining and driven shaft, and it is from rubber kind, ultimate strength is 15 MPa, also with 0.5 of passions ratio, and the modulus of elasticity is (0.01-0.1) GPa

2.2 ANSYS results

In this chapter each part of the machine will be tested using ANSYS 9.0 program to ensure that each part of the system will be safe under the applied loads and the selected parts with the dimensions given in appendix C were suitable.

Using Ansys each part will be plotted , simulated , meshed , and then solved with von misses theory to ensure that the maximum stress smaller than the yield strength in all parts and the parts in the safe range , the dimension of all part determined depending on the ansys result and the final dimension that satisfy safety are given in appendix

The von misses theory states that the failure occurs when the energy of distortion reaches the same energy of yield.

Mathematically:

$$\frac{1}{2}\left[(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2\right]\leq\sigma_y{}^2$$

Where:

σy : The yield strength of the material.

$\sigma 1, \sigma 2, \sigma 3$: Principle stresses.

Units that were used in analysis are mm for lengths, seconds for time, Newton for forces and MPa for pressure.

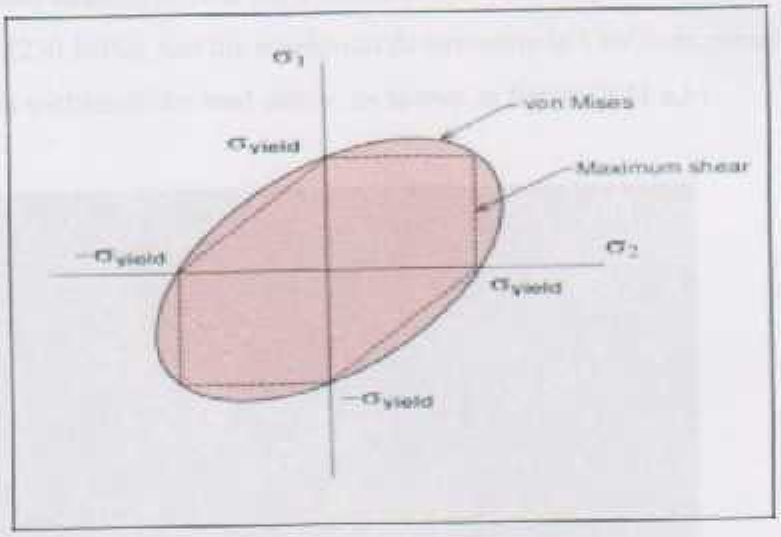


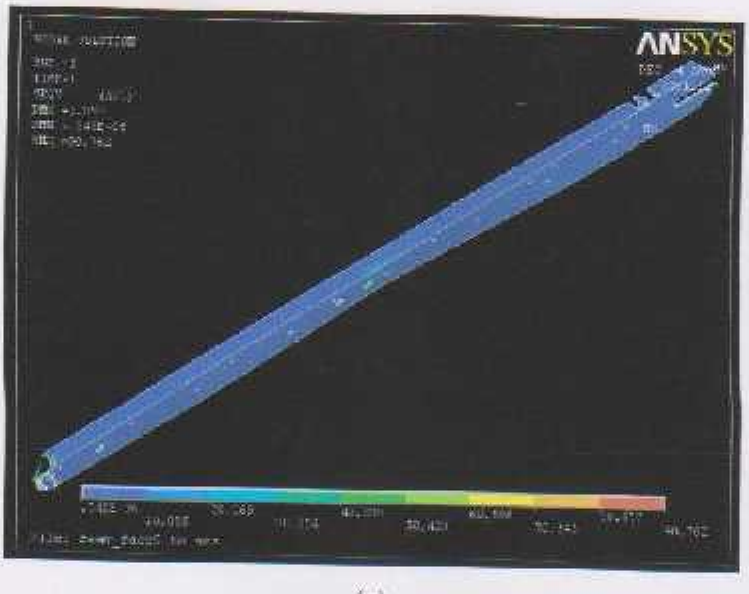
Figure (2.41) Von misses Stress

2.2.1 The Conveyor side analysis:

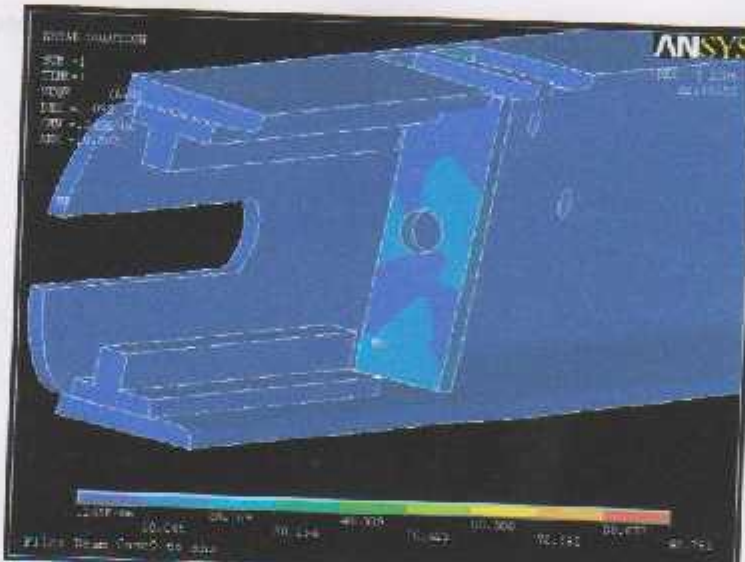
The load which is applied to this part is the distributed load and the weight of the conveyor body which is equal to 4.41 kN and affect mostly the supported places (the hollow places). And the tension of the belt which is equal to 1.9 kN affect the hollow of ball bearing unit.

<u>Von Misses stress:</u>

The Von Misses stress is 90.762 MPa which is less than the yield strength of structural steel (250 MPa), and the maximum deformation is 1.092mm, which means that the part can withstand the load safely, as shown in figure (2.41 a,b).



(a)



(b)

Figure (2.42) Von misses Stress of Conveyor side

Stress components:

The following figures (2.43), (2.44), (2.45) show the stress components in the x, y and z axis, it shows that z-component stress which is mostly affected by distributed load; is more than x and y components.

X-component:

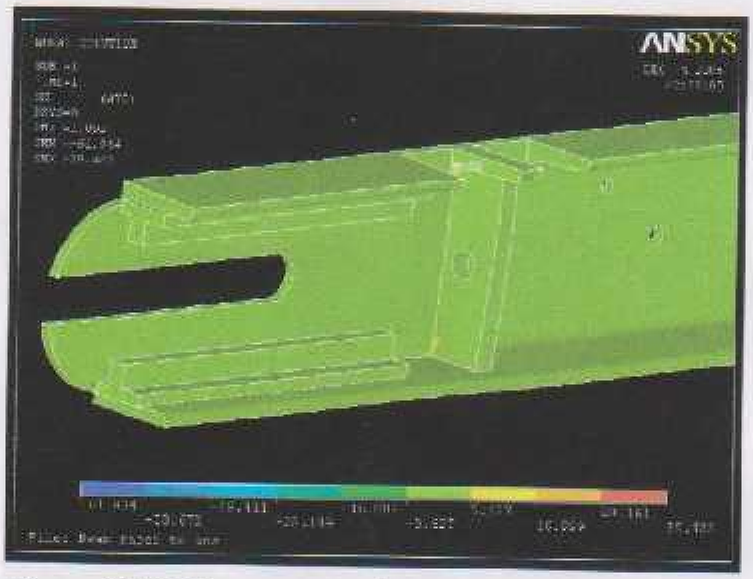


Figure (2.43) X component of stress on the conveyor side

Y-component:

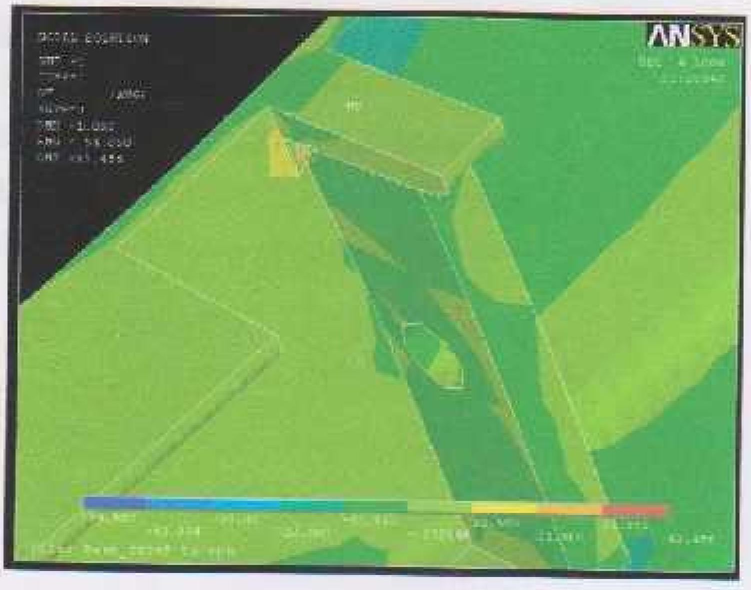


Figure (2.44) Y component of stress on the conveyor side

Z-component:

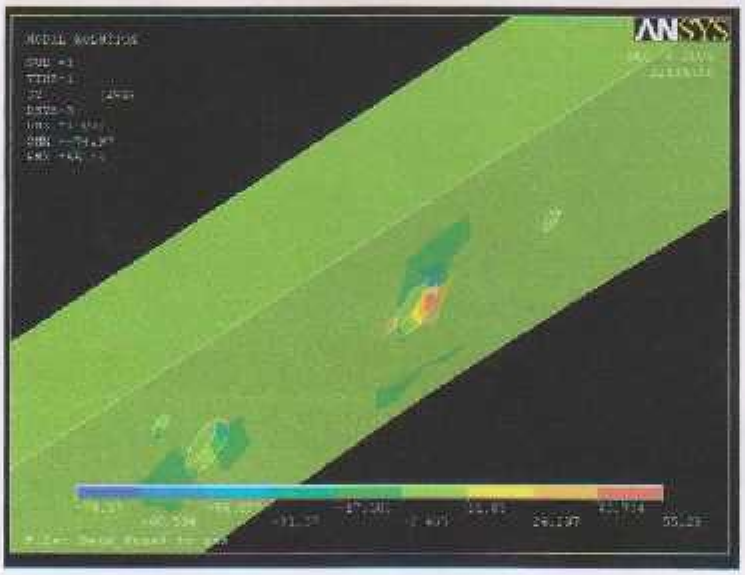


Figure (2.45) Z component of stress on the conveyor side

Maximum deformation:

The maximum deformation due to maximum load occurs at the end of the conveyor side as shown in figure (2.46) which is equal to 1.092mm, and this is a small value that will have no effect on the structure.

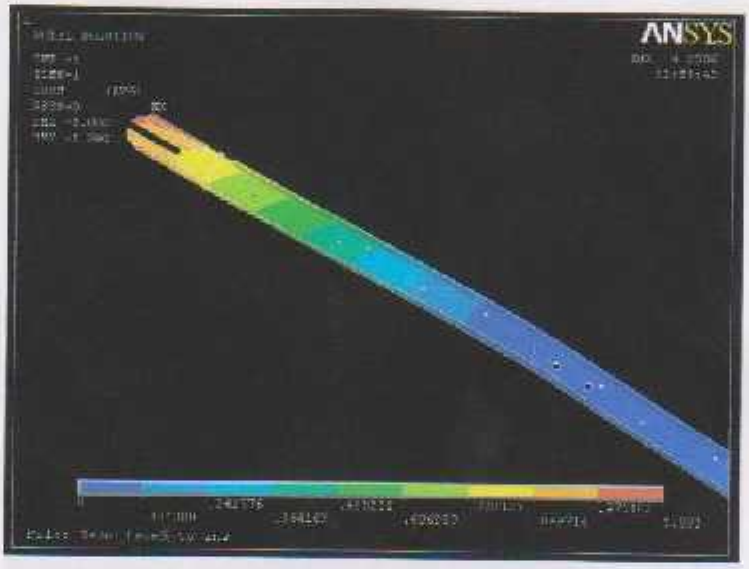


Figure (2.46) Maximum deformation of the conveyor side

2.2.2 Driving shaft:

The force applied to the shaft is the lifting force needed to lift the objects found on the conveyor at the maximum inclination. This lifting force is considered to be 1900 N and acting vertically on the upper edge of the groove, where the shaft is coupled with the motor. The analysis executed by ANSYS includes the Von misses stress, X component, Y component, Z component and maximum deformation.

Von misses stress:

The simulating results of the Von misses stress analysis is shown in figure (2.47), the maximum stress which is 192.23 MPa is less than the yield strength of the steel (250 MPa), and the maximum deformation DMX is 0.131 mm.

Thus, the shaft is in the safe region under the preceding conditions.

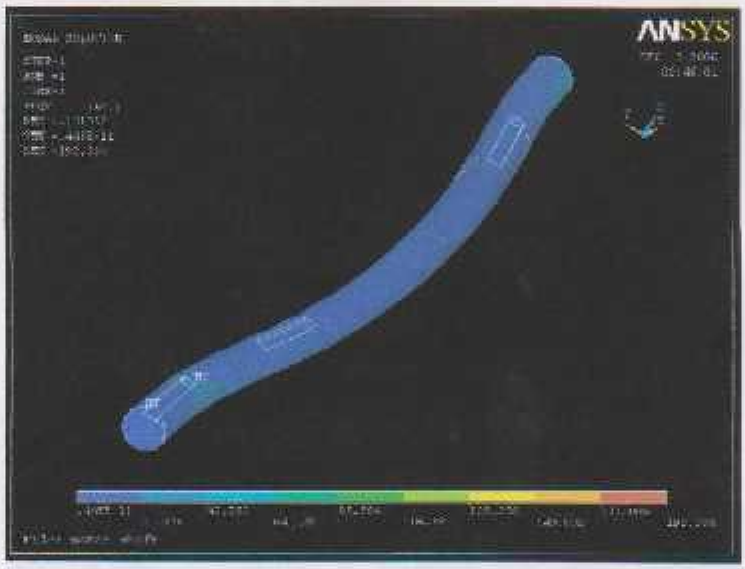


Figure (2.47) Von misses stress of driving shaft

Stress components:

The result of stress components in x, y and z direction are shown in figures (2.48), (2.49), (2.50), the maximum stress is in the y direction (in the same direction of the load) and it is equal to 182.814 MPa.

X- component:

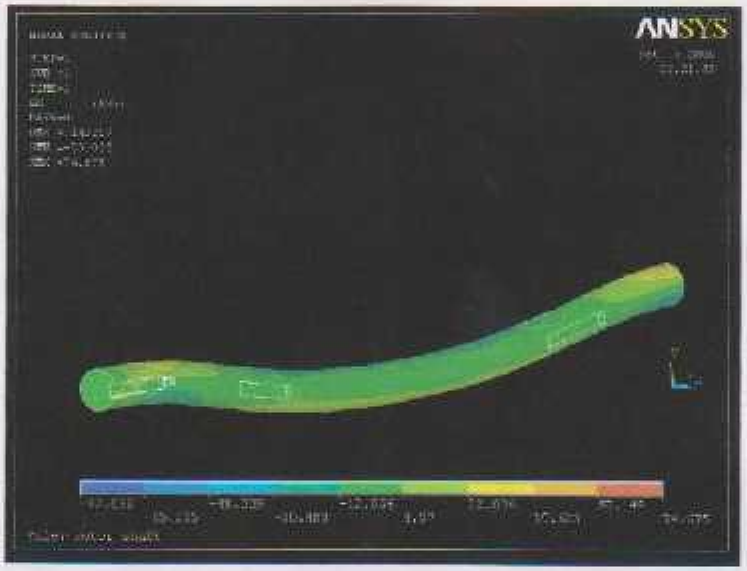


Figure (2.48) X component of stress on the driving shaft

Y- Component:

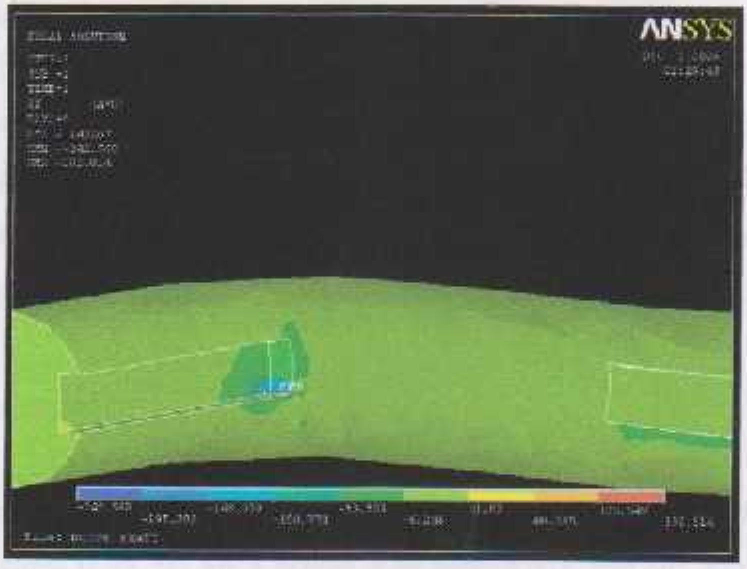


Figure (2.49) Y component of stress on the driving shaft

Z-Component:

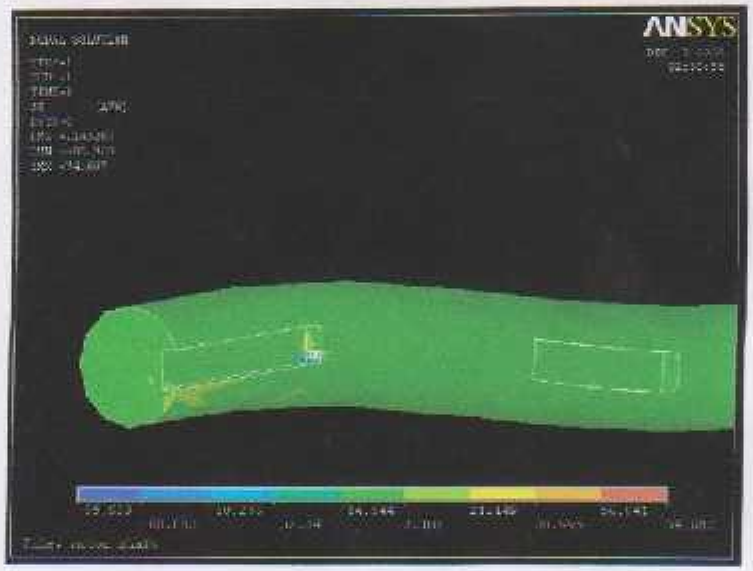


Figure (2.50) Z component of stress on the driving shaft

2.2.3 Sheet analysis

The load applied to the sheet is the maximum distributed load (3KN) applied at the surface of the sheet, it is considered as a pressure acts at the surface area (0.0024 N/mm^2), the analysis executed by ANSYS include the Von misses stress, x, y and z components of stess and maximum deformation.

<u>Von misses stress:</u>

The Von misses stress analysis of the sheet in figure (2.51) shows that the maximum stress is 98.205 MPA occurs at he hole of bolt and this maximum stress is less than the yield strength of the steel (250 MPa), thus the sheet can withstand the load safely.

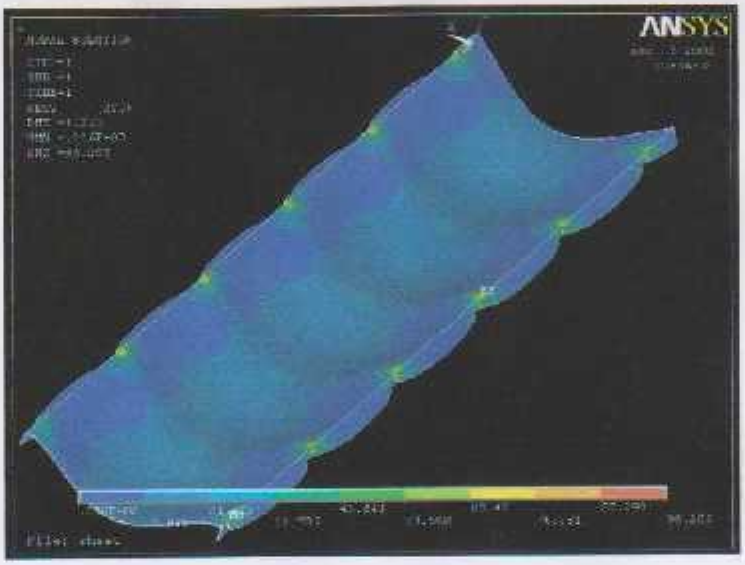


Figure (2.51) Von misses stress of Sheet

Stress components:

The figures (2.52), (2.53), show the stress components in the x and z axis, It shows that x component stress (normally to the side of the sheet); is more than z component stress.

X- component:

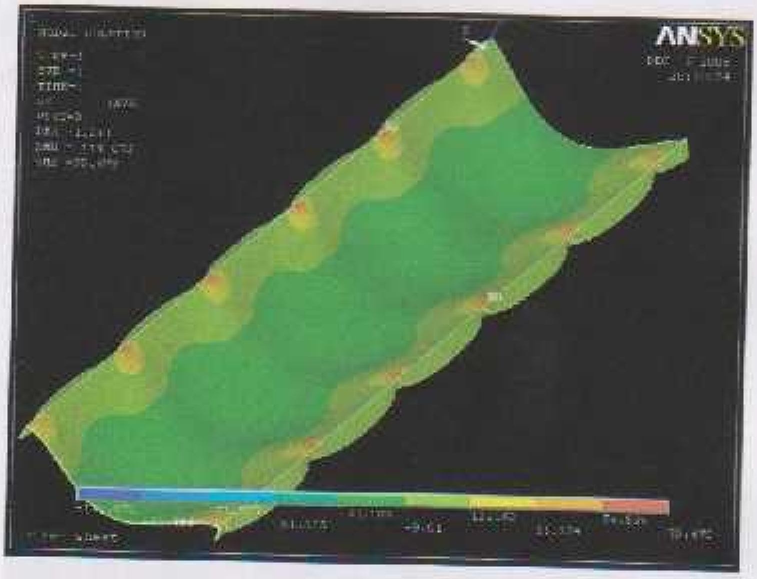


Figure (2.52) X component of stress on the sheet

Z-component:

Figure (2.53) Z component of stress on the sheet

Maximum deformation:

The maximum deformation due to maximum load on the sheet is equals to 1.2 mm occurs in the area shown in the red color in figure (2.54, this deformation is a maximum vector deformation.

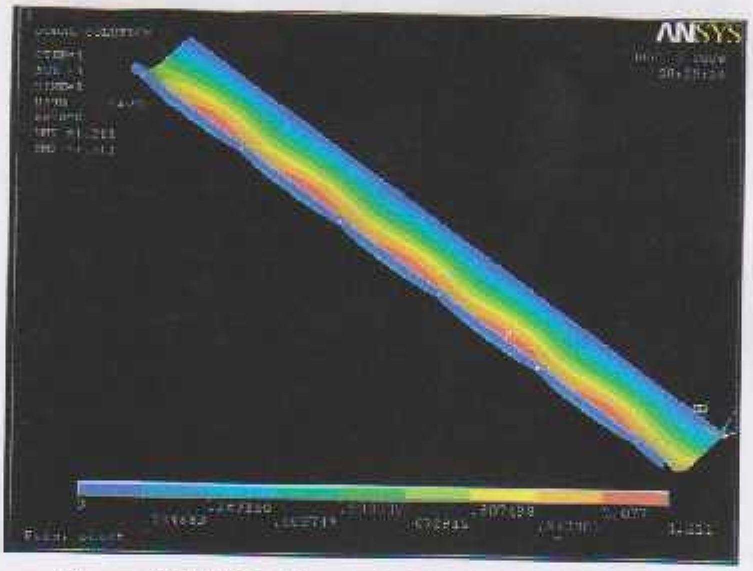


Figure (2.54) Maximum deformation of the Sheet

2.2.4 Driving pulley analysis:

The force applied to this part is the torque required to lift the load at maximum inclination, this torque acts at the grove edge of the driving pulley as shown in figure (2.55) and equals to 95.0 kN.mm.

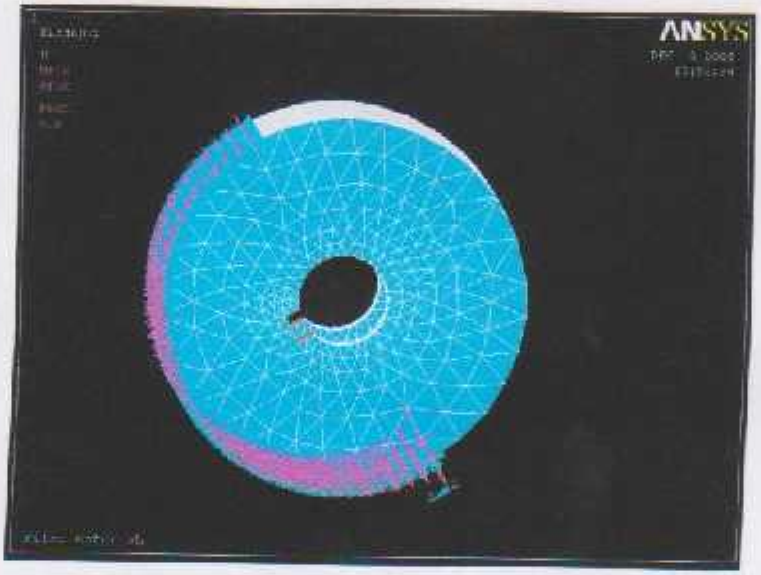


Figure (2.55) the torque applied to the pulley.

Von misses stress

The maximum stress is 14.476 MPa occurs in the grove edges as shown in figure (2.56), this value is less than the yield strength of the steel (250 MPa) and the part can withstand the applied torque safely.

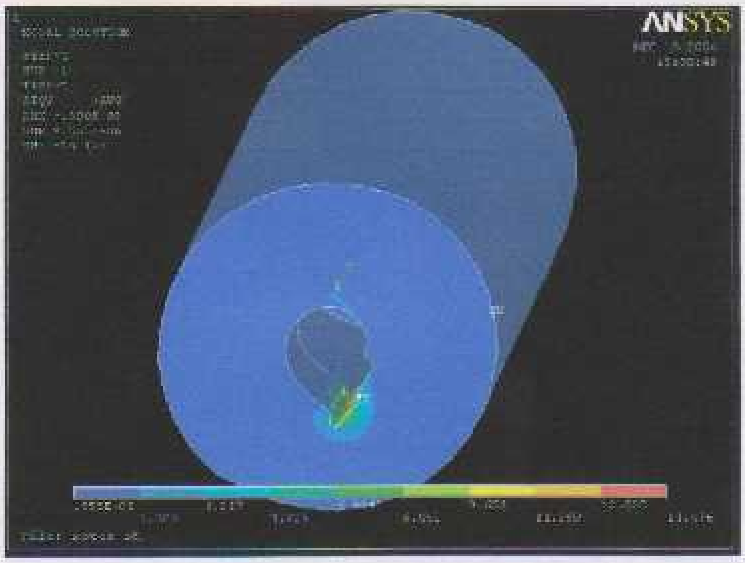


Figure (2.56) Von misses stress of the pulley

Stress components:

The figures (2.57), (2.58), (2.59) show the stress component in x, y and z axis, It shows that the variations of stress in y axis is more than x and z axis

X- component:

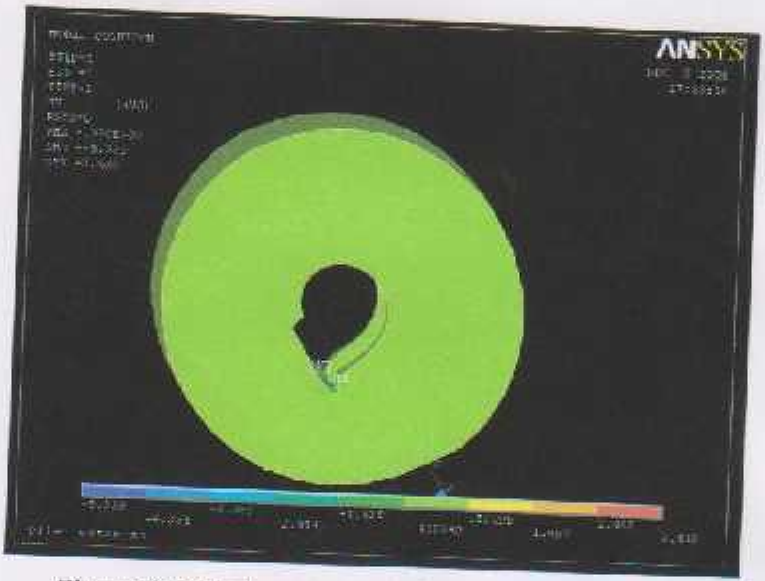


Figure (2.57) X component of stress on the pulley.

Y-component:

Figure (2.58) Y component of stress on the pulley.

Z-component:

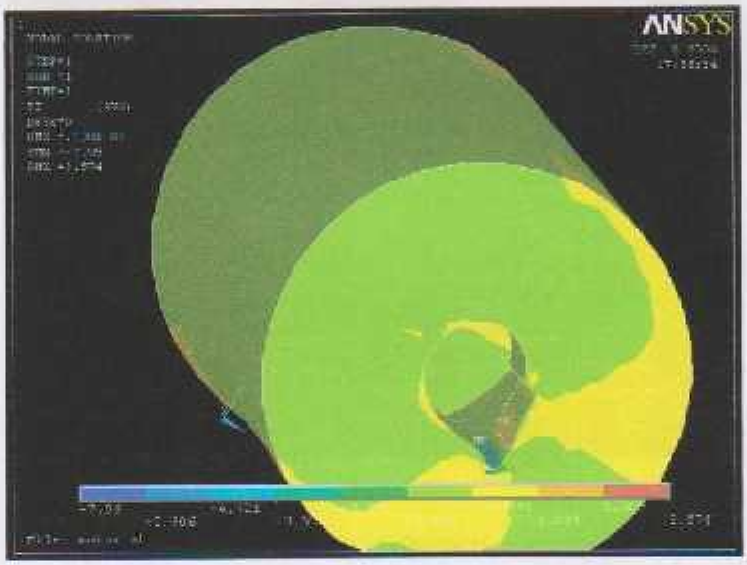


Figure (2.59) Z component of stress on the pulley.

Maximum deformation:

The maximum deformation due to maximum load on the pulley is equals to .00039 mm occurs in the grove edge as shown in the figure (2.60), this is small deformation and can be neglected.

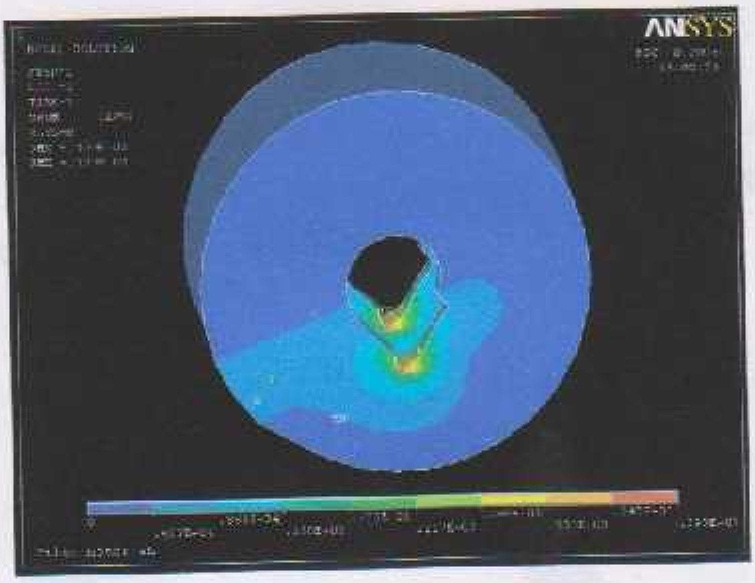


Figure (2.60) Maximum deformation of the Pulley.

2.2.5 Supported beam analysis:

The force applied to this part is the maximum force acts on the supported beam, this maximum force acts on the supported beam at the smallest angle of inclination above the zero angle, so it considered to be 1 degree , at this angle of inclination the supported beam angle is 7 degree and the force acts on it is 27KN; thus the applied force is 27KN acts on nodes in the upper shaft of supported beam, analysis executed by Ansys for this part includes the Von misses stress, x, y and z components of stress and the maximum deformation.

Von misses stress:

The maximum stress is 230 MPa occurs in upper shaft at the loaded area as shown in figure (2.61), this value is less than the yield strength of steel (250 MPa) and the part can withstand the applied torque safely

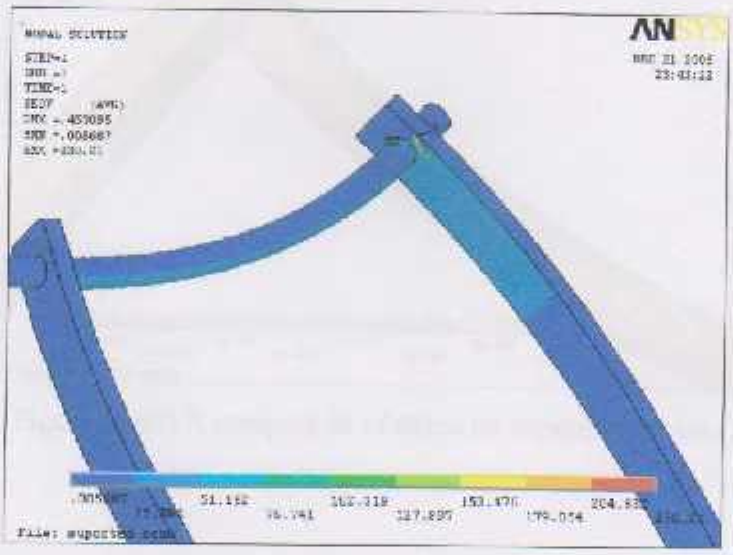


Figure (2.61) Von misses stress of the supported beam

Stress components:

The figures (2.62), (2.63), (2.64) show the stress components in x, y and z axis, It shows that the variations of stress in y axis is more than x and z axis.

X- component:

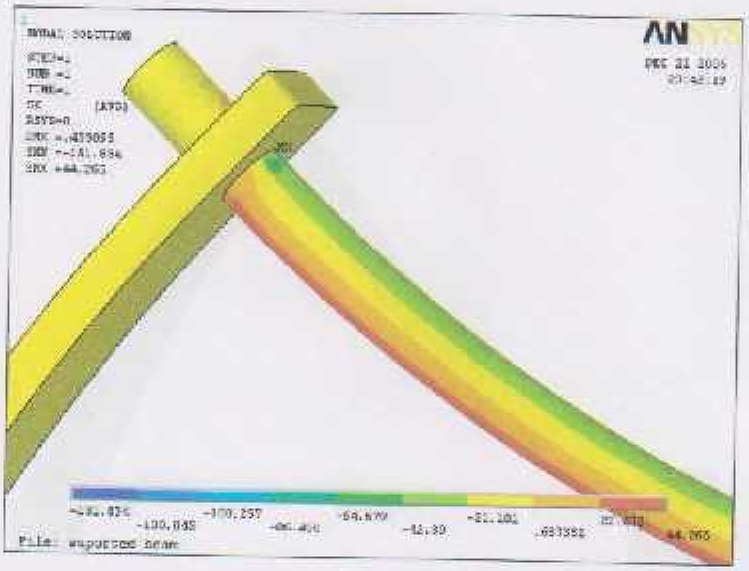


Figure (2.62) X component of stress on supported beam.

Y- component:

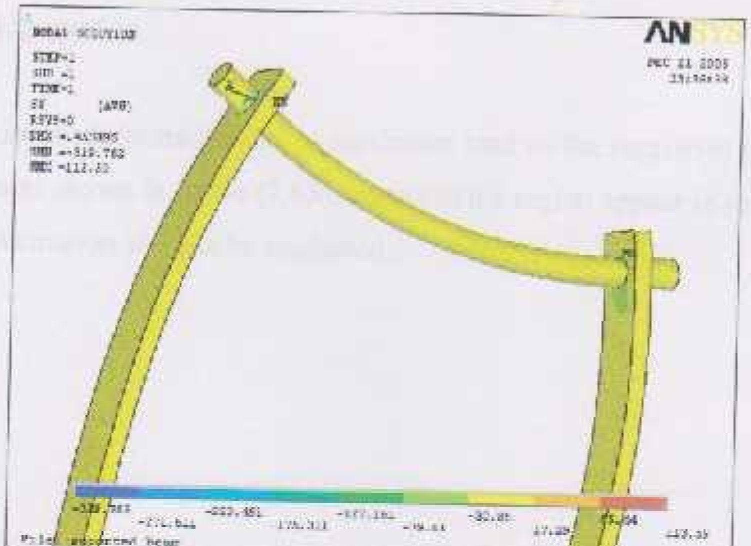


Figure (2.63) Y component of stress on the supported beam.

Z- component :

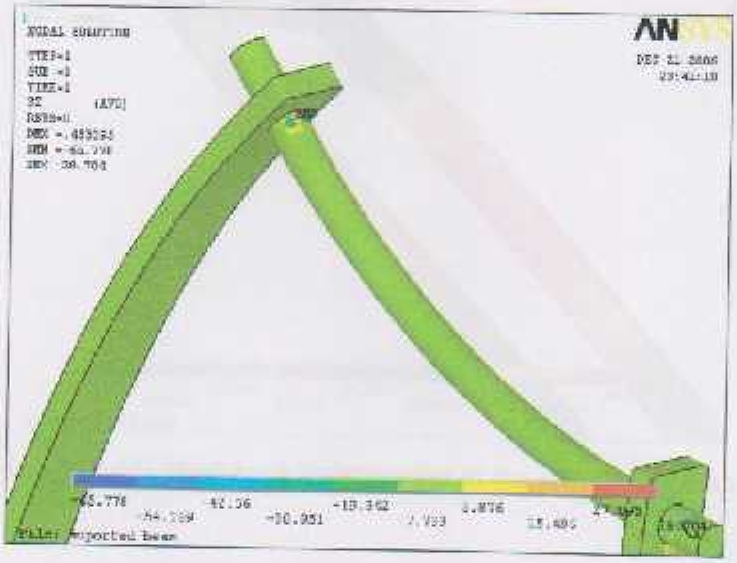


Figure (2.64) Z component of stress on the supported beam.

Maximum deformation:

The maximum deformation due to maximum load on the supported beam is equal to 0.45 mm as shown in figure (2.65), occurs in the region appear in red color, this is a small deformation and can be neglected.

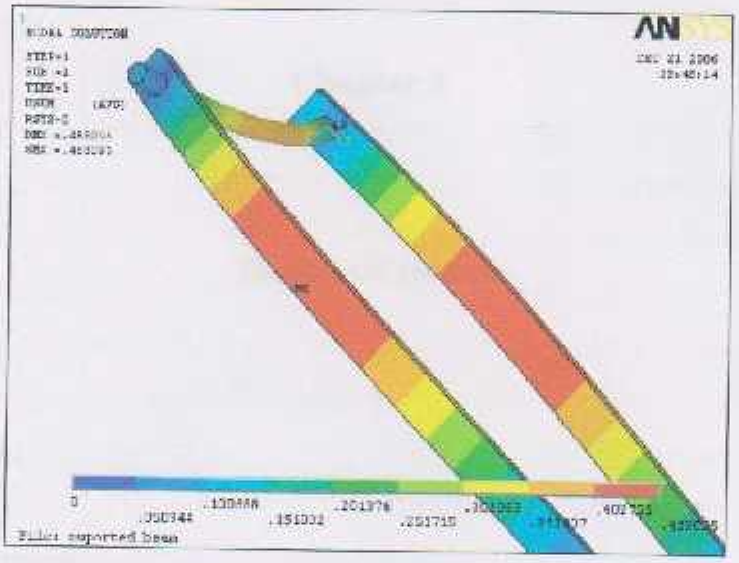


Figure (2.65) Maximum deformation of the supported beam.

Chapter 3

Electrical system

3.1 Introductions

The electrical system the main important part of mechatronics system, its concerned with the beaver of three fundamental quantities: charge, current, and voltage (or potential). When a current exist, electrical energy is usually being transmitted from one point to anther. Electrical system is consisting of two categories; power systems and communication systems. Communication systems are designed to transmit information as low-energy electrical signal between points .such as information processing, and transmission are common parts of communication system. This area of electrical engineering is called electronics. On the other hand, power systems are design to transmit large quantities of electrical energy, not information, between pointes efficiently .frequently, rotating machines are used to convert energy between electrical, and mechanical domains. Generators are convert energy from mechanical to electrical and motors are used to convert it back.

In this project will use the two categories; power systems and communication systems. In power system will use two electrical motors. AC motor for drive the belt, and DC motor for control of the angle of conveyor. And in communication system will use two potentiometers for control of the input of DC motor, and will use logic-control of conveyor which need other switches for used in the PLC connection.

3.2 DC-motors

3.2.1 Introduction

The direct current (DC) motor is one of the first machines devised to convert electrical power into mechanical power, for design this system the dc-motor will be in the position that the number one refer to in figure 3-1; this motor used to drive the screw (number 4 in figure 3-1), which drive the support beam (number 2 in figur3-1) that is used for moving the conveyor in different angles.

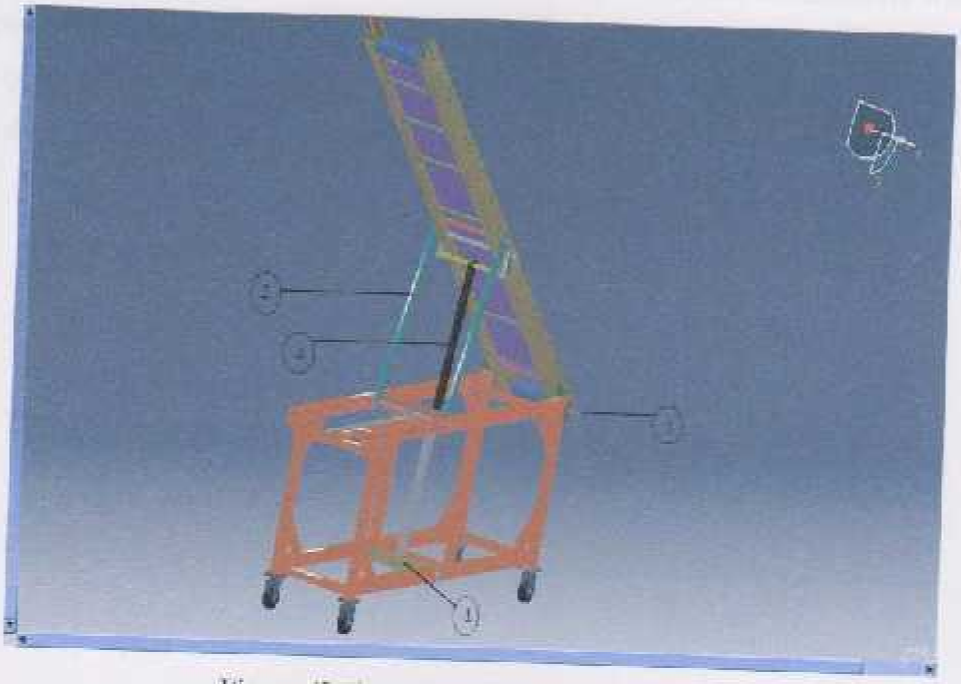


Figure (3:1): design of conveyor system

3.2.2 Advantages of DC Motors

The dc motors advantages are generally the reason for its choice, which are; Firstly the excellent speed control with very good torque and horsepower characteristics because its armature design and function ,it has very smooth torque from zero rpm to base speed .the dc motor also has full-rated horsepower above base speed.

3.2.3 Construction of DC Motor

The armature and the stator are the main parts of the DC motor; the armature winding is composed of coils embedded in slots in the rotor. The rotor of a dc machine usually is simply called the armature. The armature has a cylindrical core consisting of a stack of slotted laminations see the figure (3-1).

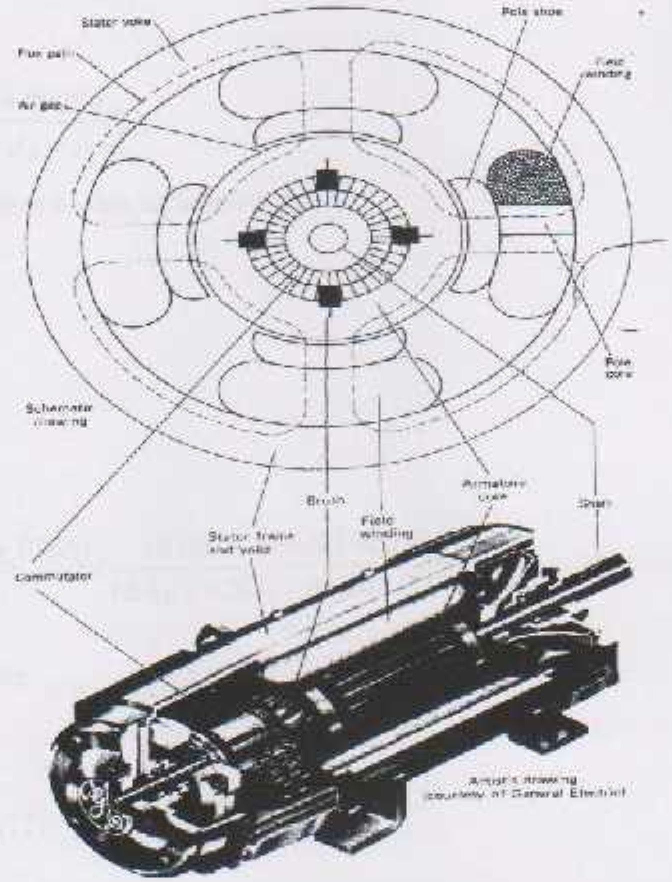


Figure (3:2): Construction of DC motor

3.2.4 Selecting the dc motor

To select the dc motor you will know the torque and speed needed for driving the screw to get a different angles of conveyor, then you know the power of motor that is satisfy this values.

From the design of the screw, the following equation will gives the value of the torque:

$$T = \frac{F \cdot d_m}{2}\left(\frac{L + \pi \cdot \mu \cdot d_m}{\mu \cdot d_m - \mu \cdot L}\right) \quad (3.1)$$

The parameters of this equation are:

$l = 7mm$

$d_m = 26.5mm$

$F = 1.8KN$

$\mu = 0.6$

Then:

$$T = \frac{(1.8*10^3)(.0265)}{2}\left(\frac{(0.007 + \pi(0.6)(.0265)}{(0.6)(0.0265) - (0.6)(0.007)}\right)$$

$T = 101.82 \ \ Nm$

$$P_{sh} = T \cdot W \quad (3.2)$$

$P_{sh} = (101.82)(12)$

$P_{sh} = 1221.84 \ \ W$

$$P_m = \frac{P_{sh}}{\eta_G} \quad (3.3)$$

$P_m = \frac{1221.85}{0.84}$

$P_m = 1454.57 \ \ W$

$P_m = 1.9498 \ \ hp$

$P_m \cong 2 \ hp$

This means the motor that drive the conveyor in different angles will be give a 2hp in previous specifications.

3.3 AC-motors

3.3.1 Introduction

AC motors can be divided into two major categories: asynchronous and synchronous. The induction motor is the most common form of asynchronous motor and is basically an ac transformer with a rotating secondary. The primary winding (stator) is connected to the power source, and the shorted secondary (rotor) carries the induced secondary current. Torque is produced by the action of the rotor (secondary) currents on the air gap flux.

The AC single phase induction motor that will be used in this project is in the position that the number three refer to in figure 3-1, the function of this motor is to drive the belt of conveyor that is used to transport the materials on conveyor

3.3.2 Advantages of AC motors

AC induction motors are the most common motors used in industrial motion control systems, as well as in main powered home appliances. Simple and rugged design, low-cost, low maintenance and direct connection to an AC power source are the main advantages of AC induction motors.

Various types of AC induction motors are available in the market. Different motors are suitable for different applications. Although AC induction motors are easier to design than DC motors, the speed and the torque control in various types of AC induction motors require a greater understanding of the design and the characteristics of these motors.

3.3.3 Selecting the AC motor

To select the AC motor you will know the speed of the load on conveyor, and the torque that is needed to drive the load, and then when you know the efficiency of the gear you will know the power of the AC motor.

The desired speed of the load is (0.5 m/s), and the radius of the shaft that drive the belt of conveyor is (0.05 m).

If you know the maximum torque will don at the angel of (40 degree), then the calculation will be as the flow.

$$T_L = F * r \quad in \ N-m \tag{3.4}$$

$$F = mg \sin 40 \quad in \ N \tag{3.5}$$

$$F = 300 * 9.81 * \sin 40$$

$F = 1891.72 \quad N$

$T_L = 1891.72 * 0.05$

$T_L = 94.586 \quad in \ N-m$

$$P = T_L * W \quad in \ W \tag{3.6}$$

$P = 94.586 * 10$

$P = 945.86 \quad W$

From data sheet of worm gear that will use for transmit the power from motor to the load, the efficiency of this gear is 85%, then the output power of the AC motor will be :

$P = 945.86 * .85$

$p = 113 \quad W$

$P = 1.5 \quad hp$

This mean the AC motor needed will give output power of (1.5hp), to drive the load.

3.3.4 Power circuit of AC motor

By using an inverter which controls the speed of AC motor by using frequency inverting, an inverter which accept AC signal and output is AC signal can be joint directly to AC motor.

Also here we use a VFD015S21 inverter type which available for 1.5 hp by the following external wiring as shown in figure (3:3), and another specification of this type shown in

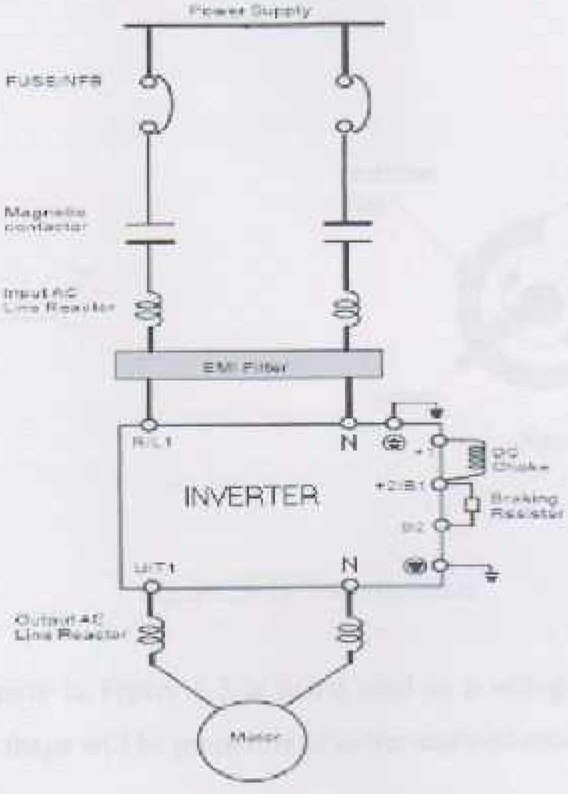


Figure (3:3): external wiring

3.4 Potentiometers

Potentiometers measure the angular position of a shaft using a variable resistor. A potentiometer is shown in Figure 3-3. The potentiometer is resistor, normally made with a thin film of resistive material. A wiper can be moved along the surface of the resistive film. As the wiper moves toward one end there will be a change in resistance proportional to the distance moved. If a voltage is applied across the resistor, the voltage at the wiper interpolates the voltages at the ends of the resistor.

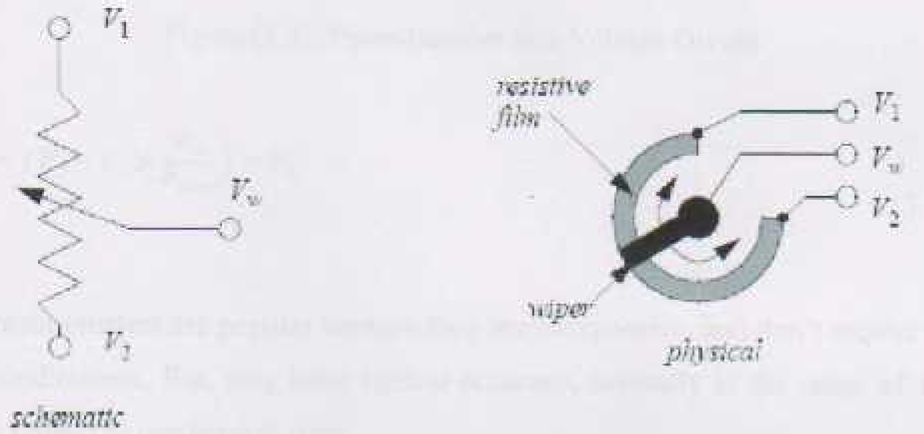


Figure (3:4): Potentiometer

The potentiometer in Figure 3-3 is being used as a voltage divider. As the wiper rotates the output voltage will be proportional to the angle of rotation.

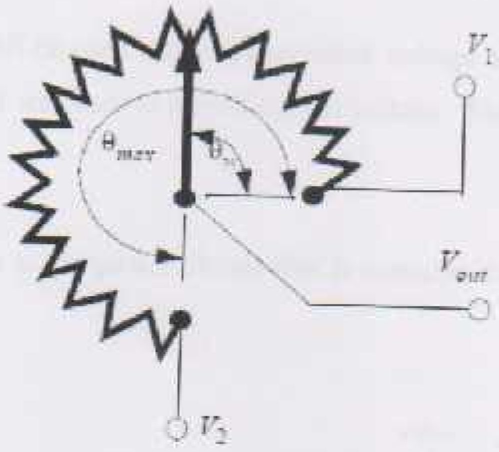


Figure (3.5): Potentiometer as a Voltage Divide

$$V_{out} = (V_2 - V_1)\left(\frac{\theta_w}{\theta_{max}}\right) + V_1 \qquad (3.15)$$

Potentiometers are popular because they are inexpensive, and don't require special signal conditioners. But, they have limited accuracy, normally in the range of 1% and they are subject to mechanical wear.

Potentiometers measure absolute position, and they are calibrated by rotating them in their mounting brackets, and then tightening them in place. The range of rotation is normally limited to less than 360 degrees or multiples of 360 degrees. Some potentiometers can rotate without limits, and the wiper will jump from one end of the resistor to the other.

3.5 Power circuit

The power circuit will be used because the output voltage of differential amplifier is small , the power circuit will uses to amplificat the voltage that is used as a input to the DC motor.

The following figure is the power circuit that is contains the limit switches used in logic control.

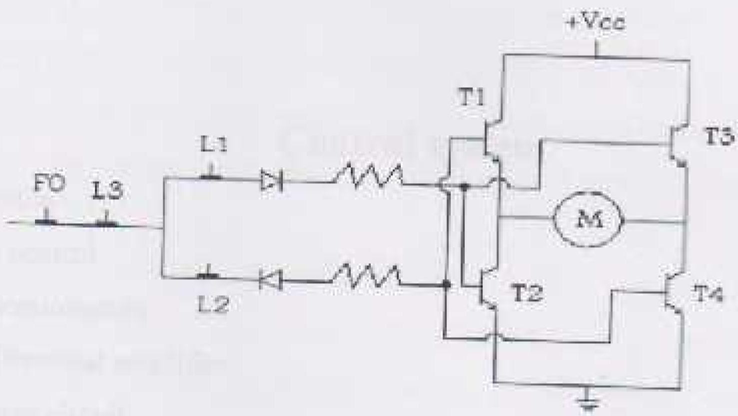


figure (3.6):the power circuit of position control

The symbols in figure 3-5. (T1,2,3,4):is a transistors used in H-BRIDEG to amplify the voltage and inverting the rotation of dc motor,(L1):limit switch for motor at angel (40 degree), (L2):limit switch for the motor at angel (0 degree), (l3):limit switch when the pin of supported beam is potted in the supported beam,(F0): is the over load of the motor .

Chapter 4

Control system

4.1 Introduction

Control system is an integral part of modern society numerous application are all around us: the rockets fire ,and the space shuttle lifts off to earth orbit; in splashing cooling water, metallic part is automatically machined; a self-guided vehicles delivering material to workstation in an aerospace assembly plan glides along the floor seeking its destination. These are just a few examples of the automatically controlled systems that we can create.

In this chapter will talks how use the position control for control of the angle of conveyor; and will use logic control for control of the sequence of operations in the conveyor system in the same loop of position control, also will talk how to use the speed control to drive the AC motor in constant speed.

4.2 position control

The position control system converts a position input command to a position output response .position control systems find widespread application in antennas, robot arms, and computer disk, for this system its uses for control of the angle of conveyor.

The position control design of conveyor system is required the following component that is shown in figure 4.1:-

1-Two potentiometers

2-Diferantial amplifier

3-Power circuit

4- Motor and load plant

4.2.1 Potentiometers

As shown in figure 4.1, the two potentiometers; one for input the desired angle by changing the resistance of the potentiometer; and the other potentiometer for feedback the output angle by the same way.

4.2.2 Differential amplifier

The differential amplifier is used for summing the voltage proportional to the input from the first potentiometer and the voltage proportional to the output from the feedback potentiometer, the output of the differential amplifier goes to the power amplifier.

4.2.3 Power circuit

The power circuit is used for convert low electrical power to high electrical power that can drive the dc motor, the voltage which is the output of differential amplifier (error) can not be turn on the DC motor because its always small value, the power circuit amplify this value to give the motor the Vcc voltage that is appear in the figure (3.5) in chapter three which is can drive the DC motor regardless the value of the error, this means the motor will be work under any value of error.

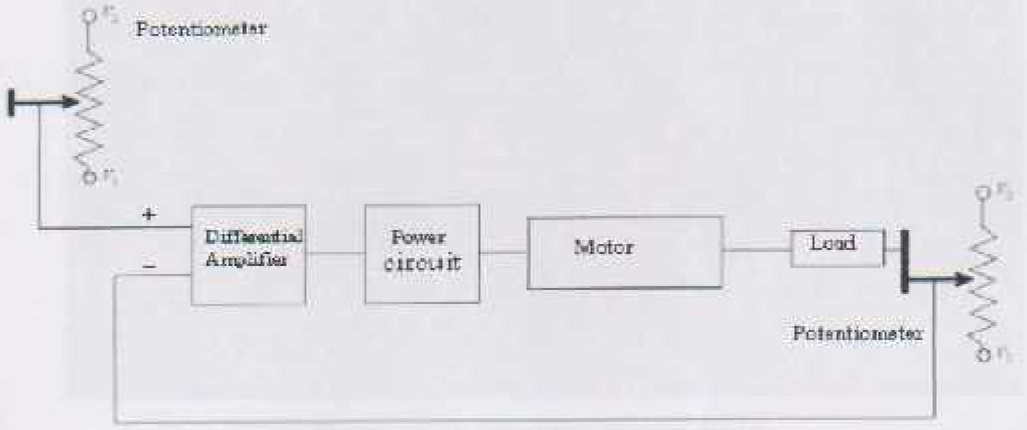


Figure (4.1) schematic diagram of position control

In figure 4-1 when you turn the first potentiometer to desired angle, the resistance of potentiometer will be change, the same story for the input voltage this means the output voltage of differential amplifier not zero, and so the power circuit will be give the power needed to turn on the motor.

When the motor is turn on the load of dc motor is moved and the angle(θ) in figure 4-2 will be change ,this cause the feedback potentiometer to turn and feedback the output angle, when the input angle equal to the output angle the differential amplifier drive the output to zero and the dc-motor will be turn off.

Figure (4.2): conveyor system design

4.3 Position control transfer functions

For the schematic diagram of position control the transfer function of each sub system will be determined.

4.3.1 The input and output potentiometers transfer function

Since the input and output potentiometers are Plant of configured in the same way, then their transfer function will be the same, the relation between the output voltage and the input angular displacement, since the input angel is (40 degree), the output voltage will be (2.667 V).

$$\frac{V_i(s)}{\theta_i(s)} = \frac{2.667}{0.222\pi} = \frac{12}{\pi} \tag{4.1}$$

4.3.2 Differential amplifier and Power circuit

The transfer function of the differential amplifier which is the voltage from the differential amplifier ($V_p(s)$) divided by the voltage from potentiometers ($V_e(s)$), will be determined later by root locus design in matlab program is:

$$\frac{V_p(s)}{V_e(s)} = K \tag{4.2}$$

The transfer function of power circuit where the $E_a(s)$ is the voltage to motor and $V_p(s)$ is power from differential amplifier is:

$$\frac{E_a(s)}{V_p(s)} = 10 \tag{4.3}$$

4.3.3 Motor and load

The transfer function of DC motor and load is described in the following equation [4]:

$$\frac{\theta_m(s)}{E_a(s)} = \frac{K_t/(R_a J_m)}{s\left[s + \frac{1}{J_m}\left(D_m + \frac{K_t K_b}{R_a}\right)\right]} \tag{4.4}$$

If you know the ($T_{stall} = 850 \ \ Nm$), ($\omega_{no-load} = 14.5 \ \ rad/s$), ($e_a = 100 \ \ V$), and the gear ratio (a=0.1278), then:

$$\frac{K_t}{R_A} = \frac{T_{stall}}{e_a} = \frac{850}{100} = 8.5 \tag{4.5}$$

$$K_b = \frac{e_a}{\omega_{no-load}} = \frac{100}{14.5} = 6.9 \tag{4.6}$$

$$J_m = J_a + a^2 J_L = 15 \tag{4.7}$$

$$D_m = D_a + a^2 D_L = 12 \tag{4.8}$$

The transfer function of the 2hp dc motor is:

$$\frac{\theta_m(s)}{E_a(s)} = \frac{(8.5/15)}{s\left[s + \frac{1}{15}\left(12 + (8.5)(6.9)\right)\right]} \quad (4.9)$$

$$\frac{\theta_m(s)}{E_a(s)} = \frac{0.567}{s(s+4.7)} \quad (4.10)$$

When the gear ratio is (a =0.178), then the transfer function is:

$$\frac{\theta_G(s)}{E_a(s)} = \frac{(0.1278)0.567}{s(s+4.7)} \quad (4.11)$$

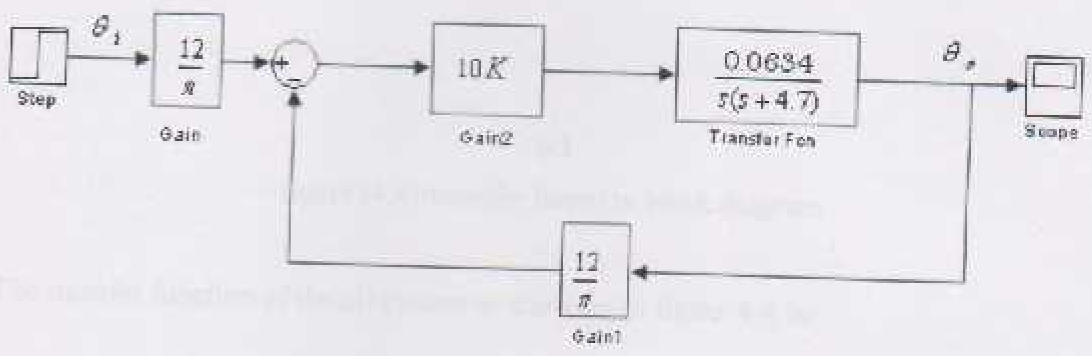
If the ratio between the output angle at the load and the input angle to the screw is (0.88) then the all transfer function of the motor and the load will be:

$$\frac{\theta_l(s)}{E_a(s)} = \frac{0.072(0.88)}{s(s+4.7)} \quad (4.12)$$

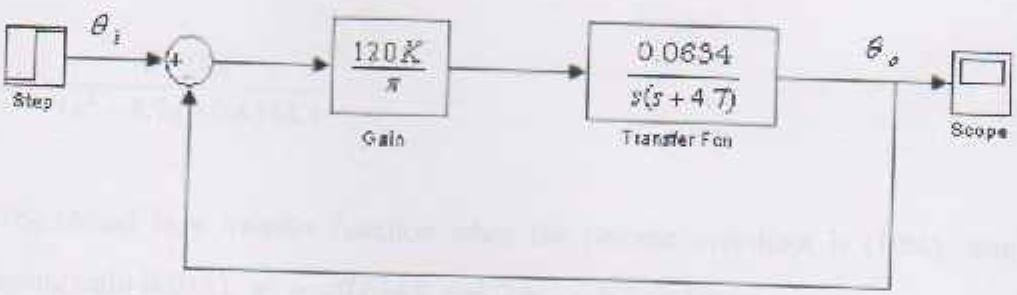
$$G_m(s) = \frac{\theta_L(s)}{E_a(s)} = \frac{0.0634}{s(s+4.7)} \quad (4.13)$$

4.3.4 The transfer function of the all system

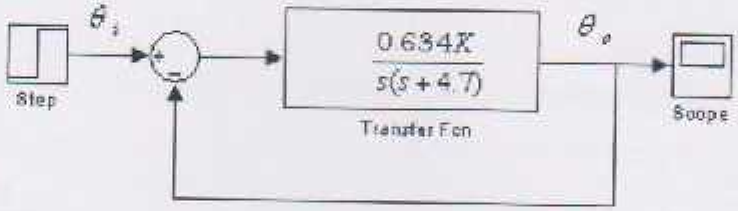
The transfer function of the system is the combination of all subsystems; figure4-4 (transfer function block diagram) will illustrate that.



(a)



(b)



(c)

figure (4.4):transfer function block diagram

The transfer function of the all system as showing in figure 4-4 is:

$$G(s) = \frac{0.634K}{s(s+4.7)} \tag{4.14}$$

The closed loop transfer function is:

$$T(s) = \frac{0.634K}{(s^2 + 4.7s + 0.634K)} \tag{4.15}$$

For closed loop transfer function when the percent overshoot is (10%), then the damping ratio is (0.6), $w_n = \sqrt{0.634K}$ and $2\xi w_n = 4.7$ and then:

$\omega_n = 3.98$, from the last values ($K = 25$), this mean the closed loop transfer function of the all system will be:

$$T(s) = \frac{15.85}{(s^2 + 4.7s + 0.634K)} \qquad (4.16)$$

And

$$G(s) = \frac{15.85}{s(s + 4.7)} \qquad (4.17)$$

4.3.5 Matlab analysis

From the matlab program the root locus of this transfer function is:

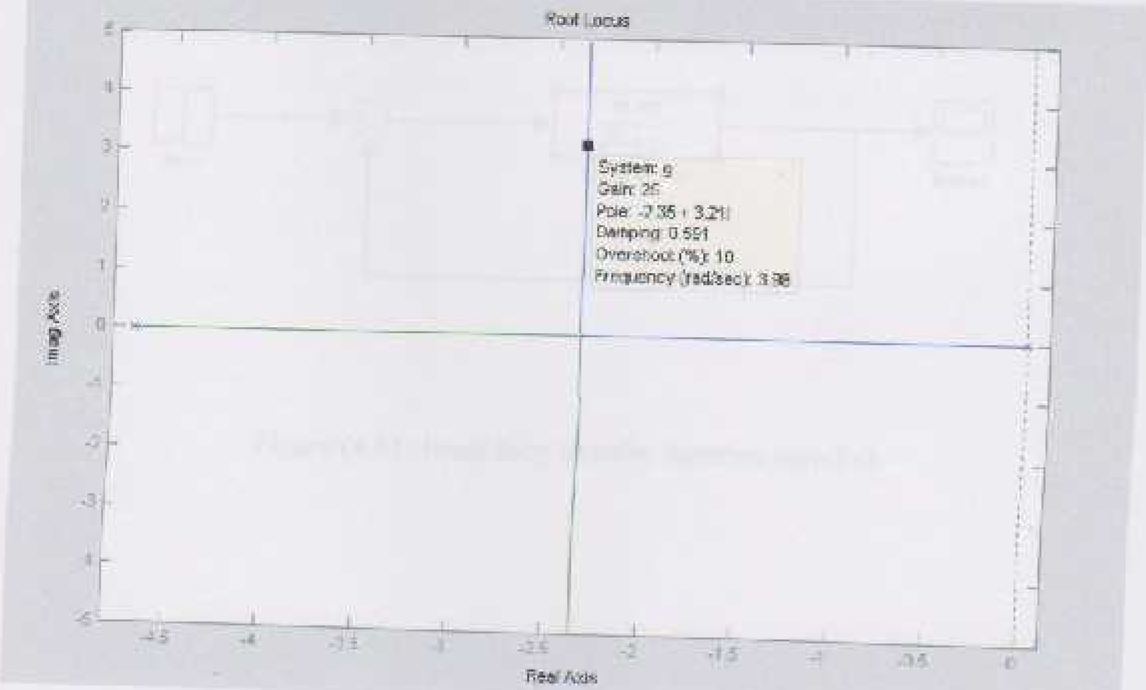


Figure (4.5): root locus of the transfer function

From the root locus in figure 4-5 the value of dominant poles is (-2.35 ± 3.21), this mean $\varpi_d = 3.21$, and $\varpi_n = 3.98$, the settling time (T_s) and the peak time (T_p) is:

$$T_s = \frac{4}{\xi\omega_n} = 1.67 \tag{4.18}$$

$$T_s = \frac{\pi}{\omega_d} = 0.98 \tag{4.19}$$

The simulink of this transfer function will gives:

Figure (4.6) closed loop transfer function simulink

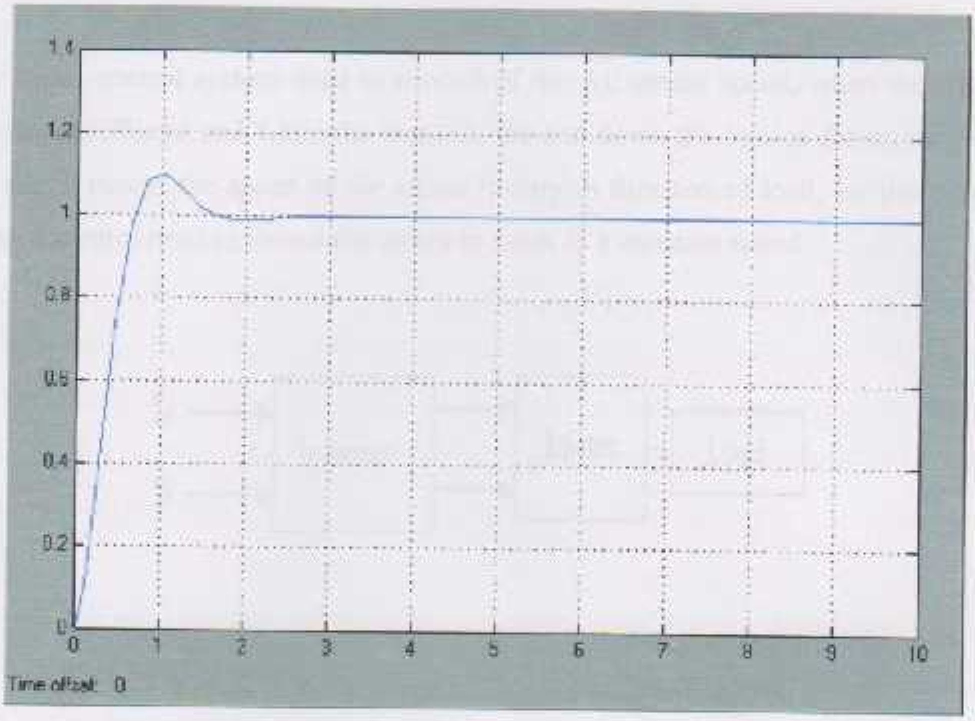


Figure (4.7) the behavior of the system when a step function is applied

4.5 schematic diagram of speed control

The speed control system used to control of the AC motor speed, when the angel of conveyer is different and when the motor is lift and down the load at the motor will be vary, which means the speed of the motor is vary in function of load, for this problem the speed control used to forced the motor to work in a constant speed.

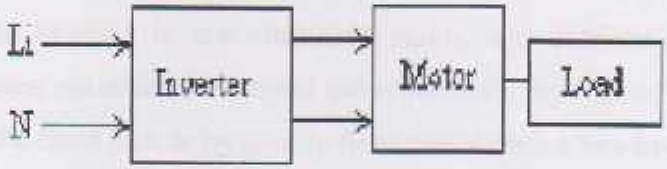


Figure (4.8) : schematic diagram of speed control

4.5.1 description of the circuit

when the load is varying that means the input voltage and the frequency of the motor will change then the speed of the motor will change, but we need a fixed motor speed, and this will achieve by using the inverter which contains PID controller internally that will keep the ratio between the voltage and the frequency relates to the motor fixed, then the speed of the motor will be constant.

Conclusion

Conveyors are used when material must be moved in relatively large quantities between specific locations over a fixed path. The fixed path is implemented by a tack system, which may be in-the-floor, above-the-floor. Conveyors divided into two basic categories (1) powered and (2) non-powered. In powered conveyors, the power mechanism is contained in the fixed path, using chains, belt, rotating rolls, or other device to load along the path. Powered conveyors are commonly used in automated material transport systems in manufacturing plants, and distribution center. In non-powered conveyors, materials are moved either manually by human workers who push the loads along the fixed path or by gravity from one elevation to a lower elevation.

This project was designed a conveyor with variable angle and achieved the aim of the project which determined in the introduction which are design the conveyor with flexibility in the work and low cost, also it achieves the need of the market by moving the material in variable heights by controlling the angle of height.

The mechatronics design approach was appear in the project specially when determine the conceptual design between every conceptual design we studied the problem that occurred then by this way we change the conceptual design more than one to achieve optimization.

After the conceptual design determined, the following is the design of each mechanical component separately, by using the CATYA program in drawing the mechanical elements and the ANSYS program to determine the stress, deflection that happens to each element then comparing, that will give us the size each mechanical element, by comparing the results which ANSYS give us of each element to the maximum result in the design table we notice that our result is logic and true, also it is able to apply.

By calculating the torque which the maximum load acting, we chose the motor one is DC nearly with 1.5hp motor which using for controlling the angle then controlling the height of the body of the conveyor, and this result is logically and able to apply, also we have an AC motor with 2hp which using for moving the materials from one place to another, and this motor is available and logically to use.

At the end we apply the result which get from ANSYS program and the result of electrical elements, AC & DC motor, to a prototype that achieve all the goals of this project specially the control of the angle of the conveyor height.

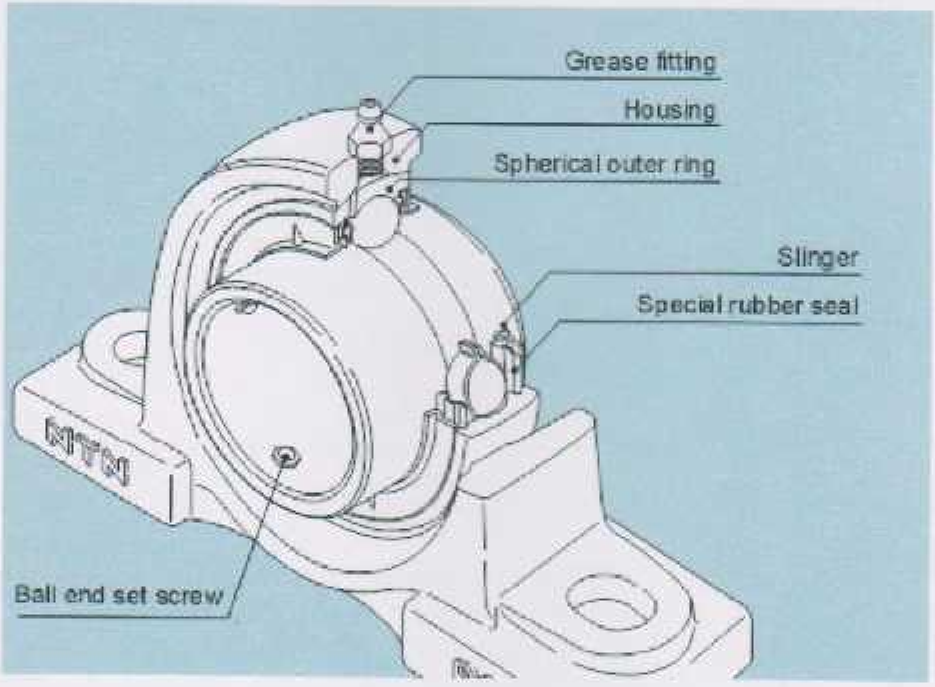
Appendix A

Ball bearing unit

A.1. Construction

The NTN bearing unit is a combination of a radial ball bearing, seal, and a housing of high-grade cast iron or pressed steel, which comes in various shapes. The outer surface of the bearing and the internal surface of the housing are spherical, so that the unit is self-aligning.

The inside construction of the ball bearing for the unit is such that steel balls and retainers of the same type as in series 62 and 63 of the NTN deep groove ball bearing are used. A duplex seal consisting of a combination of an oil-proof synthetic rubber seal and a slinger, unique to NTN, is provided on both sides.



A.2 ball bearing unit

Three kinds of ball bearing that used as mechanical element

1- UCF2
2- UCP2
3- UCT2

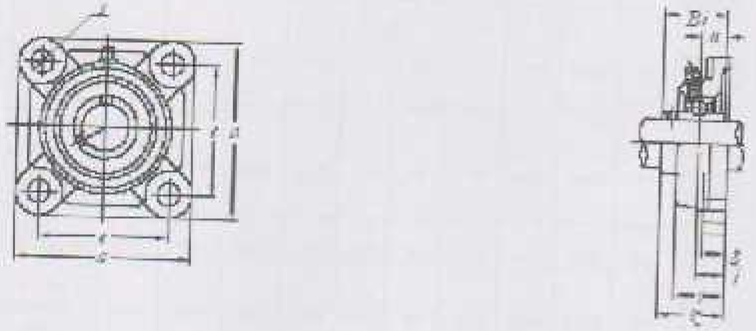


Figure (A.1): UCF2 ball bearing

Table (A.1): UCF2 ball bearing characteristics

Shaft dia. mm / inch	Unit number	Nominal dimensions mm / inch									Bolt size mm / inch	Bearing number	Housing number	Mass of unit kg
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13/16 7/8 15/16 1	UCF X05-13 UCF X05-14 UCF X05-15 UCF X05-16	4-7/16	3-1/4	45/64	5/64	1-3/16	15/32	1-37/64	1.5000	3.0269	3/8	UC X05-13 UC X05-14 UC X05-15 UC X05-16	F X05	1.20 1.18 1.16 [illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1-1/16 1-1/8 1-3/16 1-1/4	UCF X06-17 UCF X06-18 UCF X06-19 UCF X06-20	4-29/64	2-5/8	3/4	35/64	1-11/32	5/8	1-3/4	1.6890	3.6890	1/2	UC X06-17 UC X06-18 UC X06-19 UC X06-20	F X06	1.52 1.51 1.48 1.47
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1-1/4 1-5/16 1-3/8 1-7/16	UCF X07-20 UCF X07-21 UCF X07-22 UCF X07-23	5-1/8	3-63/64	53/64	35/64	1-1/2	3/8	2-1/64	1.8070	3.7480	1/2	UC X07-20 UC X07-21 UC X07-22 UC X07-23	F X07	2.07 2.00 1.96 1.95
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1-1/2	UCF X08-24	5-35/64	4-9/64	55/64	35/64	1-37/64	3/4	2-1/16	1.3370	3.7460	5/8	UC X08-24	F X08	3.23
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1-5/8 1-11/16 1-3/4	UCF X09-26 UCF X09-27 UCF X09-28	5-5/8	4-3/8	29/32	35/64	1-37/64	3/4	2-3/16	2.0315	3.4488	5/8	UC X09-26 UC X09-27 UC X09-28	F X09	2.42 2.43 2.39
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1-7/8 1-15/16 2	UCF X10-30 UCF X10-31 UCF X10-32	6-3/8	5-1/4	1-1/64	35/32	1-47/64	3/4	2-11/32	2.1500	3.8740	5/8	UC X10-30 UC X10-31 UC X10-32	F X10	3.57 3.50 3.44
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2 2-1/16 2-1/8 2-3/16	UCF X11-32 UCF X11-33 UCF X11-34 UCF X11-35	6-57/64	5-5/8	1-3/64	35/32	1-59/64	3/4	2-45/64	2.3630	4.0000	5/8	UC X11-32 UC X11-33 UC X11-34 UC X11-35	F X11	4.34 4.31 4.29 4.11

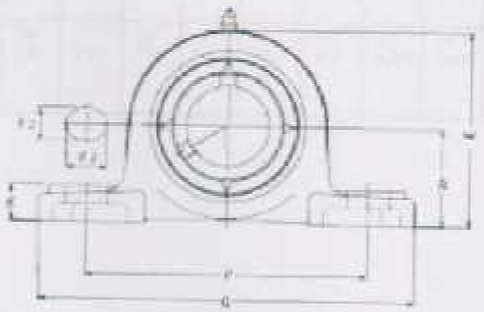
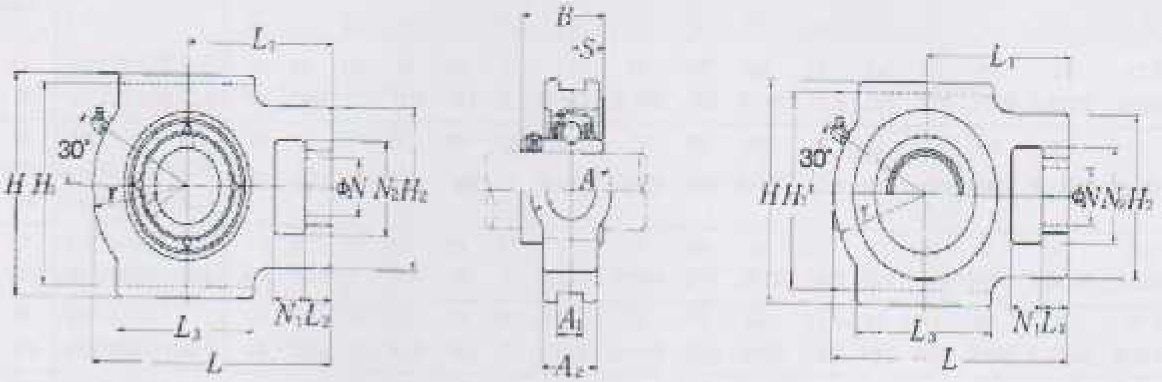


Figure (A.2): UCP2 ball bearing

Table (A.2): UCP2 ball bearing characteristics

PILLOW BLOCKS - CAST HOUSING															
Shaft Dia.	Complete Pillow Block Number	Nominal Dimensions										Bolt Size	Housing Number	Bearing Number	Basic Load Ratings (lbs)
		H	L	J	A	N_1	N_2	H_1	H_2	B_i	n				Dynamic C_r / Static C_{0r}
12 1/2	UCP201D1 UCP201-008T	30.2 1 3/16	127 5	95 3 3/4	38 1 1/2	13 1/2	16 5/8	14 9/16	62 2 7/16	31 1.220	12.7 .500	M10 3/8	P203D1 P203T	UC201D1 UC201-008D1	2,890 / 1,500
15 9/16 5/8	UCP202D1 UCP202-009T UCP202-010T	30.2 1 3/16	127 5	95 3 3/4	38 1 1/2	13 1/2	16 5/8	14 9/16	62 2 7/16	31 1.220	12.7 .500	M10 3/8	P203D1 P203T P203T	UC202D1 UC202-009D1 UC202-010D1	2,890 / 1,500
17 11/16	UCP203D1 UCP203-011T	30.2 1 3/16	127 5	95 3 3/4	38 1 1/2	13 1/2	16 5/8	14 9/16	62 2 7/16	31 1.220	12.7 .500	M10 3/8	P203D1 P203T	UC203D1 UC203-011D1	2,890 / 1,500
20 3/4	UCP204D1 UCP204-012T	33.3 1 5/16	127 5	95 3 3/4	38 1 1/2	13 1/2	16 5/8	14 9/16	65 2 9/16	31 1.220	12.7 .500	M10 3/8	P204D1 P204T	UC204D1 UC204-012D1	2,890 / 1,500
25 13/16 7/8 15/16 1	UCP205D1 UCP205-013T UCP205-014T UCP205-015T UCP205-100T	36.5 1 7/16	140 5 1/2	105 4 1/8	38 1 1/2	13 1/2	16 5/8	15 19/32	71 2 51/64	34 1.339	14.3 .563	M10 3/8	P205D1 P205T P205T P205T P205T	UC205D1 UC205-013D1 UC205-014D1 UC205-015D1 UC205-100D1	3,150 / 1,770
30 1 1/16 1 1/8 1 3/16 1 1/4	UCP206D1 UCP206-101T UCP206-102T UCP206-103T *UCP206-104T	42.9 1 11/16	165 6 1/2	121 4 3/4	48 1 7/8	17 21/32	20 25/32	17 21/32	83 3 17/64	38.1 1.500	15.9 .626	M14 1/2	P206D1 P206T P206T P206T P206T	UC206D1 UC206-101D1 UC206-102D1 UC206-103D1 UC206-104D1	4,880 / 2,540
35 1 1/4 1 5/16 1 3/8 1 7/16	UCP207D1 UCP207-104T UCP207-105T UCP207-106T *UCP207-107T	47.6 1 7/8	167 6 9/16	127 5	48 1 7/8	17 21/32	20 25/32	18 23/32	93 3 21/32	42.9 1.689	17.5 .689	M14 1/2	P207D1 P207T P207T P207T P207T	UC207D1 UC207-104D1 UC207-105D1 UC207-106D1 UC207-107D1	5,750 / 3,440
40 1 1/2 1 9/16	UCP208D1 UCP208-108T UCP208-109T	49.2 1 15/16	184 7 1/4	137 5 13/32	54 2 1/8	17 21/32	20 25/32	18 23/32	98 3 7/8	49.2 1.937	19 .748	M14 1/2	P208D1 P208T P208T	UC208D1 UC208-108D1 UC208-109D1	6,550 / 4,000
45 1 5/8 1 11/16 1 3/4	UCP209D1 UCP209-110T UCP209-111T UCP209-112T	54 2 1/8	190 7 15/32	146 5 3/4	54 2 1/8	17 21/32	20 25/32	20 25/32	106 4 3/16	49.2 1.937	19 .748	M14 1/2	P209D1 P209T P209T P209T	UC209D1 UC209-110D1 UC209-111D1 UC209-112D1	7,350 / 4,590
50 1 13/16 1 7/8 1 15/16 2	UCP210D1 UCP210-113T UCP210-114T UCP210-115T UCP210-200T	57.2 2 1/4	206 8 1/8	159 6 1/4	60 2 3/8	20 25/32	23 29/32	21 27/32	114 4 1/2	51.6 2.031	19 .748	M16 5/8	P210D1 P210T P210T P210T P210T	UC210D1 UC210-113D1 UC210-114D1 UC210-115D1 UC210-200D1	7,900 / 5,220
55 2 2 1/16 2 1/8 2 3/16	UCP211D1 UCP211-200T UCP211-201T UCP211-202T UCP211-203T	63.5 2 1/2	219 8 5/8	171 6 23/32	60 2 3/8	20 25/32	23 29/32	23 29/32	126 4 31/32	55.6 2.189	22.2 .874	M16 5/8	P211D1 P211T P211T P211T P211T	UC211D1 UC211-200D1 UC211-201D1 UC211-202D1 UC211-203D1	9,750 / 6,570
60 2 1/4 2 3/8 2 7/16	UCP212D1 UCP212-204T UCP212-206T *UCP212-207T	69.8 2 3/4	241 9 1/2	184 7 1/4	70 2 3/4	20 25/32	23 29/32	25 31/32	138 5 7/16	65.1 2.563	25.4 1.000	M16 5/8	P212D1 P212T P212T P212T	UC212D1 UC212-204D1 UC212-206D1 UC212-207D1	11,800 / 8,100

3- UCT2 ball bearing



Pressed steel dust cover type
Open end: S-UCT[illegible] D1
Closed end: SM-UCT[illegible] D1

Shaft dia. mm / inch	Unit number[1]	Nominal dimensions mm / inch															
		N_1	L_1	H_1	N_2	N	L_2	A_2	H_2	H	L	A_1	A	a	L_3	B	S
12	UCT201D1	16	12	51	32	19	51	12	76	89	94	21	32	33	61	31	12.7
1/2	UCT201-008D1	5/8	15/32	2	1 1/4	3/4	2	0.472	2 63/64	3 1/2	3 11/16	13/16	1 1/4	1 5/16	2 13/32	1.2205	0.500
15	UCT202D1	16	12	51	32	19	51	12	76	89	94	21	32	33	61	31	12.7
9/16	UCT202-009D1	5/8	15/32	2	1 1/4	3/4	2	0.472	2 63/64	3 1/2	3 11/16	13/16	1 1/4	1 5/16	2 13/32	1.2205	0.500
5/8	UCT202-010D1																
17	UCT203D1	16	12	51	32	19	51	12	76	89	94	21	32	33	61	31	12.7
11/16	UCT203-011D1	5/8	15/32	2	1 1/4	3/4	2	0.472	2 63/64	3 1/2	3 11/16	13/16	1 1/4	1 5/16	2 13/32	1.2205	0.500
20	UCT204D1	16	12	51	32	19	51	12	76	89	94	21	32	33	61	31	12.7
3/4	UCT204-012D1	5/8	15/32	2	1 1/4	3/4	2	0.472	2 63/64	3 1/2	3 11/16	13/16	1 1/4	1 5/16	2 13/32	1.2205	0.500
25	UCT205D1	16	12	51	32	19	51	12	76	89	97	31	32	35	82	34.1	14.3
13/16	UCT205-013D1																
7/8	UCT205-014D1	5/8	15/32	2	1 1/4	3/4	2	0.472	2 63/64	3 1/2	3 13/16	1 5/16	1 1/4	1 3/8	3 3/16	1.3425	0.563
15/16	UCT205-015D1																
1	UCT205-100D1																
30	UCT206D1	16	12	56	37	22	57	12	89	102	113	28	37	43	70	38.1	15.9
1 1/16	UCT206-101D1																
1 1/8	UCT206-102D1	5/8	15/32	2 7/32	1 15/32	7/8	2 1/4	0.472	3 1/2	4 1/32	4 7/16	1 3/32	1 15/32	1 11/16	2 3/4	1.5000	0.626
1 3/16	UCT206-103D1																
1 1/4	UCT206-104D1																
35	UCT207D1	16	15	64	37	22	64	12	89	102	129	30	37	51	78	42.9	17.5
1 1/4	UCT207-104D1																
1 5/16	UCT207-105D1	5/8	19/32	2 17/32	1 15/32	7/8	2 17/32	0.472	3 1/2	4 1/32	5 3/32	1 3/16	1 15/32	2	3 1/16	1.6890	0.689
1 3/8	UCT207-106D1																
1 7/16	UCT207-107D1																
40	UCT208D1	19	18	83	49	29	83	16	102	114	144	33	49	56	88	49.2	19
1 1/2	UCT208-108D1	3/4	23/32	3 9/32	1 15/16	1 5/32	3 9/32	0.630	4 1/64	4 1/2	5 21/32	1 5/16	1 15/16	2 7/32	3 15/32	1.9370	0.748
1 9/16	UCT208-109D1																
45	UCT209D1	19	18	83	49	29	83	16	102	117	145	35	49	57	88	49.2	19
1 5/8	UCT209-110D1																
1 11/16	UCT209-111D1	3/4	23/32	3 9/32	1 15/16	1 5/32	3 9/32	0.630	4 1/64	4 19/32	5 23/32	1 3/8	1 15/16	2 1/4	3 15/32	1.9370	0.748
1 3/4	UCT209-112D1																

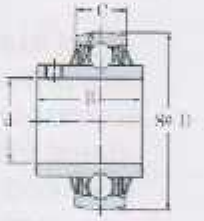
Remarks: 1) These numbers indicate relubricatable type. If maintenance free type is needed, please order without suffix "D1".
Note: Please refer to page 25 for size of grease fitting.

3. Tolerance

The tolerances of the **NTN** bearing units are in accordance with the following JIS specifications :

3.1 Tolerances of ball bearings for the unit

The tolerances of ball bearings used in the unit are shown in the following tables, 3.1 to 3.4.



Set screw type

Table 3.1 (1) Cylindrical bore (UC, UCS, AS, ASS, UEL, UELS, AEL, AELS)

Unit : m/0.0001 inch

Nominal bore diameter d				Cylindrical bore					Radial runout K_{ia} (reference)
over		incl		Bore diameter			Width		
				Δ_{dmp} Deviations		V_{dp} Variations	Δ_{Bs}, Δ_{Cs} Deviations (reference)		
mm	inch	mm	inch	high	low	max	high	low	(max)
10	0.3937	18	0.7087	h 15 h 6	0 0	10 4	0 0	h 120 h 47	15 6
18	0.7087	31.750	1.2500	h 18 h 7	0 0	12 5	0 0	h 120 h 47	18 7
31.750	1.2500	50.800	2.0000	h 21 h 8	0 0	14 6	0 0	h 120 h 47	20 8
50.800	2.0000	80	3.1496	h 24 h 9	0 0	16 6	0 0	h 150 h 59	25 10
80	3.1496	120	4.7244	h 28 h 11	0 0	19 7	0 0	h 200 h 79	30 12
120	4.7244	180	7.0866	h 33 h 13	0 0	22 9	0 0	h 250 h 98	35 14

Note: Symbols
Δ_{dmp}: Mean bore diameter deviation V_{dp}: Bore diameter variation
Δ_{Bs}: Inner ring width deviation
Δ_{Cs}: Outer ring width deviation

7. Lubrication

As bearings in **NTN** bearing units have sufficient high-grade grease sealed in at the time of manufacture, there is no need for replenishment while in use. The amount of grease necessary for lubrication is, in general, very small. With the **NTN** bearing units, the amount of grease occupies about a half to a third of the space inside the bearing.

7.1 Maximum permissible speed of rotation

The maximum speed possible while ensuring the safety and long life of ball bearings used in the unit is limited by their size, the circumferential speed at the point where the seal comes into contact, and the load acting on them.

To indicate the maximum speed permissible, it is customary to use the value of dn or $d_m n$ (d is the bore of the bearing; d_m is the diameter of the pitch circle= (I.D.+O.D.) /2; n is the number of revolutions).

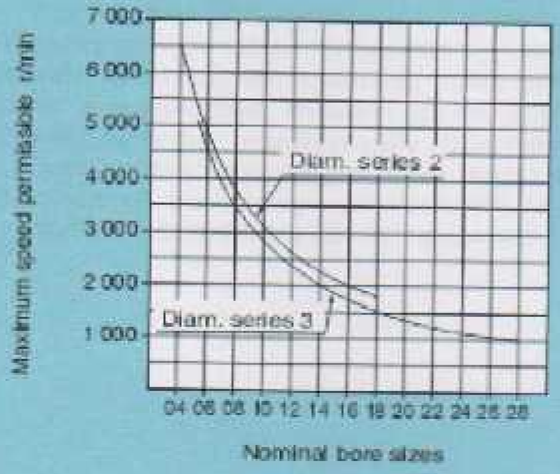


Fig.7.1

Problems connected with the lubrication of bearings are the generation of heat and seizures occurring at the sliding parts inside the bearing, in particular at the points where the ball is in contact with the retainer, inner and outer rings. The contact pressure at the points where friction occurs on the retainer is only slightly affected by the load acting on the bearing; the amount of heat generated there is approximately in proportion to the sliding velocity. Therefore, this sliding velocity serves as a yardstick to measure the limit of the rotating speed of the bearing. In the case of a bearing unit, however, there is another large factor that has to be taken into account— the circumferential speed at the part where the seal is in contact.

The graph in Fig. 7.1 indicates the maximum speed of rotation permissible, taking into account the aforementioned factors.

There are two common methods of locking the bearing unit onto the shaft— the set screw system and the eccentric collar system. However, in both of these systems high-speed operation will cause deformation of the inner ring, which may result in vibration of the bearing. For high-speed operation, therefore, it is recommended that an interference fit or a clearance fit with a near-zero clearance be used, with a shaft of the larger size as shown later in this manual in Fig. 8.1, Fig. 8.6.

For standard bearing units with the contact type seal, the maximum speed permissible is 120 000/d. Where a higher speed is required, bearing units with the non-contact type seal, are advised. Please contact **NTN** regarding the use of the latter type. Additionally, it is necessary that the surface on which the housing is mounted be finished to as a high a degree of accuracy as possible. A regularity of within ± 0.05mm, ± 0.002 inch is required.

Appendix B

Project cost

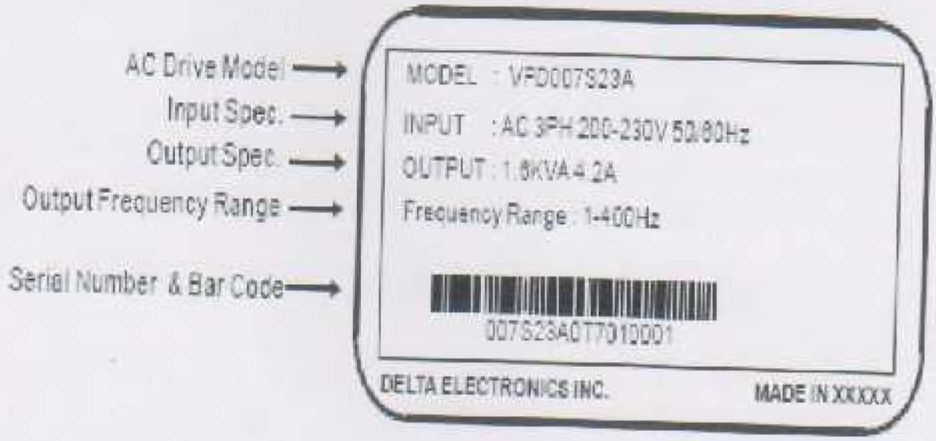
The total cost of this project are determined with respect to local market so that the cost of each part indicated separately, the total cost are indicated in the following table

	part	Description	Cost NIS
1	DC motor and friction gear	Used for driving belt	1600
2	AC motor and helical gear	Using for change the height	900
3	Rubber belt	With area 2.7 m^2	1400
4	Sheet of steel	With area 1.5 m^2 and thickness of 3 mm	400
5	U beam UPN 140	Conveyor side	700
6	Rectangular beam REC 80X40X4 mm	For building conveyor base	1500
7	Other structural steel parts	As shafts , cylinders, screws, nuts, rack	2000
8	Ball bearing unit and compression bearing		210
9	Electrical component	As overloads, limit switches , wires , potentiometers ,power circuit…,	1000
10	wheels	For wheels 5 inch	60
11	inverter	To control the speed of AC motor	500
		Total cost	10300

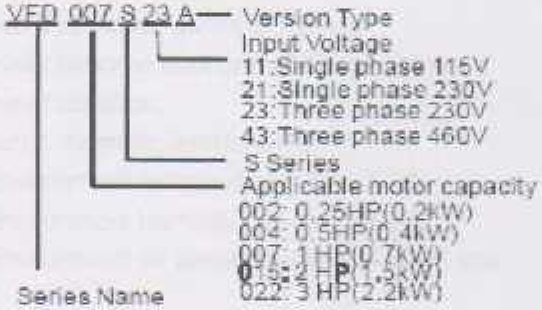
Appendix D

VFD Inverter

.1 Nameplate Information ☛Example for 1HP 230V AC drive



1.2 Model Explanation



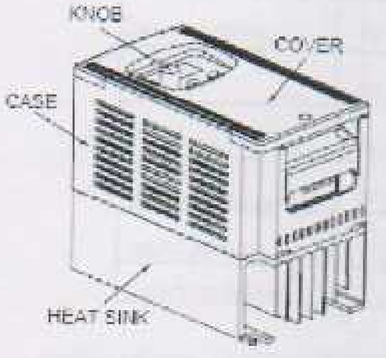
1.3 Serial Number Explanation

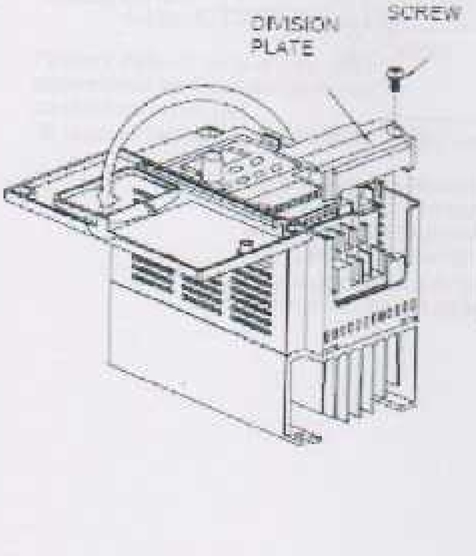
If there is any nameplate information not corresponding to your purchase order or any problem, please contact your supplier.

2.5 Environments

Avoid rain and moisture,
Avoid direct sunlight,
Avoid corrosive gases or liquids,
Avoid airborne dust or metallic particles,
Avoid vibration,
Avoid magnetic interference,
Environment temperature: -10 ~ 50°C,
Environment humidity: below 90% RH,
Environment air pressure: 86 kpa ~ 106 kpa.

2.6 Installation Steps





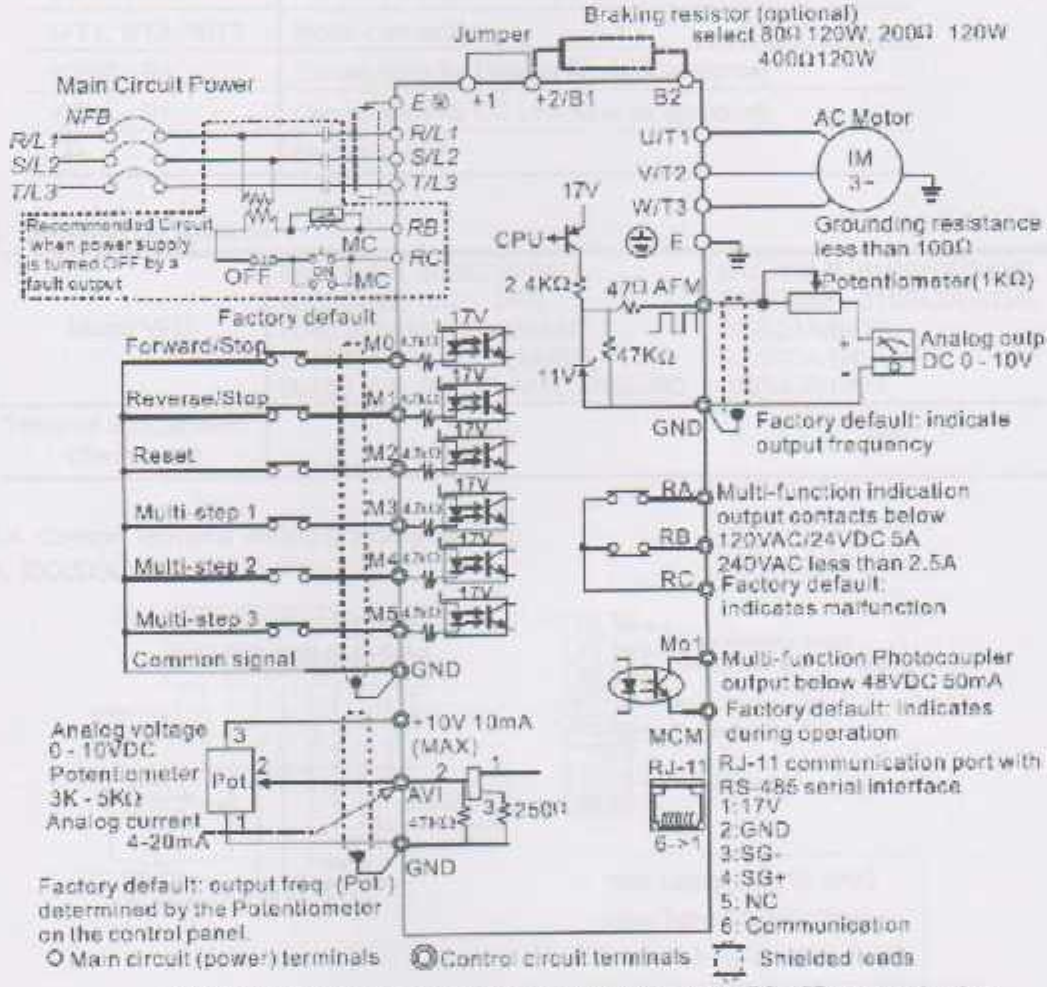
Installation Steps

1. Remove front cover screw and open.
2. Remove Division Plate.
   If using optional conduit bracket, please refer to next page.
3. Connect AC Input Power and motor leads. Never connect the AC drive output terminals U/T1, V/T2, W/T3 to main AC Input power.
4. Reinstall Division Plate.

3.1 Basic Wiring Diagram

Users must connect wiring according to the following circuit diagram shown below.

For VFDXXXSXXA/B/D



NOTE: Do not plug in a Modem or telephone line to the RS-485 communication port, permanent damage may result. Terminal 1 & 2 are the power sources for the optional copy keypad and should not be used while using RS-485 communication.

* If it is single phase model, please select any of the two input power terminals in main circuit power.

2. **Terminal Explanations**

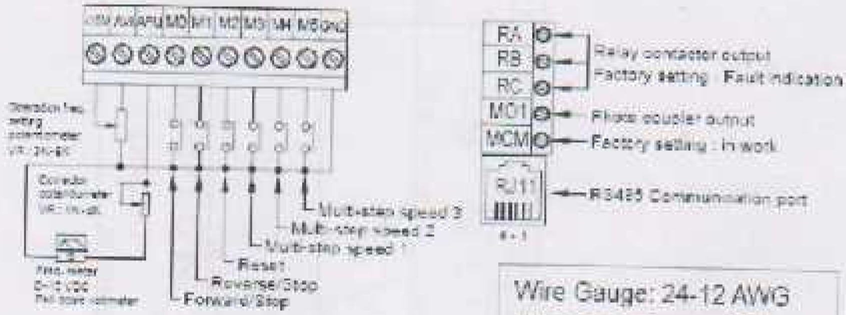
Terminal Symbol	Explanation of Terminal Function
R/L1, S/L2, T/L3	AC line input terminals (three phase)
L/L1, N/L2	AC line input terminals (single phase)
U/T1, V/T2, W/T3	Motor connections
+2/B2 – B1	Connections for Braking Resistor (optional)
+2/+1 – B1	Connections for DC Link Reactor (optional)
⏚	Earth Ground

3. **Terminal Dimensions**

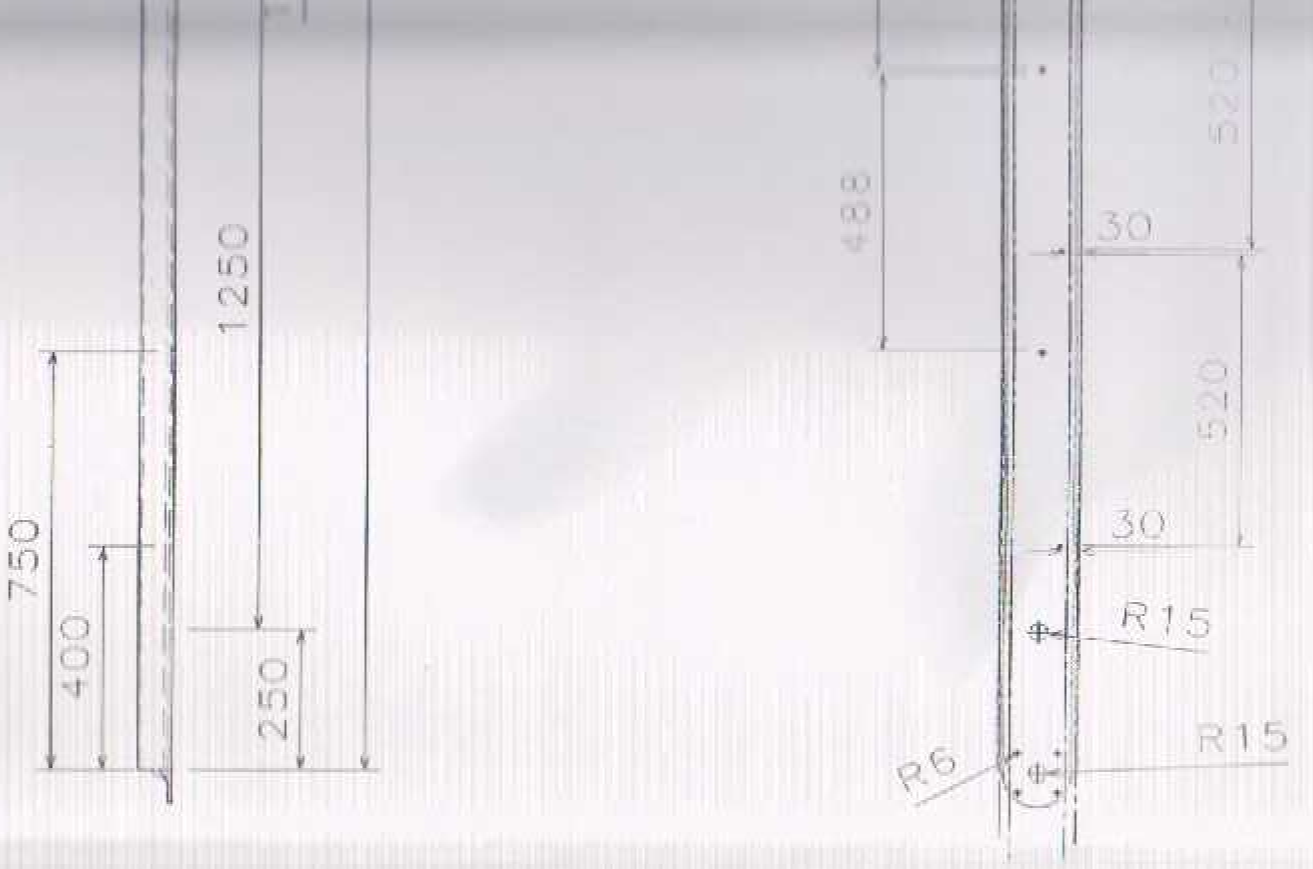
Model VFD-	002S11A/B, 002S21A/B/E, 002S23A/B, 004S11A/B, 004S 21A/B/E, 004S23A/B, 004S43A/B/E, 007S21A/B/E, 007S23A/B, 007S43A/B/E, 015S23D	007S11A/B, 015S21A/B/D/E, 015S23A/B, 015S43A/B/D/E, 022S21A/B/D/E, 022S23A/B/D, 022S43A/B/D/E
Terminal Specification (Terminal φ)	M3.5	M4

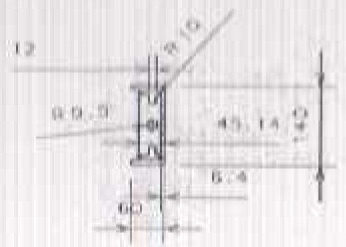
3.4 Control Terminal Wiring (Factory Setting)

A. XXXSXXA/B/D

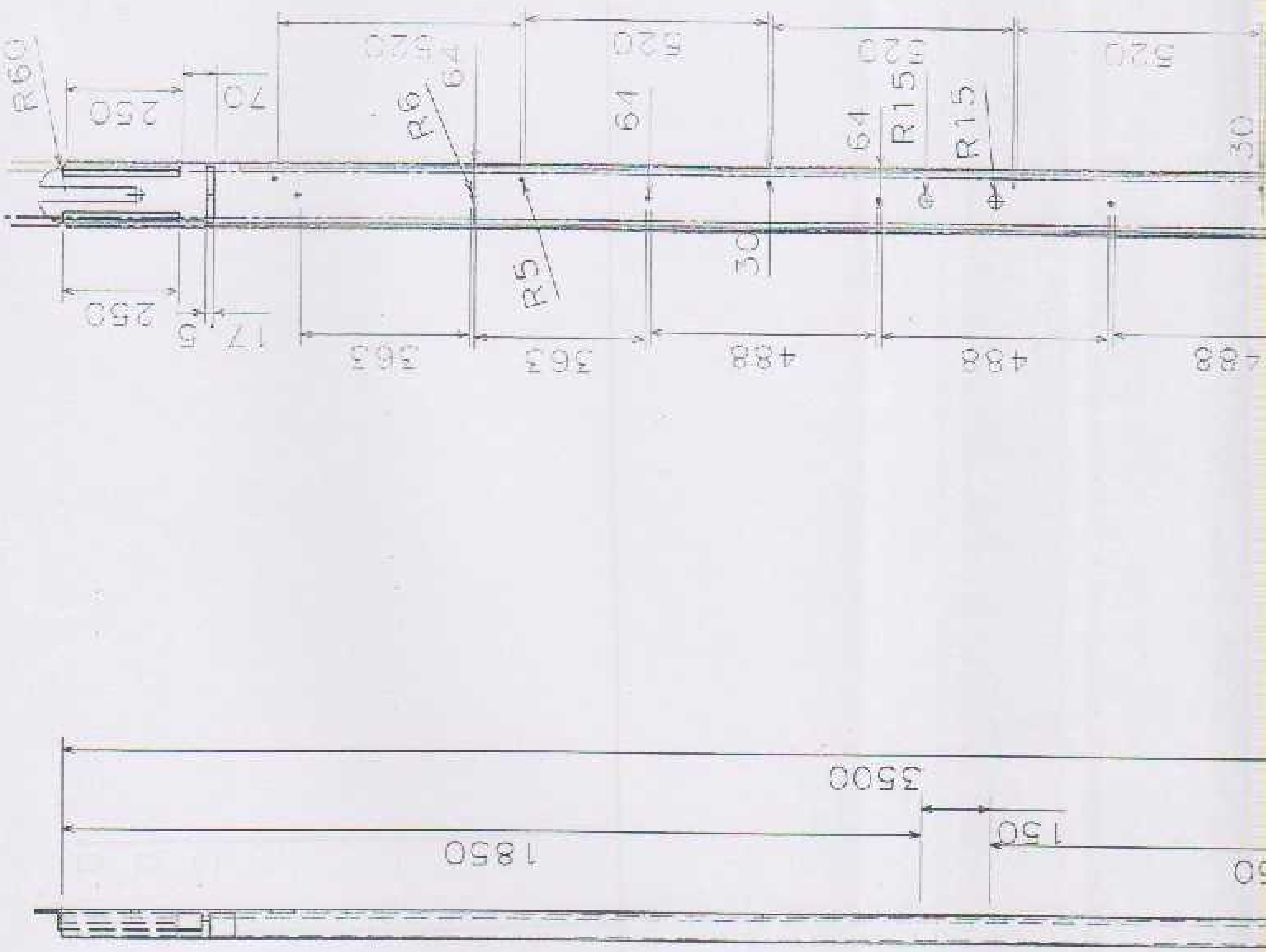


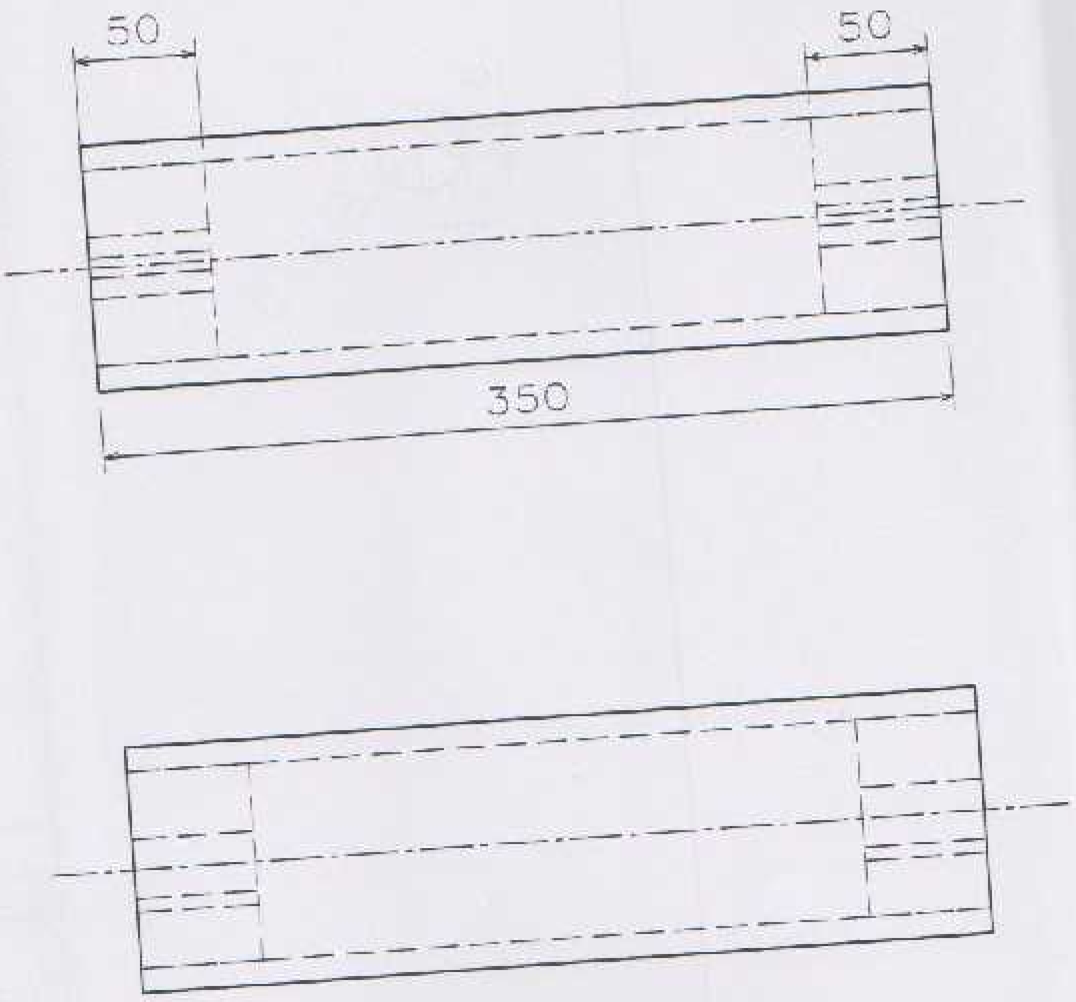
Wire Gauge: 24-12 AWG
Wire Type: Copper Only
Torque: 4 kgf-cm (3.5 in-lbf)





DESIGNED BY: ahmad DATE: 09/12/2006		conveyor side	
CHECKED BY: DATE:			
SIZE: A3			
SCALE: 1:13	WEIGHT (kg): 52	DRAWING NUMBER: Part1	dim: mm


R60
250
70
520
520
520
520
64
R6
64
64
R15
R15
30
30
R5
250
17.5
363
363
488
488
488
3500
150
1850



R12.

DESIGNED

DATE: 1

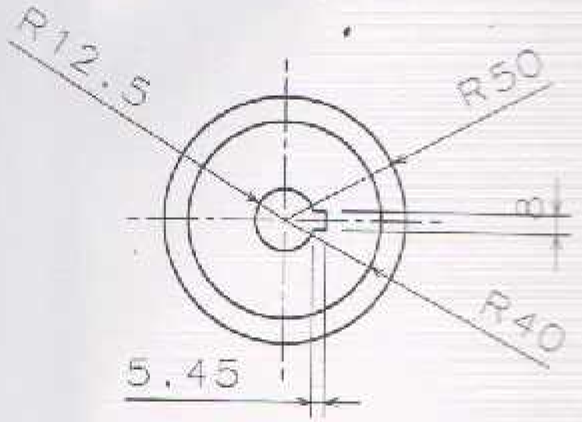
CHECKED

DATE:

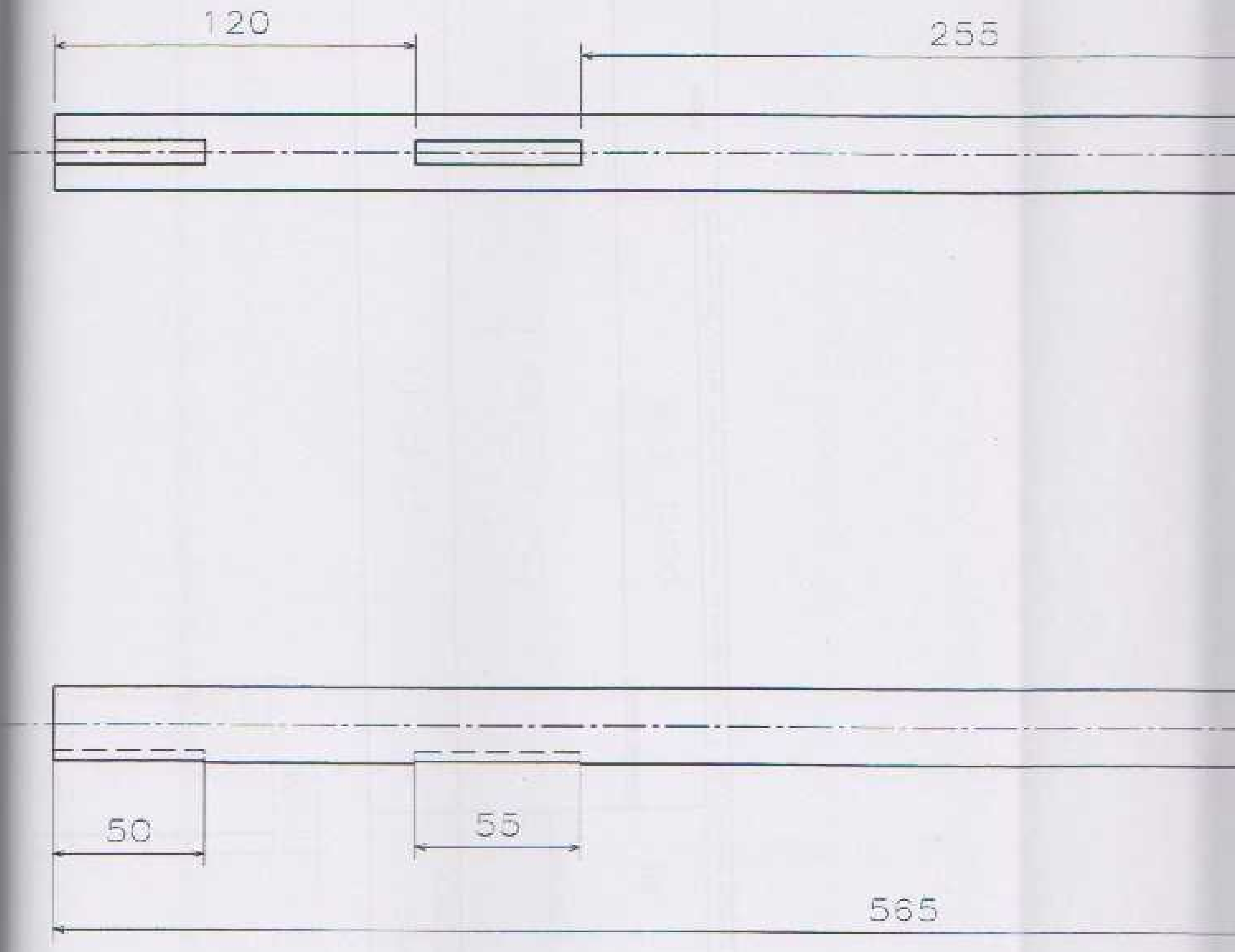
SIZE A

SCALE 1

This



DESIGNED BY: ahmad DATE: 10/12/2006		P.P.U	
CHECKED BY: DATE:		driving shaft	
SIZE: A3	material		
SCALE: 1:3	steel	DRAWING NUMBER: part 1.2.2	din: mm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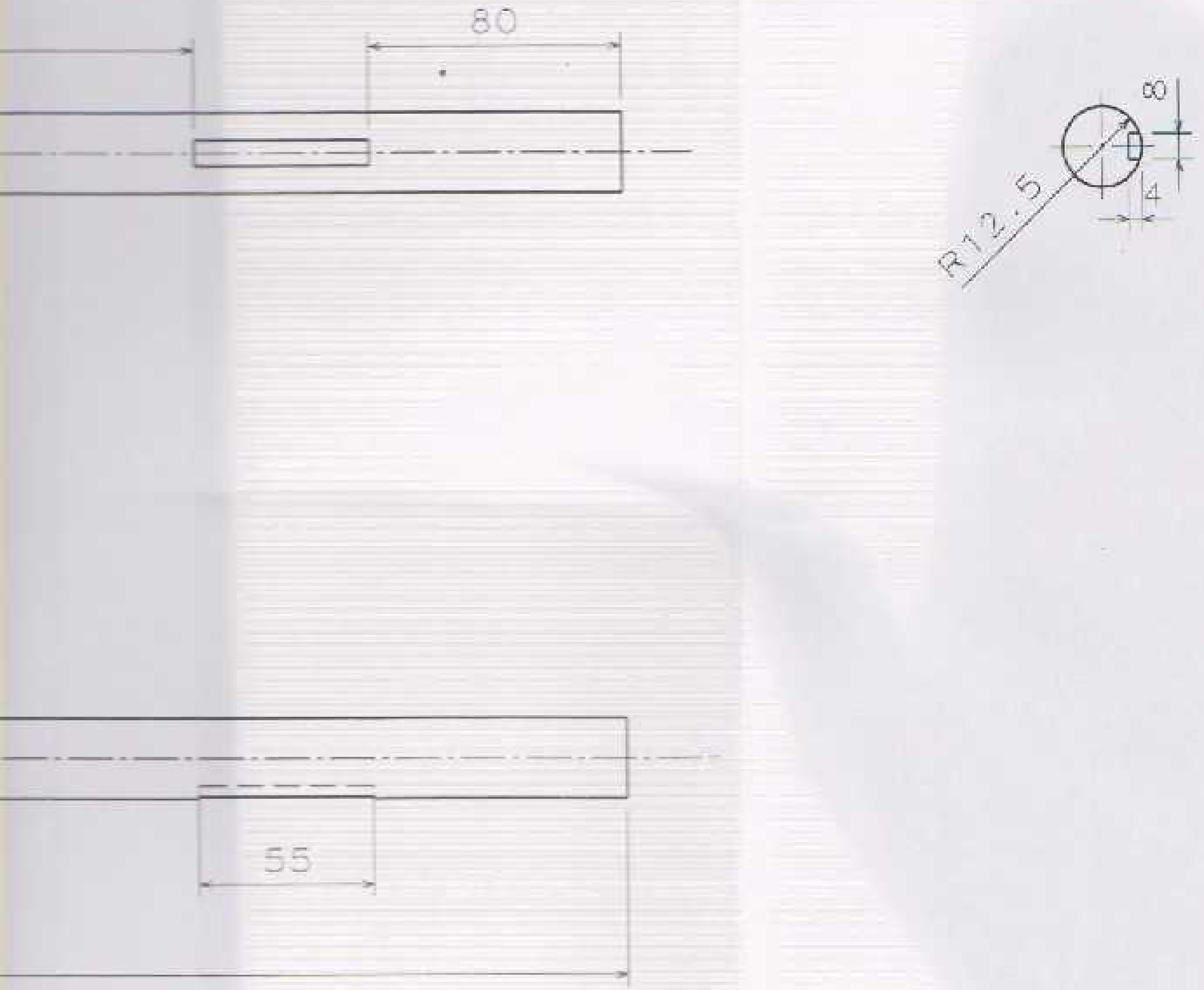
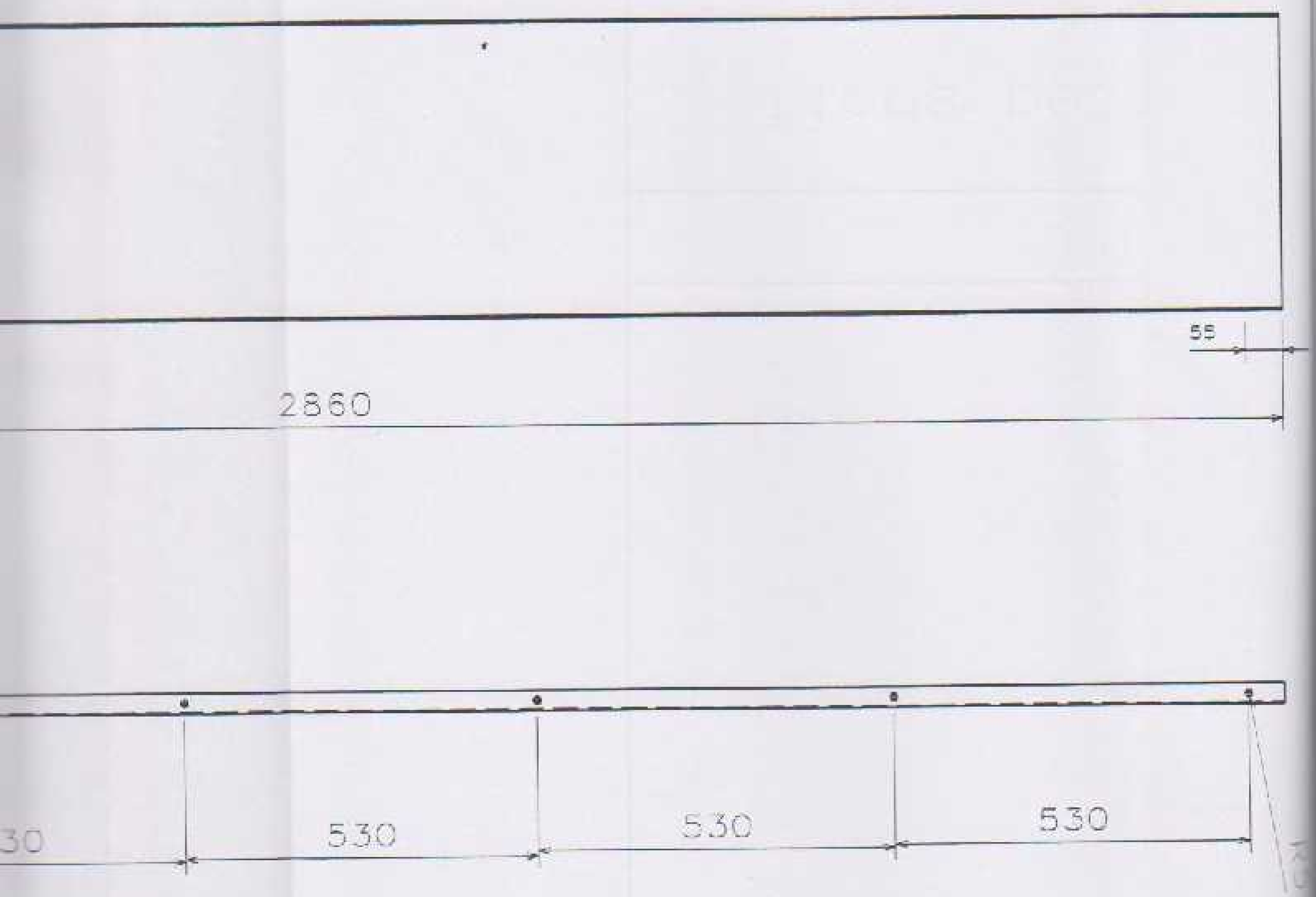
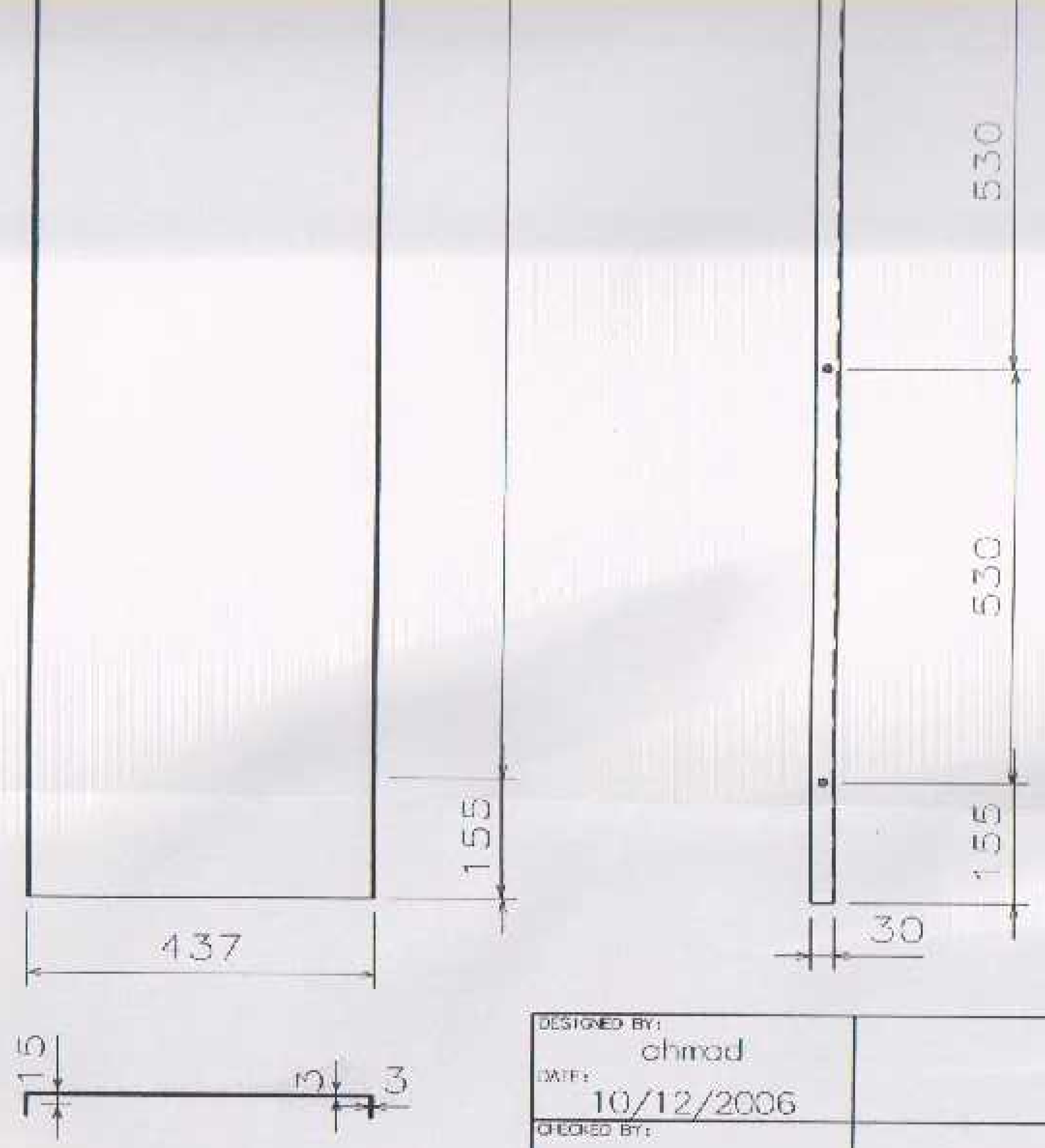
50
55
565



DESIGNED BY: ahmad DATE: 09/12/2006		P.P.U
CHECKED BY: DATE:		drining shaft
SIZE A3	material: stainless steel	
SCALE 1 : 2		DRAWING NUMBER Part 1.2.1 | dim mm


55
2860
30
530
530
530



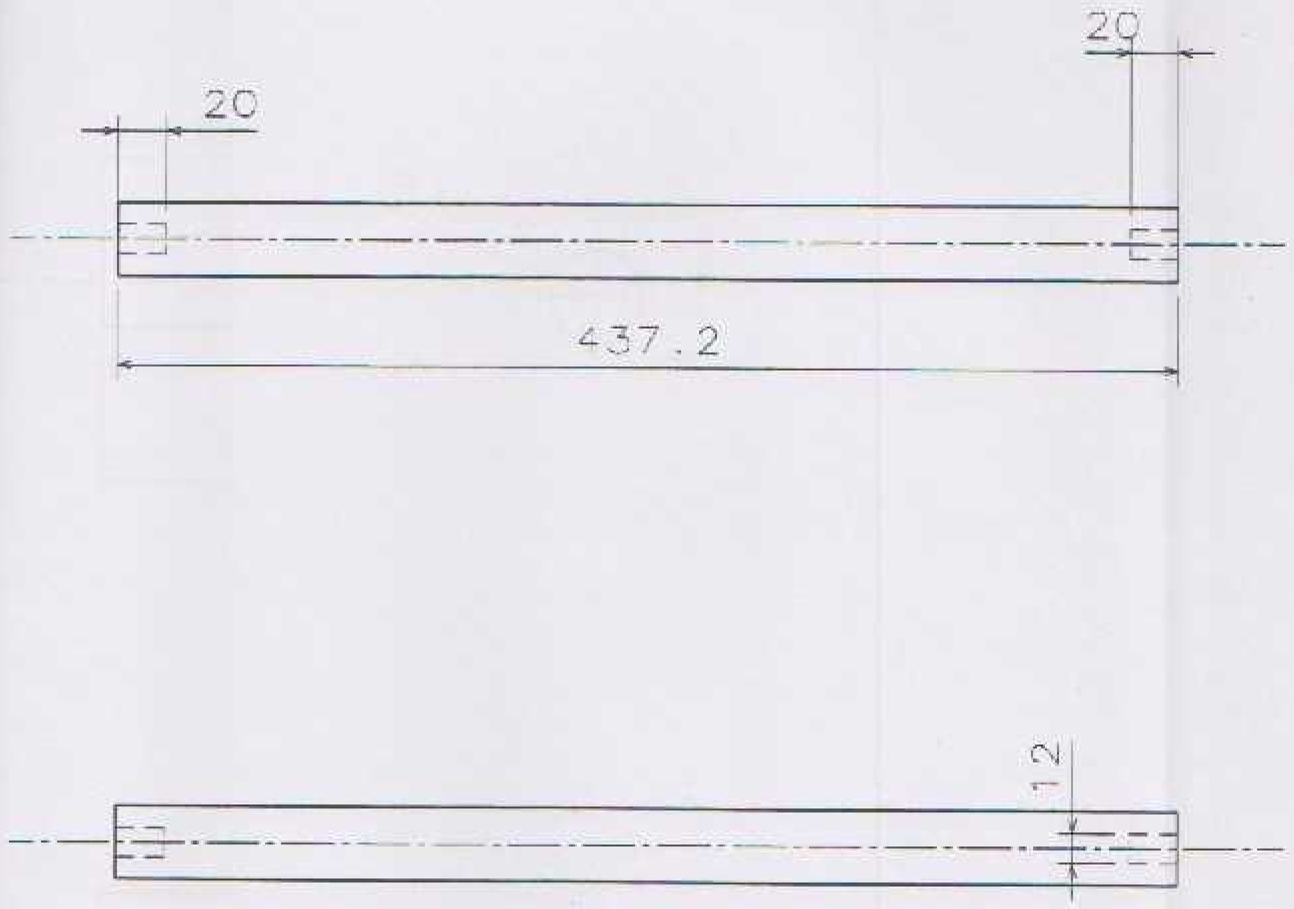
DESIGNED BY: ahmad
DATE: 10/12/2006
CHECKED BY:
DATE:
SIZE: A3
WEIGHT (kg): 45
SCALE: 1:9

P.P.U

sheet

DRAWING NUMBER: part 1.4

dim: mm



DESIGNED BY: on

DATE: 10/12

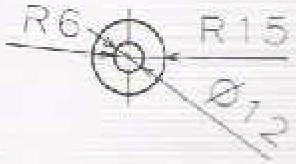
CHECKED BY:

DATE:

SIZE A3

SCALE 1:3

This drawing



DESIGNED BY: ahmad DATE: 10/12/2006	P.P.U	
CHECKED BY: DATE:	connected shaft	
SIZE: A3 / SCALE: 1:3 / Material: steel	DRAWING NUMBER: part 1.5	dim: mm

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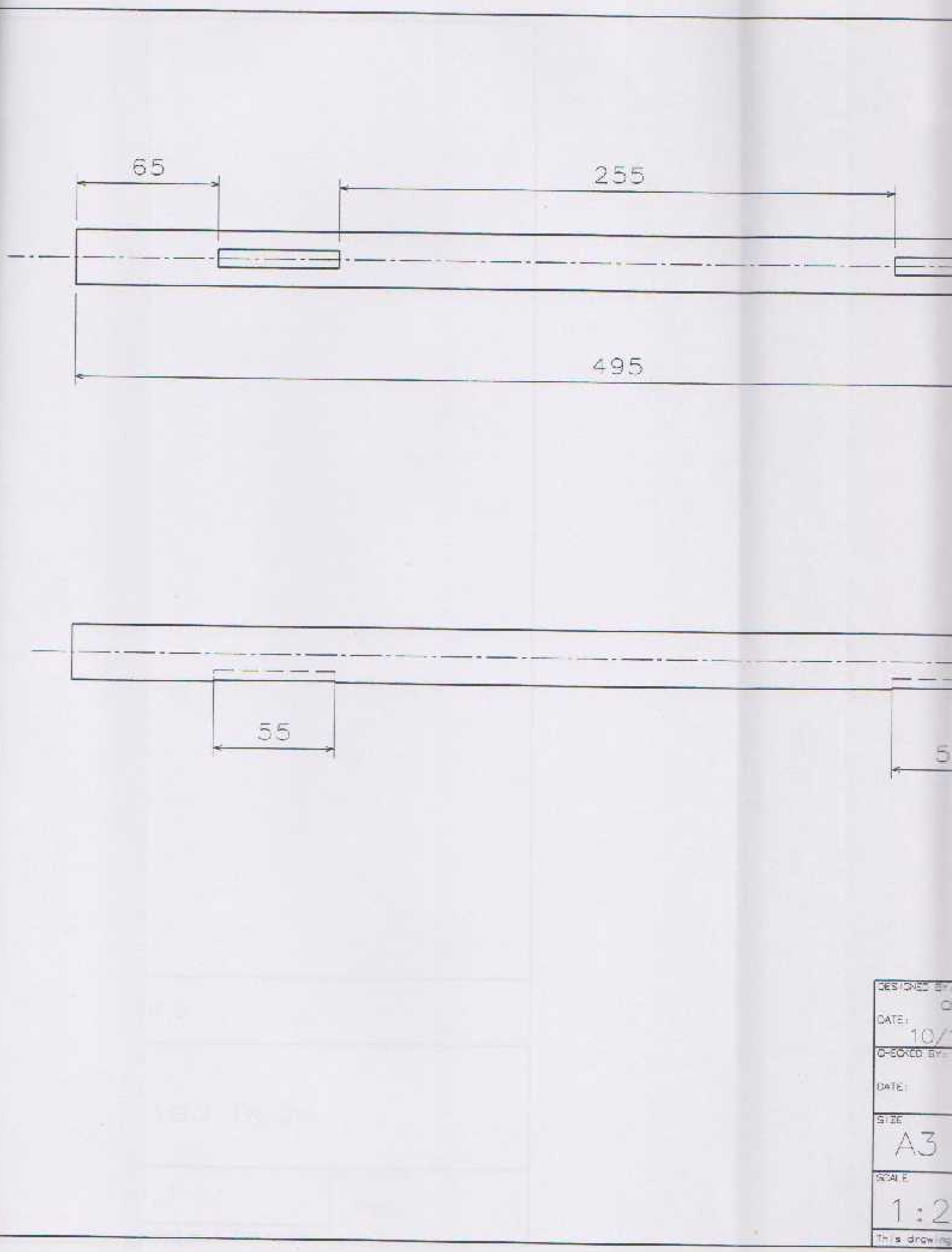
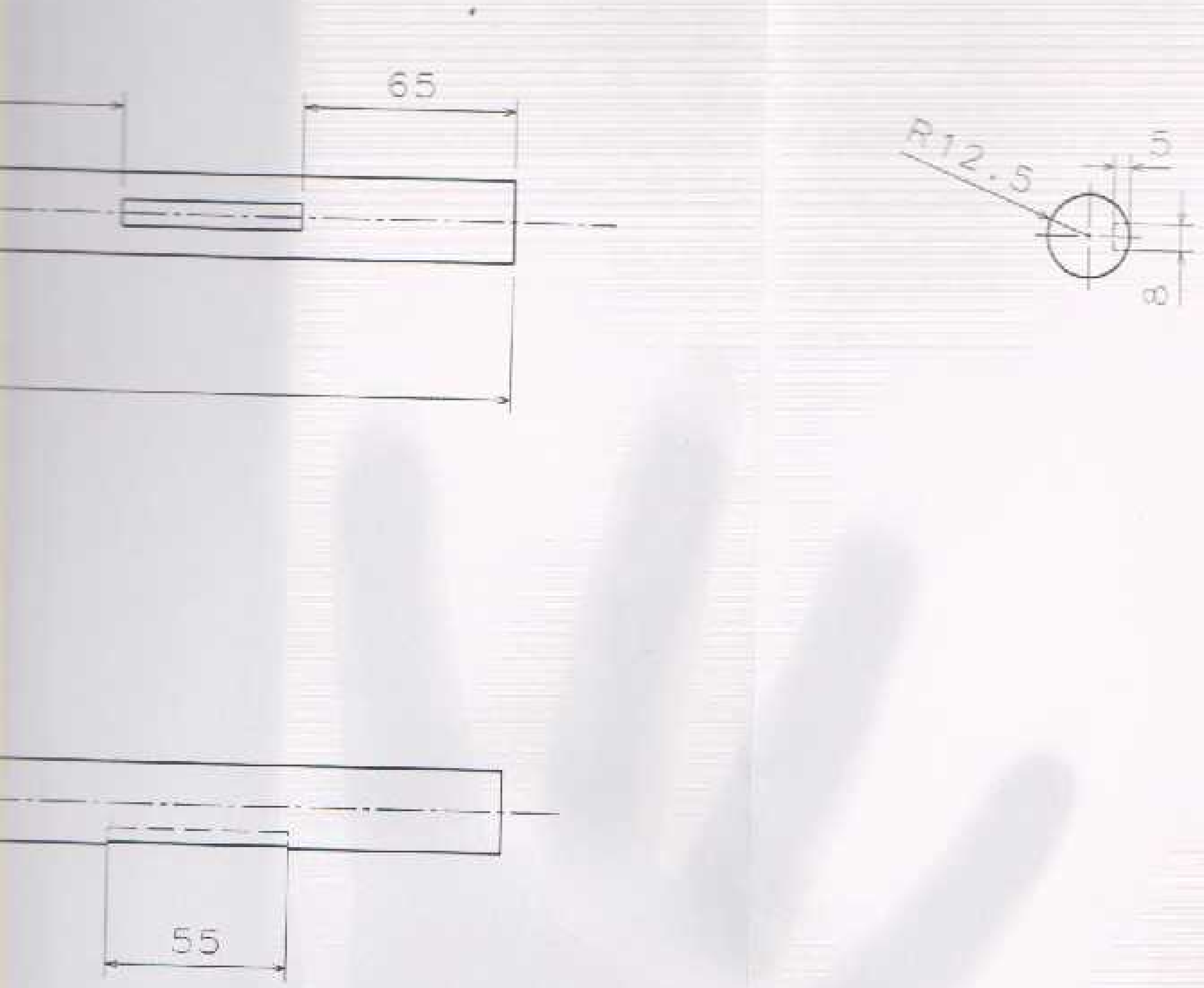

65
255
495
55
5
DESIGNED BY:
DATE:
10/
CHECKED BY:
DATE:
SIZE
A3
SCALE
1:2
This drawing



DESIGNED BY: ahmad DATE: 10/12/2006		P.P.U
CHECKED BY: DATE:		driven shaft
SIZE A3	material	
SCALE 1:2	steel	DRAWING NUMBER part1.6 — mm

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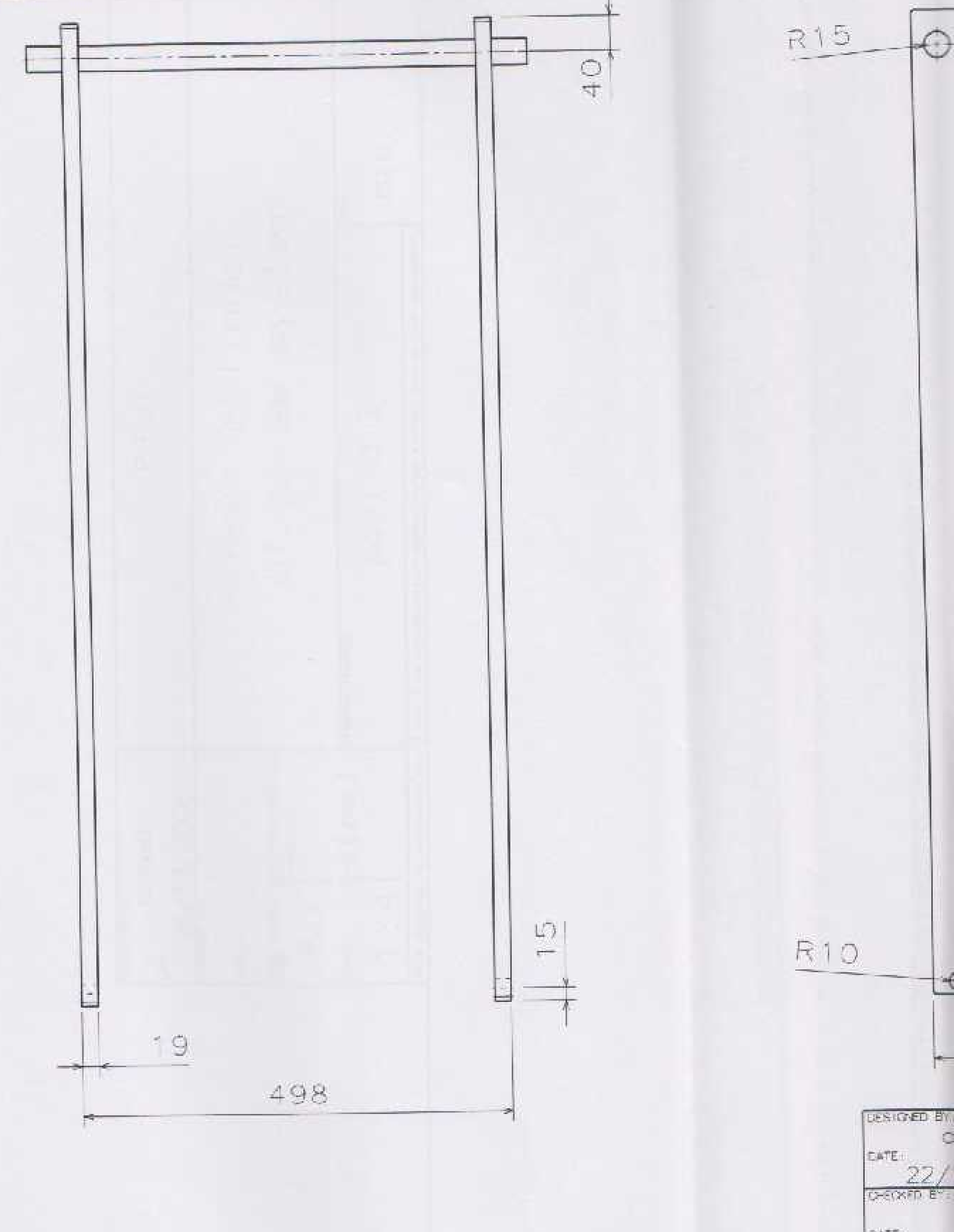
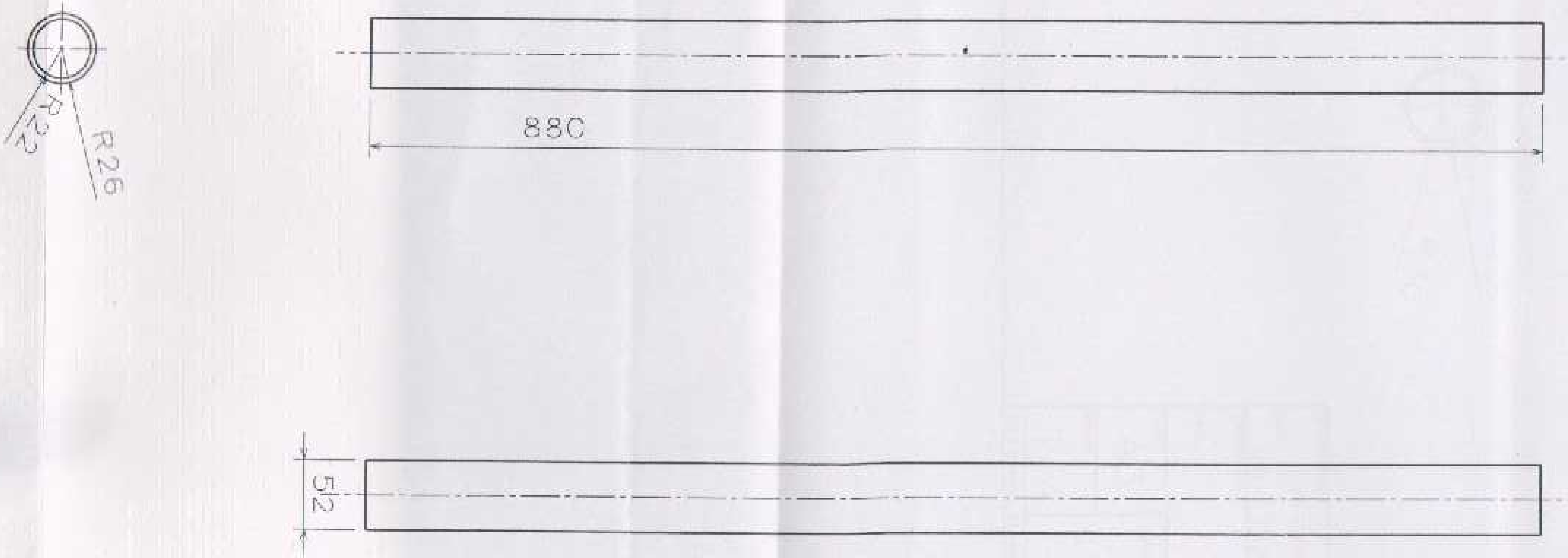
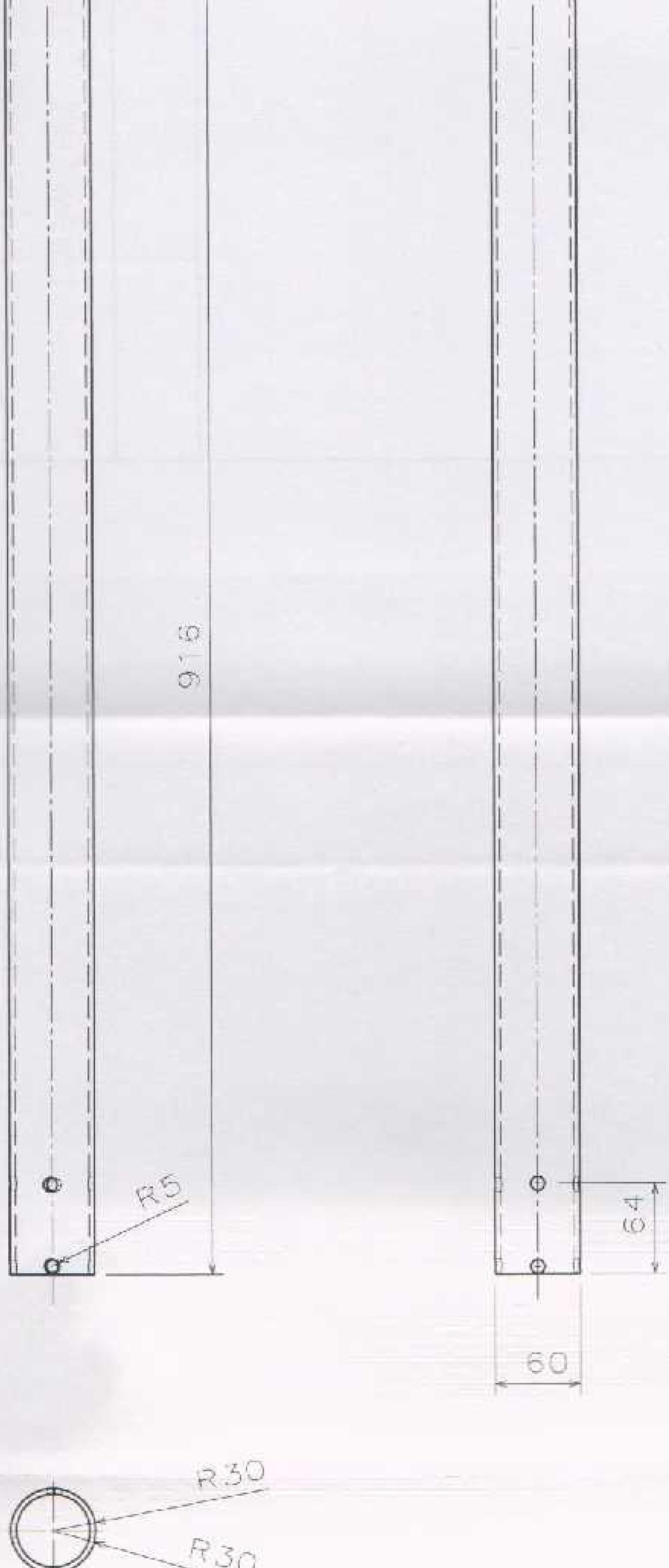
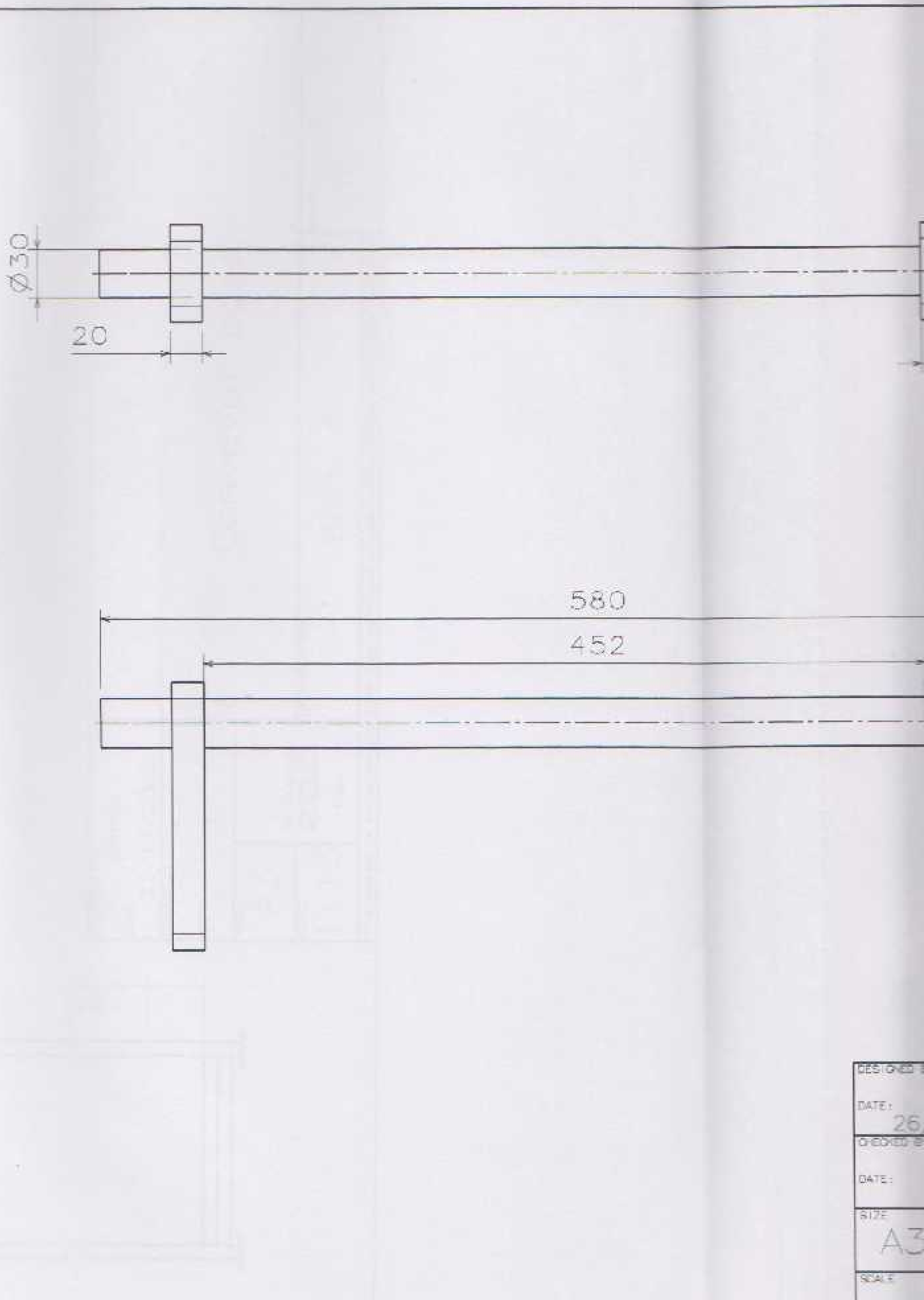

40
R15
15
R10
19
498
580
DESIGNED BY:
DATE:
22/
CHECKED BY:
DATE:
SIZE
A3
SCALE
1:6
This drawing

DESIGNED BY: ahmad DATE: 22/12/2006		P.P.U	
CHECKED BY: DATE:		Supported beam	
SIZE A3	WEIGHT (kg) 0.00		
SCALE 1:6		DRAWING NUMBER part 10.1	dim mm

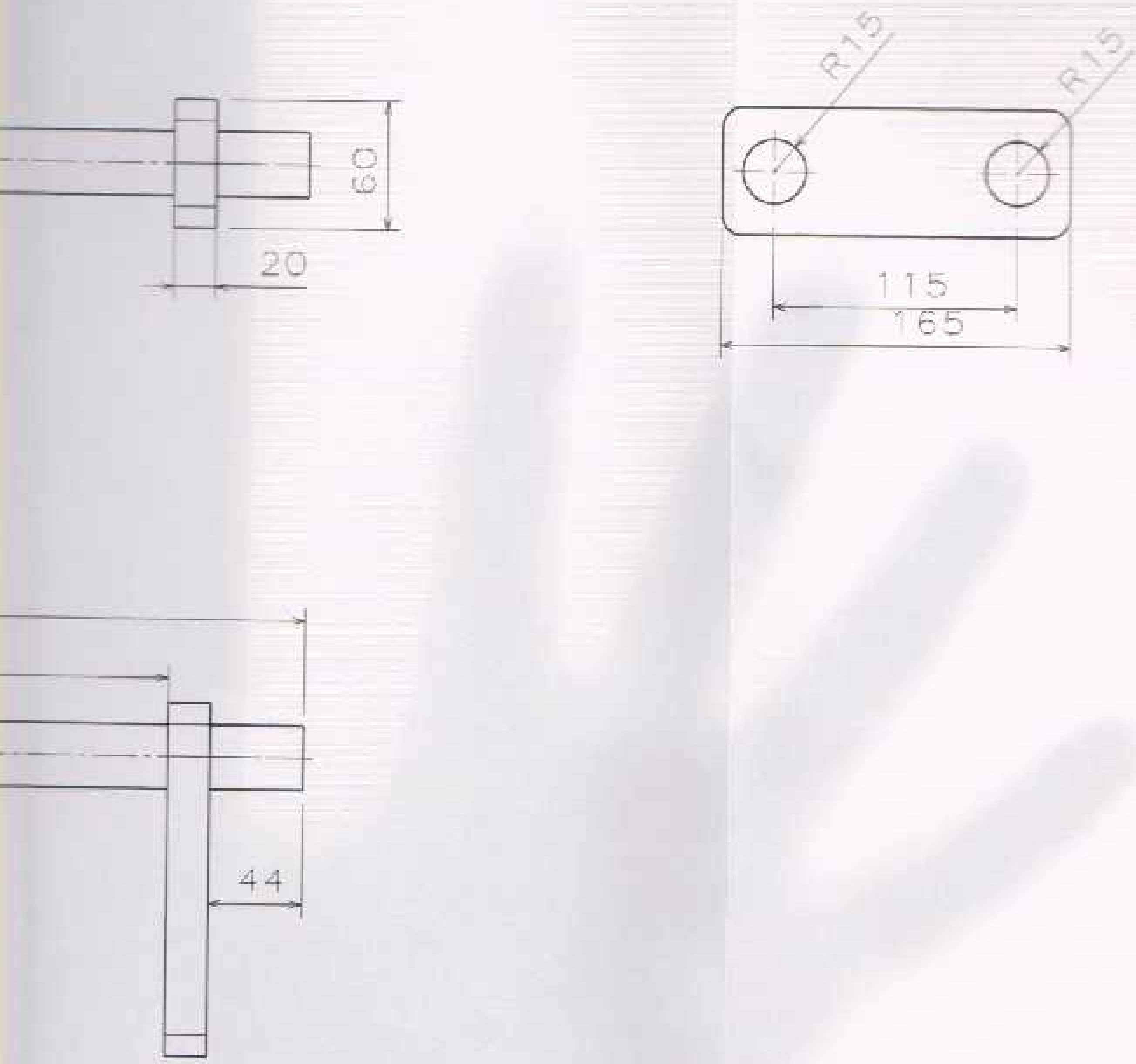

R22
R26
88C
52



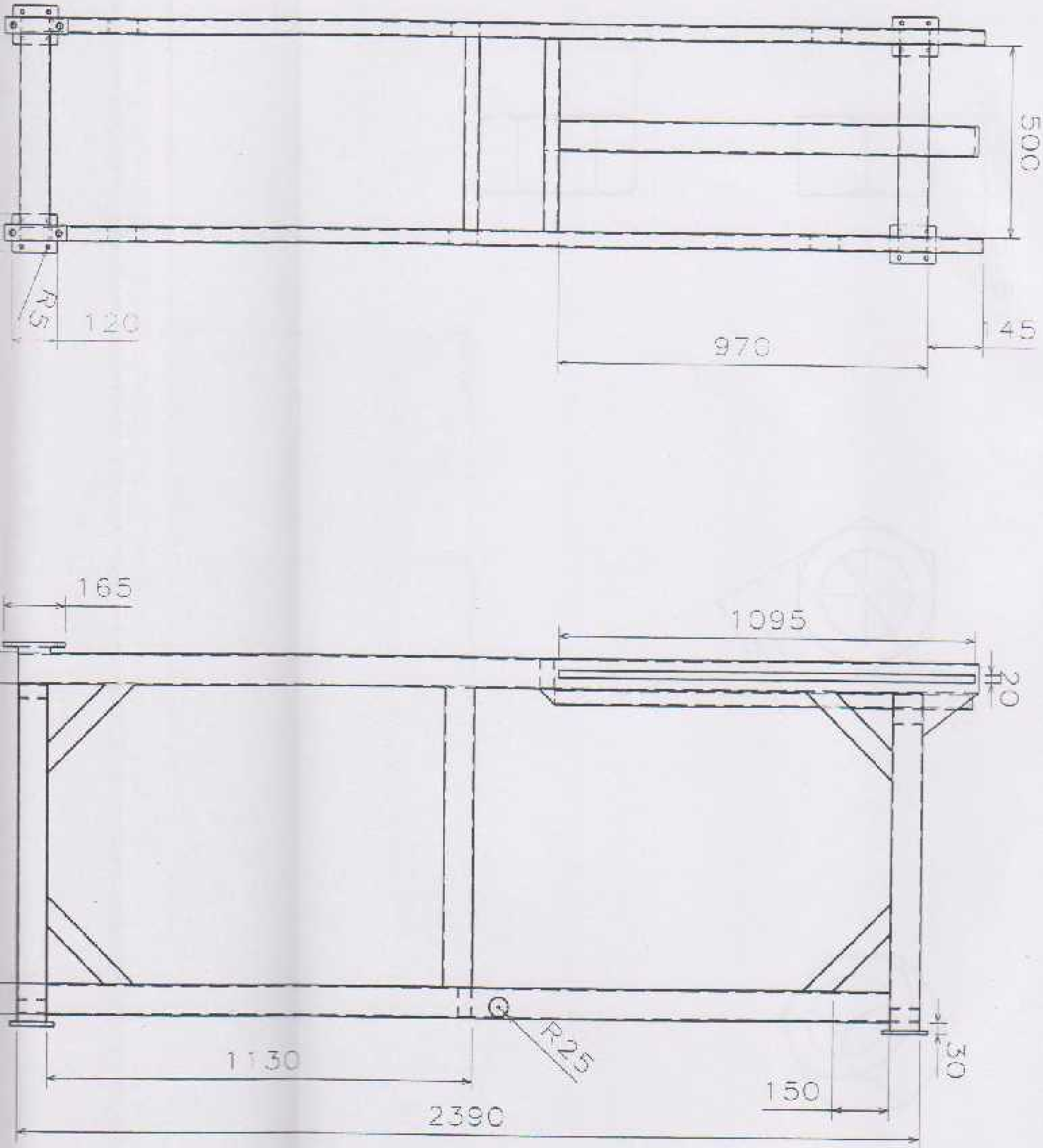
DESIGNED BY: ahmad DATE:	P.P.U

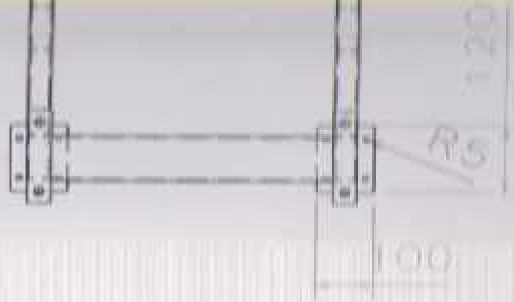


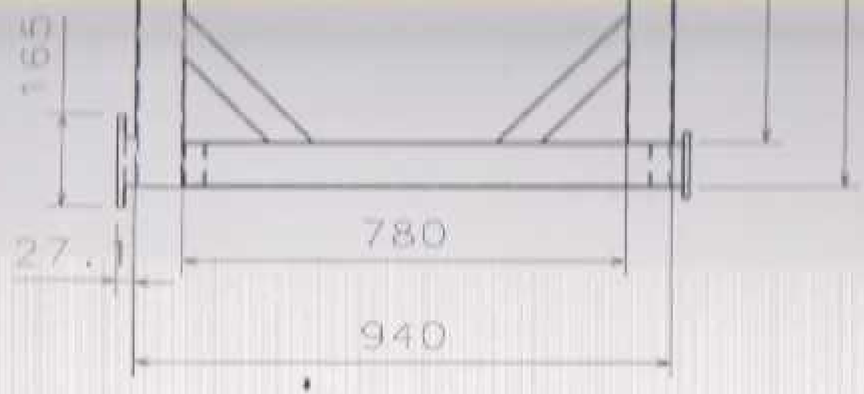
Ø30
20
580
452
DESIGNED B
DATE:
26
CHECKED B
DATE:
SIZE
A3
SCALE
1 :
This draw

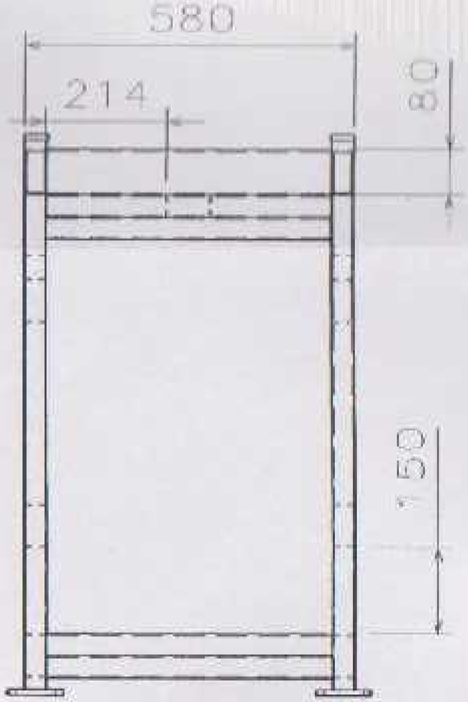


DESIGNED BY: ahmad DATE: 26/12/2006	P.P.U	
CHECKED BY: DATE: XXX	Connected part between screw and conveyor	
SIZE: A3 / material: steel SCALE: 1:3	DRAWING NUMBER: part 3.3	mm

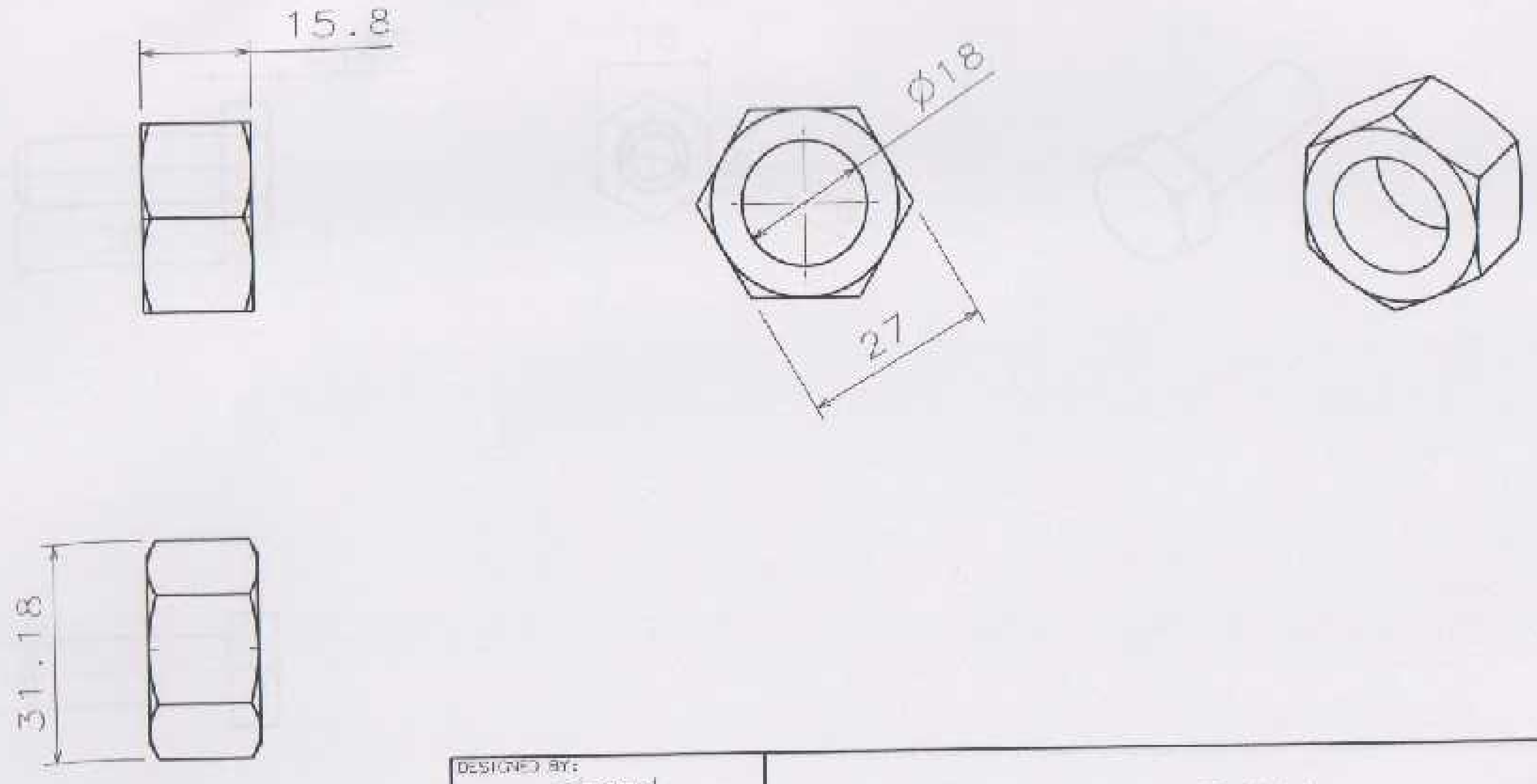

500
R5
120
970
145
165
1095
20
1130
R25
30
150
2390



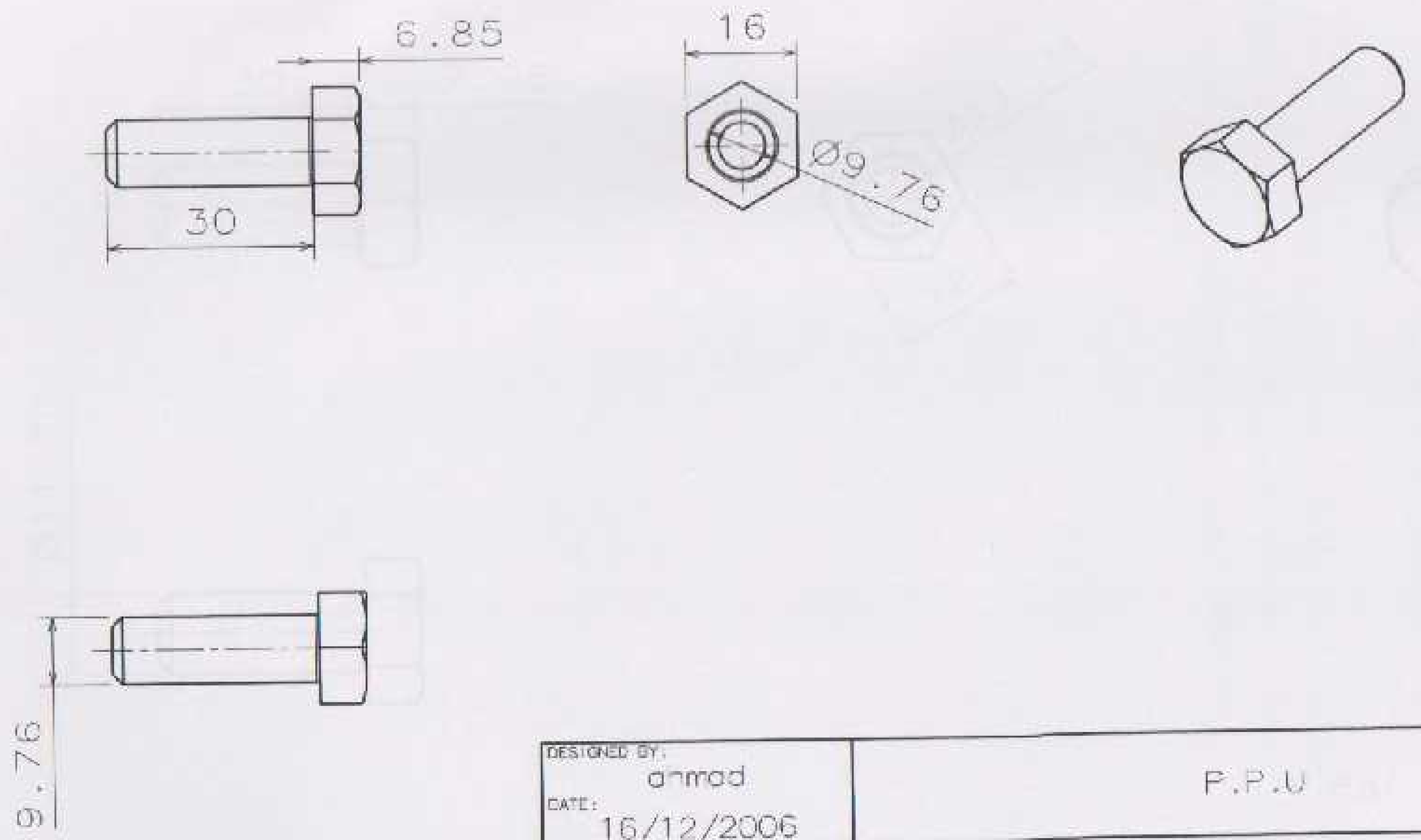




DESIGNED BY: ahmad DATE: 22/12/2006	P.P.U		
CHECKED BY: DATE:	Conveyor base		
SIZE A3	All Beam are rectangular REC 80x40x40 Steel		
SCALE 1:13		DRAWING NUMBER Part .5	dim mm



DESIGNED BY: ahmad DATE: 16/12/2006		P.P.U	
CHECKED BY: DATE:		ISO 4032 NUT M18 STEEL GRADE A HEXAGON	
SIZE A4	Part quantity 8		
SCALE 1 : 1		DRAWING NUMBER part 7	dim mm



DESIGNED BY: ahmad DATE: 16/12/2006		P.P.U	
CHECKED BY: DATE:		ISO 4018 SCREW M10x30 STEEL GRADE C HEXAGON HEAD	
SIZE A4	Parts Quantity 28		
SCALE 1 : 1		DRAWING NUMBER part 9	d·m mm

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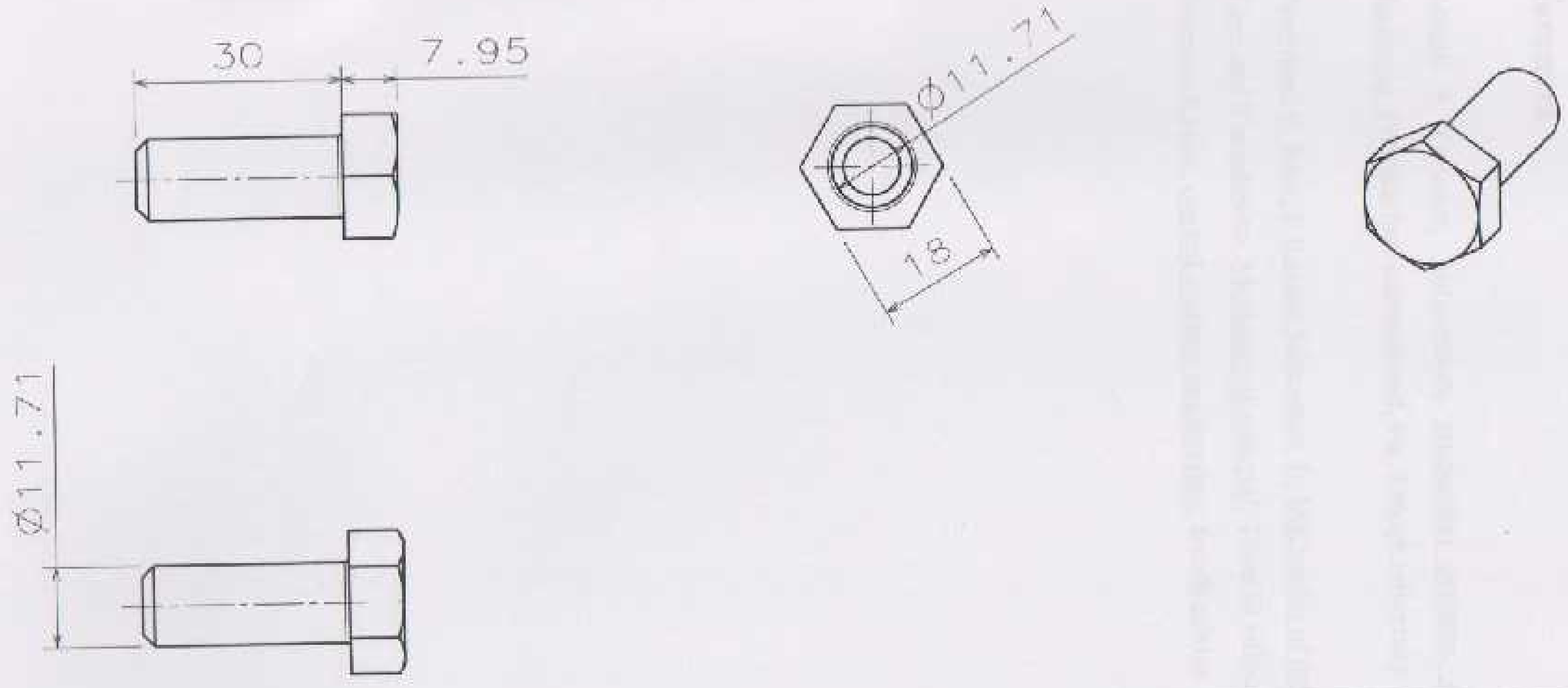

DESIGNED BY: ahmad DATE: 16/12/2006		P.P.U
CHECKED BY: DATE:		ISO 4018 SCREW M12x30 STEEL GRADE C HEXAGON HEAD
SIZE A4	Part quantity	
SCALE 1 : 1	12	DRAWING NUMBER part 11 — SHEET 1/1

References

[1]- Mikell P. Groover, Automation, production systems, and computer-integrated manufacturing, Prentice hall international, Inc, Lehigh university.

[2]- Ferdinand P. Beer, E.Russell Johnsdton, Jr, Mechanics of material, SI metric edition.

[3]- Gere and Timoshenko, Mechnics of material, Third SI edition.

[4]:-Norman S.Nise, control systems engineering, fourth edition