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An Analysis of Overhead Crane Model with Three Directional Motions

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ABSTRACT:

A crane is lifting machinery, discontinuous movement aimed at raising and distributing loads in space, suspended from a hook. Cranes available in the market are grinder travelling crane, overhead travelling crane, jib cranes, wire rope hoist, and gantry cranes. The Gantry cranes are one of the most important mechanical components in the heavy weight lifting and loading in to cargos, into trains, in to heavy truck vehicles, etc. Different types of gantry cranes available in the industries are container cranes, workstation gantry cranes or light weight mobile gantry cranes and semi gantry cranes. These vase verity of gantry cranes are differed based on the tonnages and area to be covered for lifting and moving the weight.The main aim of this paper is to study various components of electric overhead crane& crane components. Planned and unplanned requirements may necessitate changes in component of overhead crane. In such condition we have to modify the existing crane to suit the required parameters. We will study effect of modifying for various components like rack and pinion system in beam instead of hoist system for motion of machinery.

Keywords: Lifting Crane; Gear Assembly; DPDT Switch; Hoist Cable; Rack and Pinion

1. INTRODUCTION:

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 or vertically. 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. There is no "one size fits all" approach to defining an overhead crane, as each overhead crane is carefully designed and engineered for a specific purpose or application to suit a business' material handling needs.

Overhead cranes can be designed and built in all kinds of configurations, and different components can be swapped out or engineered to improve its capacity and performance. 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. In material handling, the cranes play a vital role in modern manufacturing industries.

2. RESEARCH WORKS RELATED TO OVERHEAD CRANE:

Yogi Raval, in "Design analysis and improvement of EOT crane", analyzed the crane wheel for optimum size. Using FE as a optimization tool,theoptimization of the crane wheel size is carried out **[1]**

AbhinaySuratkar and Vishal Shukla, "3D Modeling and finite element analysis of EOT crane" made a comparison between the analytical calculations and FE analysis. As a result of study they have proposed the design optimization method for overhead crane **[2]**

Patil P. and Nirav K. in "Design and analysis of major components of 120T capacity of EOT crane" analyzed various components of crane like wheels, pulleys, rope drum and girder. They have done the manual calculations using Indian standards and on the basis of these calculations 3D modeling and

analysis has been carried out. For modeling they have used Creo software and ANSYS as analysis software **[3].**

Dr. Frank Jauch in a post "Care, use and maintenance of wire ropes on cranes", he has discussed about drum. There are two types of drum: single layer drum and multi-layer drum. Both are used based on lifting capacity of an object. He has also discussed about crane rope **[4]**

Pradyumnakesharimaharana, in the thesis "Computer aided analysis and design of hoisting mechanism of an EOT crane" states that wire rope is liable component in crane and failure due to large amount of stresses. So increase the number of rope falls decrease the tension on rope falls and also used factor of safety. Ultimately reduce the risk of wire rope failure.Increase number of rope falls so increase length of wire rope which is expensive.The arrangement of wire rope is also important and arrange in between upper pulley block and bottom pulley block **[5]**

K. NareshChauhan, P. M. Bhatt in the paper, "Improving the durability of the EOT crane structure by finite element analysis and optimize the hook material for improving its solidity" states that crane is one of the most important material handling equipment and wide application in different fields of engineering. Many cranes are used beyond their lifting capacity so analysis of crane structure is essential. So the analysed has been calculated. The stresses and strains state of the power structure of overhead crane bridge for increasing its toughness is made using the NX NASTRAN. The results are shown that resulting stresses are well under the permissible stresses limits. And also study about the dimension optimization **[6]**

RajendraParmanikin a post "Design of hoist arrangement of EOT crane(2008), he has discussed about the history of crane, various types of crane, application, the design of the hoist of EOT crane is done by algebraic calculations and a model design of the various parts of EOT crane. and gearbox shaft fractured as a result of rotational bending fatigue. Fracture occurred due to high stress concentration**[7]**

Tomas H Orihuela and A D Anjikaret al.describe the basic procedure of monorail system design. Generally I section beams are used for monorail system having high load capacity. Thestructural design should follow the design criteria given in CMAA 74. The monorail system is checked for the stress developed, deflection and local capacity check. For high speed monorail system, it is also compulsory to check for fatigue**[8]**

Ismail Gerdemeli, Serpil Kurt, HasanOnurAlkan had determined height of the crane, distance between the rails, the lifting height, speed of the crane and speed of the transmission components for gantry crane used in shipyards. Construction geometry was analyzed in Abaqus software program.Three dimensional geometrywas created on cad software and then modeled with Finite Element Method (FEM). Then crane is tested under various loads. During their work, they found that if any component has an un-permitablestress value, the thickness of the sheets should be increased or suitable supports should be added. For Finite Element Analysis (FEA), the element type used in the model is 4 node quadratic shell element. Hence by this way they had prevented material waste. After this study, construction is now more reliable, light and durable. This study is very important with respect to aspects like low cost design and low design duration**[9]**

OzdenCaglayan, KadirOzakgul, OvuncTezer, ErdoganUzgider had studied about fatigue life of crane runway girders. Detailed finite element models of the crane runway girders were prepared using shell and beam elements. Here Finite ElementAnalysis (FEA) technique is used for calculating remaining fatigue life **[10]**

3. ESSENTIAL PARTS FOR MODEL:

3.1. Steel Block for Frame: To support the frame and withstand the load of whole frame.

3.2. Motors: Generally DC SERIES MOTOR is used.Crane motor is a part of gantry crane and overhead crane, which is a kind of equipment for electrical energy into mechanical energy. It is through the electric coil (i.e. stator winding) to produce a rotating magnetic field and its function in the form of

rotary torque.

Figure 1: Motor

3.3. DPDT Switch with a Board:DPDT (Double Pole Double Throw) This switch is equal to two SPDT switches, it means two separate circuits, connecting two inputs of each circuit to one of two outputs.The switch position controls the number of ways and from the two contacts each contact can be routed.

Figure 2: Switch Board

3.4. Electrical Connecting Wires: Wires are used for establishingelectrical conductivity between two devices of an electrical circuit. They possess negligible resistance to the passage of current.

3.5. SMPS system : A switched-mode power supply (SMPS) can be understood as an electronic circuit converting power with switching devices that turn on and off at high frequencies. They are also storage component like inductors or capacitors that supplies power when the switching as at its non-conduction state.

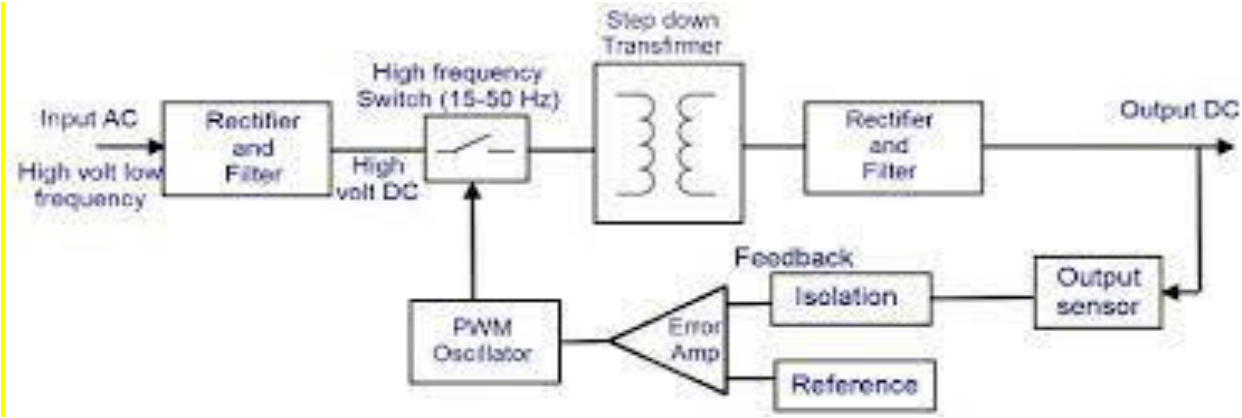

Figure 3: SMPS Circuit

3.6. Hoist :A hoist is a device used for lifting or lowering a load by means of a drum or lift-wheel around

which rope or chain wraps. It may be manually operated, electrically or pneumatically driven and may use chain, fiber or wire rope as its lifting medium.

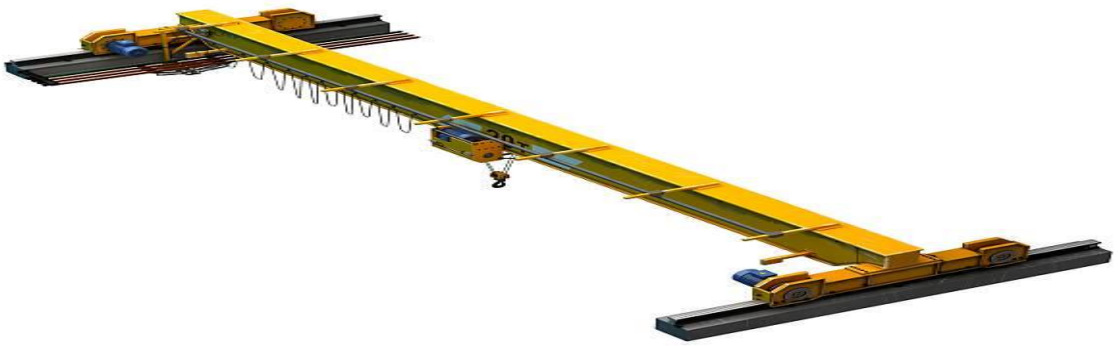

Figure 4: Hoist

3.7. Hoist Cable:A hoist cable is the braided steel cable that runs from the cable drum of a crane, up through the mast, and to the hook. When braided together, fine steel strands or wires become extremely strong and durable. The cable is easily rolled onto a winch drum and spooled out when called upon to lift and move a load.

Figure 5: Cable of Hoist

3.8. Crane hook : Crane hook is very significant component used for lifting the load with the help of chain or wire ropes.Different materials like forged steel, wrought iron and high tensile steel.

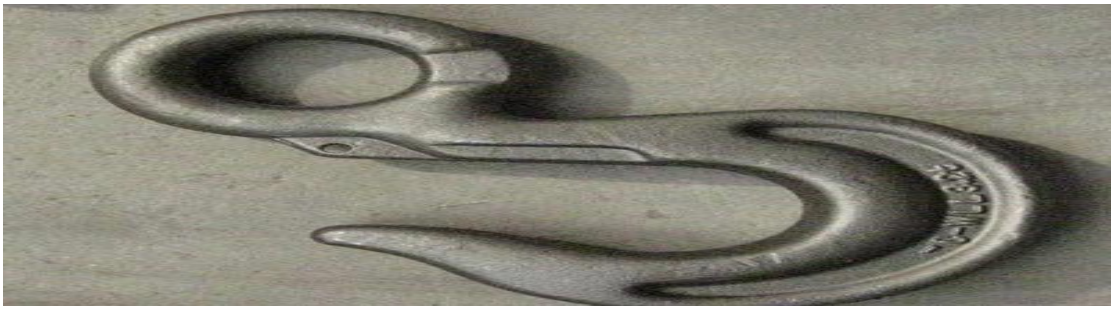

Figure 6: Crane Hook

3.9. Rack and Pinion Mechanism:A rack and pinion is a type of linear actuator that comprises a circular gear (the pinion) engaging a linear gear (the rack), which operate to translate rotational motion into linear motion.Driving the pinion into rotation causes the rack to be driven linearly.

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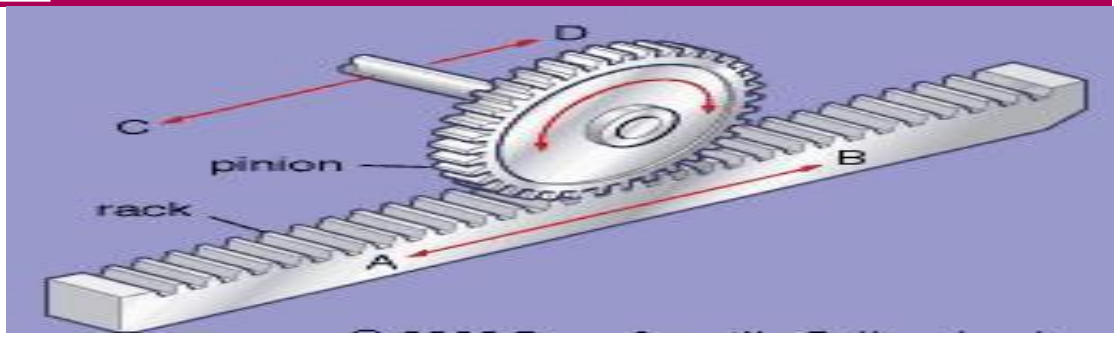

Figure 7: Mechanism of Rack and Pinion

3.10. Pulley:A pulley is a wheel with a groove along its edge, that holds a rope or cable.When pulleys are used together in this way, they reduce the amount of force needed to lift a load. A crane uses pulleys to help it lift heavy loads.

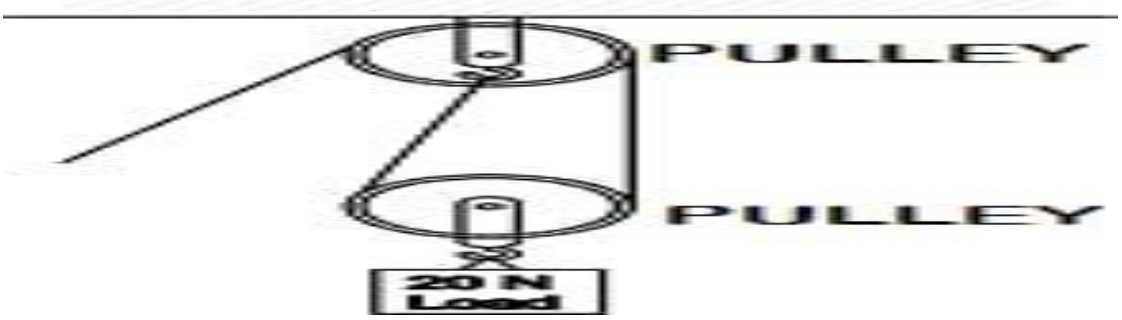

Figure 8: Pulley

3.11.RunWay : The rails,beams,brackets and framework on which the crane operates.

Figure 9: Runway

3.12.Trolly: The unit carrying the hoisting mechanism which travels on the bridge railsin a direction at right angles to the crane runway. Trolley frame is the basic structureof the trolley on which are mounted the hoisting and traversing mechanisms.

Figure 10: Trolley Crane

3.13.Runway Rail : The rail supports the runway beam on which the crane travel.

4. Design of components of the overhead crane system:

The overhead crane consists of the following components:

1. Beam for holding chain hoist
2. Columns for structural support of crane
3. The Rack Pinion mechanism
4. Gear box for changing rpm

5. Design of Beam for Chain Hoist:

The existing chain hoist will be transferred to a new beam which will move on channels situated over the columns in the workplace. The beam has to withstand bending and shear forces which will be caused due to the load being lifted by the chain hoist.

The dimensions of the work place are:

Length = 60mm

Width = 20mm

Height = 55mm

The beam will be as long as the total width of the workplace and the bearings at the side will facilitate linear movement along the length of the place.

6. Design of Beam:

The material selected for the beam is Fe 410. This material is used in 90% manufacturing works as it is cheap and readily available.

The material properties are:

- Ultimate tensile strength (σ_u) = 410 MPa
- Yield tensile strengt (σ_y) = 220 MPa
- Young's modulus (E) = 210 GPa
- Considered FOS over yield = 2
- Allowable bending stress (σ_b) = 110 MPa

Available Data:

Total weight on beam (W) = 0.5kg = 0.5 x 9.8N≈5N

Total length of beam (L) = 1.2m = 1200mm

Total moment acting(M) = WL/4 = (5x1200)/4 N-mm=1500 N-mm

Required section modulus (Z) = M /σ= 1500/11x10^3 mm^3 =0.13636 mm

For rectangle beam Cross Section 100x50mm

I_{xx}=1.0416x10^6 mm^4

Deflection of beam (δ) = $WL^3/48*E*I_{xx}$ = 0.000822mm

7. Design of Column:

By Euler's formula,

For, one end fixed and one end free column,

$P_c = \pi^2 E*Ic /4*L_c^2$

where, P_c= Buckling load,

E = 205 GPa,

L_c = Length of column=1500mm

Cross section of column=30x25mm

I_c= Moment of inertia of considered column section

= 39062.5 mm^4

$P_c = \pi^2$ x 205 x 10^3 x 39062.5/ (4 x 1500^2) = 8781N

Considering FOS = 5 (as safety is a primary concern, an FOS of 5 is selected.)

Safe load = Pc /FOS = 8781/5 = 1756 N

Total maximum load on 1column = (Load on beam /2) + Beam weight = (0.5/2)+4=4.25kg < Safe load

Therefore, the considered section is safe and design is proper.

7.1. Gearbox:

Our gearbox is a triple stage gearbox with a reduction ratio of 100, using spur gears to transmit power and provide the needed reduction ratio with the first stage having reduction ratio of 5:1, the second stage also having 5:1, and the third reduction ratio having 6:1.

Here W_{in}=285 rpm

d =Dia of drum=100mm

w= v/r = 1x2/100x(100x10^{-3})=0.2=(0.2*60)/(2*π)=1.90 rpm

1st stage :

ω=275/5=57rpm

2nd stage :

ω=57/5=11.4rpm

3rd stage :

ω=11.4/6=1.9rpm

7.2. PINION CALCULATION :

N_p= 18 teeth

rpm=285

phi(Ø) = 20°

Module (m) =6

D_p=6x18=108

f =3 x π x 6=56.55mm

wt=$2T/D_p$= 2x182.576/108x10^{-3}=3370N

K_v= 6/(6+v)= 6/(6+(π x 108 x 10^{-3} x 285/60) =0.788

From The Table,
y =0.33327
s=wt/(f * K_v* m *g) =3370/(56.55 x 0.788 x 6 x 0.333327)=37.82 Mpa

7.3. GEAR BOX ASSEMBLY:

Ratio between Gears= $w_1/w_2=d_2/d_1=N_2/N_1$

Stage 1:
Pinion, N=18 Teeth, d= 108mm
Mesh Gear= 108 x 5= 540mm

Stage 2:
Pinion,N=20 Teeth, d=120mm
Mesh Gear= 5 x 120=600mm

Stage3:
Pinion=22 Teeth, d=132mm
Mesh gear=132 x 6=792mm

Figure 11: Gear Mesh Assemble

8. CONCLUSION:

We have studied different components and mechanism of Overhead Crane in brief and we conclude that it is easy to handle by least manpower it can be very useful to move bulk weight from a place to another place. It's demand in market is increasing day by day. We can say that our project is very useful and practical oriented.

9. FUTURE SCOPE OF OVERHEAD CRANE:

The Overhead Cranes market report 2021 includes the estimation of market size for value and volume. It can also offer detailed insights, supply chain trends, technological innovations, key developments, comparative analysis of the market dynamics and customer's requirements.

The Global "Overhead Cranes Market" research reports offer detailed information regarding the leading key players to understand the market size, applications, trends, segmentation, and market potential. Also indicates major regions and future strategies about the specific requirements. The Overhead Cranes market covers professional market research with a standard version. This industry

report declares global Overhead Cranes market growth opportunities, development status, risks, and challenges. It can also represent the market dynamics, pre and post Covid-19 outbreak during the forecast period of 2021-2027.

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