Optimization in Design of Rotating Hydraulic Crane

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Abstract— This is the paper summarizing and reviewing research in Optimization in Design Of Rotating Hydraulic Workshop Crane Included 1) Brief Introduction to Hydraulics 2)Application & Advantages of Hydraulic Floor Crane 3) Concept generation Detailed Design & Force distribution analysis 4) computer-based models of design processes using CATIA & ANSYS & Manufacring Process5)A final section is Concluson by using SWOT Analysis

Index Terms—About four key words or phrases in alphabetical order, separated by commas.

I. INTRODUCTION

The main aim of the project is the design, analysis and production of a hydraulic floor crane having arm motion in the vertical as well as horizontal plane with 180 degree rotation.

These hydraulic floor cranes provide an efficient, low cost alternative to other material handling equipments. Strong, robust, sturdy and built to very standard, these cranes are maneuverable in loading, unloading and shifting of heavy loads. Crane structure consists of chassis, vertical column, horizontal arm, and the hydraulic pump with cylinder assembly. The box crane can take heavy loads effectively, avoids damage under rough and unskilled handling.

The hydraulic cranes used in the industry are efficient but they only have the ability to lift the load and put it down at some other position. In this general design, the arm of the crane moves in the vertical plane only, i.e it has constrained motion. The aim of our project is to re-design the hydraulic crane and give its arm the rotational ability. The gearbox provides rotational motion to the column, thus gears are to be designed.

II. LITERATURE SURVEY

Material Handling is the movement, storage, control and protection of materials, goods and products throughout the process of manufacturing, distribution, consumption and disposal. The focus is on the methods, mechanical equipment, systems and related controls used to achieve these functions. Hydraulic cranes are an important part of the material handling equipments. The hydraulic cranes that are being used work on electrical supply or manual power.

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A crane is a type of machine, generally equipped with a hoist, wire ropes or chains, and sheaves, that can be used both to lift and lower materials and to move them horizontally. It is mainly used for lifting heavy things and transporting them to other places. It uses one or more simple machines to create mechanical advantage and thus move loads beyond the normal capability of a man. Cranes are commonly employed in the transport industry for the loading and unloading of freight, in the construction industry for the movement of materials and in the manufacturing industry for the assembling of heavy equipment.

A. Application of Cranes

Cranes exist in an enormous variety of forms – each tailored to a specific use. Sometimes sizes range from the smallest jib cranes, used inside workshops, to the tallest tower cranes, used for constructing high buildings. For a while, mini - cranes are also used for constructing high buildings, in order to facilitate constructions by reaching tight spaces. Finally, we can find larger floating cranes, generally used to build oil rigs and salvage sunken ships.

These days hydraulics principle is being used extensively in material handling processes through cranes. Depending on the loads to be handled and the operations to be performed there are different types of cranes like Crawler Cranes, Truck Cranes, Floor Cranes.

Hydraulic Crawler cranes are used for picking and moving huge amount of loads. Generally loads are kept in containers for Bulk loading.

Hydraulic truck cranes have good flexibility with high load carrying capacities.

Hydraulic workshop foldable crane used in industries for moving small to medium sized materials from one place to other. The load carrying capacity can vary from half ton to 2 ton or more.

B. Fluid Power Systems

The transmission of power by fluid power system is most convenient and highly efficient. Due to this, the present conventional power transmission system are being replaced and changed over to fluid transmission system. In this prime mover supplies mechanical energy to a pump which is used to pressurize fluid. Then the pressurized fluid is transmitted to different parts of the system through special piping's or tubing's. At desired places pressure energy is converted back to mechanical energy by the devices called actuators consisting of hydraulic cylinders, hydraulic motors etc. Since the power is transferred through the fluid as a medium, such a system is called as fluid power system.

C. Components Of Fluid Power System

Hydraulic Power Pack: A hydraulic power pack is the device used to supply pressurized fluid to the piston cylinder so as to extend or contract it. It is required to move the arm in the intended direction. A hydraulic power maybe electrically

powered or manually powered. The system contains an NRV valve also.
Base: Base is the bottom most part of the hydraulic floor crane which supports all the other parts. It should be designed so as to sustain the weight of the crane as well as the weight to be lifted.
Support Column: Support column is fixed to the base and it supports the arm of the crane, also the cylinder is hinged to it. In the rotary design of crane the support column is connected to the output gear through which rotation force is transmitted, it also contains the bearings. Support column can be put vertically on the base or can be inclined at an angle with the base for better support.
Arm: It is fixed to the upper end of the support column and a hook is fixed to the other end of the arm to lift the weight. The arm is crucial in design as it takes the bending loads and may bend due to weight. For variable load distribution, the arm can be split up into two parts that can slide in eachother.
Piston Cylinder: Hydraulic floor crane has a piston cylinder arrangement to provide the movement of the arm. the maximum and minimum height of the arm is achieved by the piston cylinder. Thus it acts as an actuator to do the intended work.
Steer wheel: It is rear wheel of the hydraulic floor crane. It is situated near the steering so the name steer wheels. These are responsible for the turning of the crane.
Load wheels: It is the front wheel of the hydraulic floor crane. The weight to be lifted acts downward where the load wheels are mounted. Thus they are called as load wheels and are to be designed so as to sustain the load lifted.
Hook: It is attached to the arm of the hydraulic floor crane. It is used to lift the weight. The design of hook is also crucial. Standard hooks are available in the market for different loads

III. RESEARCH ELABORATION

A. CONCEPT GENERATION –

Based on customer feedback & requirement was understood.The Concept was generated for design, analysis and production of a hydraulic floor crane that is easy to handle, does not require any electrical supply and can be stored in a relatively small space, and To vary the load carrying capacity from ½ ton to 2 tons are studied.
For making our crane more cost efficient and easy to handle, we are using various unique features as listed below;
Manually operated hydraulic systems are used to eliminate the use of electrical supply thereby decreasing the overall cost.
The storage of floor cranes in industries is a matter of concern as the floor space available is limited, also employing a larger space for the same will result in wastage of floor space especially in small scale industries. Thus to solve the space related problems, our crane is designed to be folded by its base hence making it compact and can be stored in industries with space constraints thereby eliminating the issues of space constraints.
The mechanism used for transferring the load from ½ ton to 2 ton does not involve any complex operating systems or additional machinery thereby increasing the cost of the crane, it is a simple process involving an adjustable arm whose length is varied from 115mm for 2 ton to 715mm for ½ ton .
A non adjustable floor crane designed for lifting 2 ton can also lift a load of ½ ton but the desired range will not be achieved. Thus our crane is designed to overcome the above problem. The adjustable arm thus provided ensures that a specific amount of load is lifted easily to a desired range and can achieve the following for a longer range
Since our crane is not electrically equipped, wheels are provided for easy transportation for the purpose of moving or transporting our crane from one place to another or in the industry itself thus decreasing human labour.
The wheels provided are the load bearers of the entire structure. They take the load of the entire structure and provide stability when the crane is in its folded position
These are mechanical machines working on principles of hydraulics, used for lifting and transportation of heavy loads in industries. A 'crane' is a type of machine, generally equipped with a hoist, wire ropes or chains, and sheaves, that can be used both to lift and lower materials and to move them horizontally. It is mainly used for lifting heavy things and transporting them to other places. It uses one or more simple machines to create mechanical advantage and thus move loads beyond the normal capability of a man. Cranes are commonly employed in the transport industry for the loading and unloading of freight, in the construction industry for the movement of materials and in the manufacturing industry for the assembling of heavy equipment.
Force distribution analysis shows how the forces are distributed among the components of the crane after the load has been applied. Free body diagram and Moment equilibrium principle is used to find out force components in different directions. Intended work:Design calculations for various Parts,basic CATIA designs for the various parts,Analysis by using ANSYS ,Prototype manufacturing,Testing the Prototype

B. DETAIL DESIGN

Hydraulic Cylinder
Aim is to find the stroke length of the hydraulic cylinder. For this the most important data required is the maximum and minimum height of the crane arm to be achieved.

STROKE LENGTH OF CYLINDER

Aim is to find the stroke length of the hydraulic cylinder. For this the most important data required is the maximum and minimum height of the crane arm to be achieved.
The arm of the crane moves in a vertical plane with the hook reaching a maximum height of 2500mm from the ground, and a minimum height of 500mm from the ground.

PROCEDURE FOR FINDING THE STROKE;

1. From the given specifications, the angle subtended by the arm for maximum and minimum heights at point B is calculated through the use of basic trigonometry.

The angles are found out to be; (**refer fig. 1**)
Angle CBC’’ = 300
Angle CBC’ = 500

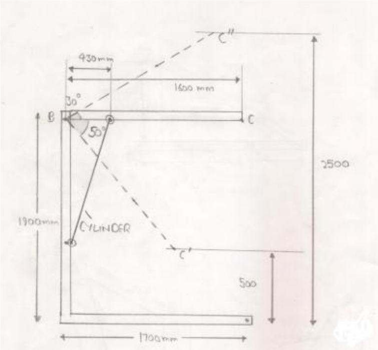


Fig. 1

2. Drawing the crane using a definite scale and from given specifications, the position of the hinges for piston and cylinder can be found out using geometry **(refer fig. 2).** The approx values are;

Hinge for cylinder to be attached = 725mm from ground level
Hinge for piston to be attached = 430mm from point B on the arm.

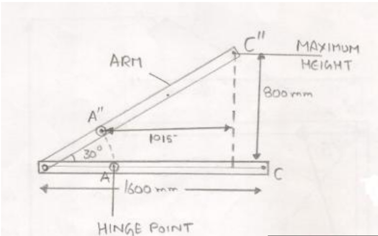
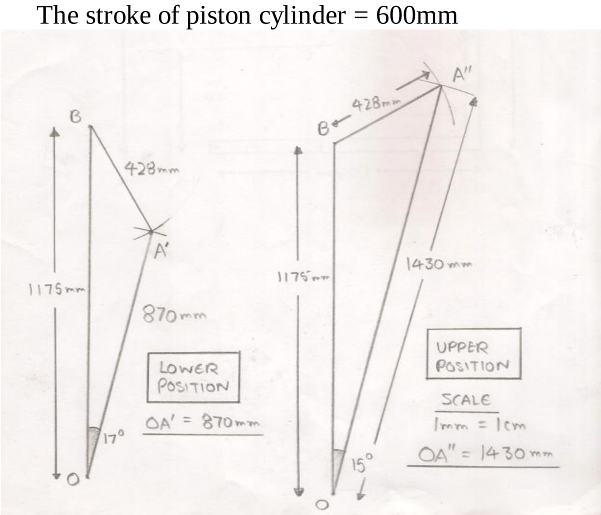


Fig. 2

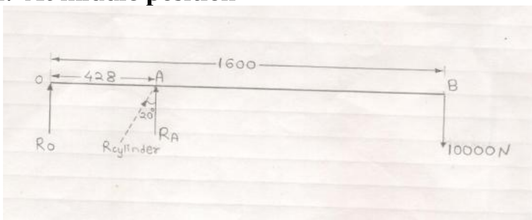
3. The angles subtended by hinge for piston i.e. point A, about point O are calculated for maximum height and minimum height of arm. The required values are distance of hinge from point B and the angles subtended by the arm about point B i.e. 300 for uppermost position and 500 for lower most position. **(refer fig. 3)**
   The angle subtended by cylinder when arm is at highest point = 150
   The angle subtended by cylinder when arm is at lowest point = 170
4. From fig. 3 it can be calculated that how much the piston needs to extend .
   The stroke of piston cylinder = 600mm



FORCES ON CYLINDER

Various forces acting on arm at different lifting positions-
Taking moment about point O:

1. **At middle position-**



Mo = 10000*1600 - R_A*428 = 0
R_A= 37383 N
Reaction in the direction of cylinder will be given by
$R_{cylinder}$ = R_A(cos20)
$R_{cylinder}$ = 37383(cos20)
$R_{cylinder}$ = 35128 N
Ro = 47383 N

2. **At upper position-**

Mo = 0
Mo = 10000*(1600cos30) + R_A* (428cos30)
R_A = 37383 N
Reaction in the direction of cylinder will be given by
$R_{cylinder}$= R_A(cos15)
$R_{cylinder}$= 36109 N
Ro = - 47383 N

3. **At lower position-**

Similarly reaction in the direction of cylinder at extreme lower position
$R_{cylinder}$= 35750 N
Hence it can be seen that, maximum force on cylinder is acting at upper position i.e.
$R_{cylinder}$= 36109 N

DESIGN OF CYLINDER

Assuming the internal pressure, (P_i)= 150 kg/cm^2

$$(P_i) = \frac{150*9.81}{10^2} \text{ kg/cm}^2$$

(P_i)= 14.715 N/mm^2
Material used for cylinder is Mild steel IS 226
Yield strength of mild steel = 250 N/mm^2
Ultimate tensile strength of mild steel = 410 N/mm^2
Factor of safety = 1.5 (assumed)

(P_i)= F/A
A = F/P_i
= 36109/14.715
A = 2453.89mm^2
But, A = $(\pi/4)\ d^2$
2453.89 = $(\pi/4)\ d^2$
d = 55.89 mm

Using cylinder of standard diameter,
Bore diameter = 63 mm
Now, allowable tensile strength $\sigma_{all} = S_{yt}/\ FOS$
= 250/1.5
= 166.66 N/mm^2

Allowable shear stress **T_{all}** = S_{sy}/ FOS
S_{sy} = Yield strength in shear of the cylinder material, N/mm^2
T_{all} = 0.5S_{yt}/ FOS
= 0.5*250/1.5
= 83.33 N/mm^2
According to maximum principal stress theory thickness of cylinder,

Using Lame's equation,

$$t = di/2[\{\sqrt{6all + Pi}/\sqrt{6all - Pi}\} - 1]$$

$$= 60/2\,[\{\sqrt{166.66 + 14.715}/\sqrt{166.66 - 14.715}\} - 1]$$

= 5.55 mm

t = 6 mm

Thus Cylinder specifications;

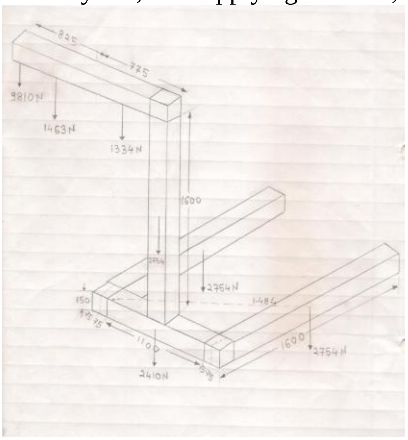
Bore diameter of cylinder = 63 mm

Thickness = 6 mm

Stroke = 600 mm

C. Calculation For Crane Stability

To calculate the moment at fulcrum point for verifying that the structure will not tilt or bend when the arm of the crane has been rotated by 90^0, after applying the load;



Forces on part one-

Load applied to the arm at the hook is 1000kg i.e.= 1000*9.81

= 9810 N

Self weight of the overhanging part of arm-

Volume of overhanging arm= L*B*H

= 850*150*150

= 19125000 cu mm

= 0.019125 cu m

Density of the material used is = 7800 kg/cu m

Mass of the overhanging arm= Volume*Density

= 0.019125*7800

= 149.175 kg

Weight of the overhanging arm= 149.175*9.81

= 1463.406 N

Moment on fulcrum point due to left hand side forces-

Mo= (9810*0.9) + (1463.406*0.487)

= 9541.67 N-m

Force on part two-

Volume of remaining arm= L*B*H

= 775*150*150

= 17437500 cu mm

= 0.0174375 cu m

Density of material used = 7800 kg/cu m

Mass of the remaining arm= Volume*Density

= 0.0174375*7800

= 136.0125 kg

Weight of remaining arm= 136.125*9.81

= 1334.2 N

Force on part three-

Volume of column= L*B*H

= 1600*150*150

= 36000000 cu mm

= 0.036 cu m

Density of material used= 7800 kg/cu m

Mass of the column= volume*Density

= 0.036*7800

= 280.8 kg

Weight of the column= 280.8*9.81

= 2754 N

Force on part four-

Volume of base= L*B*H

= 1400*150*150

= 31500000 cu mm

= 0.0315 cu m

Density of material used= 7800 kg/cu m

Mass of the base= volume*Density

= 0.0315*7800

= 245.7 kg

Weight of the base= 245.7*9.81

= 2410 N

Force on part five-

Volume of base arm= L*B*H

= 1600*150*150

= 36000000 cu mm

= 0.036 cu m

Density of material used= 7800 kg/cu m

Mass of the base arm= volume*Density

= 0.036*7800

= 280.8 kg

Weight of the base arm= 280.8*9.81

=2754 N

Moment on fulcrum point due to right hand side forces;

Mo= (1334.2*031) + (2754*0.625) + (2754*0.8) + (2754*1.484) + (2410*0.625)

= 9931.26 N-m

As the moment due to right hand side forces (i.e 9931.26 Nm) is more than the moment due to left hand side forces (i.e 9541.67 Nm), the crane will not tilt or bend when the arm will be extended to extreme positions.

Hence it is confirmed that the crane is able to withstand the load of 1000 kg.

Pascal's law:

Pascal's law is the basis of all hydraulic and pneumatic systems. Pascal's law states that "Pressure applied to a confines fluid at any point is transmitted undiminished throughout the fluid in all directions and acts up on every part of the confining vessel at right angles to its interior surface and equally up on equal areas."

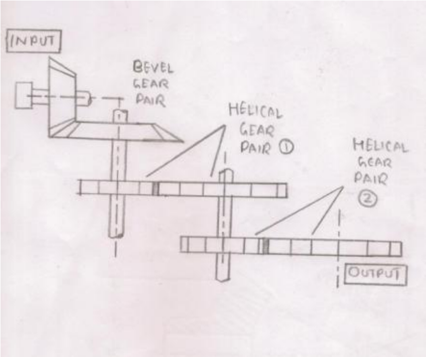
It can also be stated as "In a body of equally dense fluid at rest, the pressure is the same depth below the fluid surface."

One is the input cylinder, also called as the small cylinder. A force is applied through the lever to the piston fitted on the input cylinder.

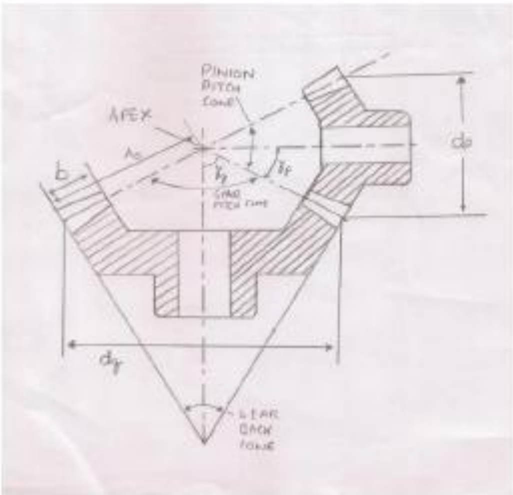
Average force that can be exerted by a adult human using full hand is about 500N to 600N.

D. Design For Gearbox

To transmit the motion and power from the hand wheel to the rotating column, a Gear box is used. The positions of the different gears used are as shown.



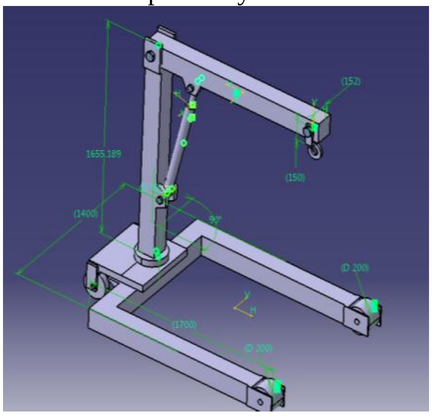
The values that are known to us are;
Input Power at hand wheel is applied manually thus, it is assumed to be 1 HP.
Where,
1 HP = 745.7 Watts
Material of the gears is chosen as Plain Carbon Steel, thus;
S_{ut} = 750 MPa
Ultimate tensile stress (S_{ut}) for gear and pinion is same as the material used is same.
Brinells Hardness Number (BHN) = 340
Speed of the helical gear at the output = 2rpm
Service factor (K_a) = 1.5
Factor of Safety (FOS) = 2 assumed
Bevel gears are used to transmit motion between two intersecting axes shafts. The Pitch surface of a bevel gear is a frustum of cone.
When two bevel gears mesh, their respective pitch cones contact along a common element. The pitch cones, when extended, meet at a common point called the apex, which is the point of intersection of the shaft axes.



Dg - Diameter of bevel gear
Dp - Diameter of bevel pinion
γ_p - Pitch cone angel of bevel pinion
γ_g - Pitch cone angel of bevel gear
b - Face Width
A_O - Pitch cone distance
M - Module
Back cone - it is an imaginary cone whose elements are perpendicular to the elements of the pitch cone.
The Beam strength for pinion & the Wear strength of gear pair is checked by calculations .The available factor of safety of the gear pair is greater than the required factor of safety and hence design of bevel gear is safe.

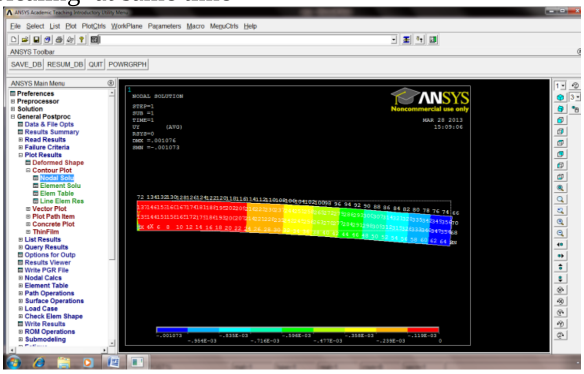
IV MODELLING & MANUFACTURING

A prototype is designed & manufactured & its operation procedure is studied for feasibility.The whole structure has to be stable, thus the stability has to be found out.. The Catia models then can be imported in the ANSYS and various analysis can be made. The production of the crane will start when the designs are stable and cost efficient. For making the design cost efficient, the electric motor used for rotation of gears is removed and replaced by manual levers



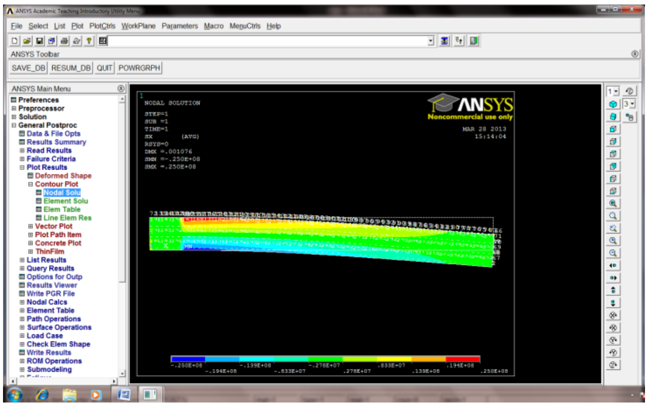
Ergonomic & Aesthetic-

The Floor Crane itself is designed for Ergonomical operation as it reduces manual effort,bending & is convenient to use .As it requires less force to operat & thus save energy It is designed as per safety & there are no sharp edges to avoid injury.It is Light weight, Noise free additionally good quality surface treatment & paint is used.
Hence it is Ergonomically designed & is Aesthetically applealing at same time



Catia Modelling

The various parts of hydraulic crane are created in CATIA Hydraulic floor crane assembly design is shown here for easy understanding and analysis



Contour Plot Of Displacements-Contour Plot Of Stresses-

Manufacturing Process

Manufacturing process is a collection of technologies and methods used to define how products are to be manufactured. Manufacturing of crane involves various process such as:

FABRICATION

Manufacturing process in which an item is made (fabricated) from raw or semi-finished materials instead of being assembled from ready-made components or parts. it involves cutting ,bending and assembly process.

Fabrication involves following process:

1. Cutting Process

Our manufacturing process involves cutting via OXY-FUEL cutting method since it is used for materials having low alloy steel.Oxy-fuel cutting is a cost-effective method of plate edge preparation for bevel and groove welding. It can be used to easily cut rusty and scaled plates and only requires moderate skill to produce successful results.Common oxy-fuel cutting applications are limited to carbon and low alloy steel. These materials can be cut economically, and the setup is quick.

2. Forming

Forming process make use of suitable stresses like compression, tension, shear or combined stresses to cause plastic deformation of the materials to produce required shapes. In forming, no material is removed i.e. they are deformed and displaced.

Sheet Metal forming involves deformation of sheet metal to achieve the desired shape.Forging ExtrusionRolling Sheet metal working Rotary swaging Thread rolling Explosive formingElectromagnetic forming are the some of the methods used for forming

3. Machinig Process

Machining is any of various processes in which a piece of raw material is cut into a desired final shape and size by a controlled material-removal process. The many processes that have this common theme, controlled material removal, are today collectively known as subtractive manufacturing, in distinction from processes of controlled material addition, which are known as additive manufacturing. Turning, milling,boring,drilling are the types of the machining process.

4. Tack Welding

Tack welding, a necessary preliminary step in many welding projects, must be performed correctly to achieve optimal results from the final weld and to minimize part defects. Quality is as important in tack welding as it is in the final weld. This article describes proper tack welding conditions been positioned as required, generally by clamping them on suitable fixtures, tack welds are used as a temporary means to hold the components in the proper location, alignment, and distance apart, until final welding can be completed.

An advantage of this provisional assembly procedure is that if the alignment for final welding is found to be incorrect, the parts can be disassembled easily, realigned, and tack welded again.

5. Final Welding

Welding is a material joining process in which two or more parts are coalesced (joined together) at their contacting surfaces by a suitable application of heat and/or pressure. Sometimes parts are united together by application of pressure only without external heat.

In the process of manufacturing we use the process of Electric Metal Arc Welding. Arc welding is a type of welding that uses a welding power supply to create an electric arc between an electrode and the base material to melt the metals at the welding point. They can use either direct (DC) or alternating (AC) current, and consumable or non-consumable electrodes. The welding region is usually

6. Assembly

Final Assembly Schedule, often abbreviated as FAS and sometimes referred to as finishing schedule, is a schedule of end items to finish the product for specific customer orders in a make to order (MTO) or assemble-to-order (ATO) environment

7.Surface Finishing

Surface finishing is a broad range of industrial processes that alter the surface of a manufactured item to achieve a certain property.] Finishing processes may be employed to: improve appearance, adhesion or wettability, solder ability, corrosion resistance, tarnish resistance, chemical resistance, wear resistance, hardness, modify electrical conductivity, remove burrs and other surface flaws, and control the surface friction. In limited cases some of these techniques can be used to restore original dimensions to salvage or repair an item Grinding is one such finishing process used to improve surface finish, abrade hard materials, and tighten the tolerance on flat and cylindrical surfaces by removing a small amount of material.

8 Testing:

The manufactured crane is tested for various load and if any failure occurs then the corrective actions are taken out .

9 Painting:

Spray painting is a painting technique where a device sprays a coating through the air onto a surface. The most common types employ compressed gas usually air, to atomize and direct the paint particles. Air gun spraying uses equipment that is generally larger. It is typically used for covering large surfaces with an even coating of liquid. Spray guns can be either automated or hand-held and have interchangeable heads to allow for different spray patterns. We have used hand held type of spray painting.

V. CONCLUSION

Using SWOT Analysis we evaluate the Strengths, Weaknesses, Opportunities, and Threats to elaborate our conclusion

SWOT ANALYSIS

Strengths

Cost efficient

Manually operated Rotation ,thus reducing the electrical load

Skilled labour are not required

It can used for load varying applications

Higher range of reach can be achieved for lower load

i.e for ½ ton to 1 ton

Weakness
Possibility of leakage of oil from the hydraulic cylinder thus making the work area untidy
Load can not be carried at an angle
i.e rotation of arm is not possible
Load on human labour increases thus increasing the possibility of manual error
Opportunities
Can be used effectively in small scale industries
Can be used in industries or application with space constrain
Used in applications with wide range of load
Threats
Oil leakage in the hydraulic cylinder may lead to the failure of the entire system
As the number of moving parts increases due to the provision of adjustable arm and foldable base, thus increasing the mechanical looses caused by friction ,also causes wear of the moving parts .

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