A Project Report
On

"INSTALLATION OF SAFETY BRAKES IN EOT CRANES"

Submitted By,
Mr.Hitesh Gopal Awate
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In partial fulfiment for the award of the Degree
Of

BACHELOR OF ENGINEERING
IN
MECHANICAL ENGINEERING

UNDER THE GUIDANCE
OF
Prof. Saad Shaikh

DEPARTMENT OF MECHANICAL ENGINEERING

Anjuman-I-Islam's
KALSEKAR TECHNICAL CAMPUS
New Panvel-410206

UNIVERSITY OF MUMBAI

ACADEMIC YEAR 2019-2020

ANJUMAN-I-ISLAM

KALSEKAR TECHNICAL CAMPUS NEW PANVEL

(Approved by AICTE, recg. By Maharashtra Govt. DTE,

Affiliated to Mumbai University)

PLOT #2&3, SECTOR 16, NEAR THANA NAKA, KHANDAGAON, NEW PANVEL,NAVI MUMBAI-410206, Tel.: +91 22 27481247/48 * Website: www.aiktc.org

CERTIFICATE

This is to certify that the project entitled

"**Insatllation of Safety Brakes in EOT Crane**"

Submitted by

Mr.Hitesh Gopal Awate
Mr.Fahim Abutaher Gudmithe
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Mr.Abuzar Sami Ansari

To the Kalsekar Technical Campus, New Panvel is a record of bonafide work carried out by him under our supervision and guidance, for partial fulfillment of the requirements for the award of the Degree of Bachelor of Engineering in Mechanical Engineering as prescribed by **University Of Mumbai**, is approved.

Internal Examinar	**External Examiner**
(Prof. Saad Shaikh)	(Prof.)
Head of Department	**Director**
(Prof. Zakir Ansari)	(Dr.Abdul Razak H.)

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APPROVAL OF DISSERTATION

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(Internal Examiner) **(External Examiner)**

__________________ __________________

Date: __________

Abstract

Emergency braking system is a mechanical device which was added to the slow speed end of Electrical Overhead Travelling Crane. The braking mechanism is working based on the wedge braking methods. Emergency braking mechanism consists of brake drum, shaft, brake block and wedge. The arrangement was added at another end of rope drum. In case of any mechanical failure or a human error this arrangement comes into picture & avoid the accident thus, improves safety.

Acknowledgement

After the completion of this work, we would like to give our sincere thanks to all those who helped us to reach our goal. It's a great pleasure and moment of immense satisfaction for us to express my profound gratitude to our guide **Prof. Saad Shaikh** whose constant encouragement enabled us to work enthusiastically. His perpetual motivation, patience and excellent expertise in discussion during progress of the project work have benefited us to an extent, which is beyond expression.

We would also like to give our sincere thanks to **Prof. Zakir Ansari** , Head Of Department, **Prof. Rizwan Shaikh** , Project Co-Guide and Prof., Project co-ordinator from Department of Mechanical Engineering, Kalsekar Technical Campus, New Panvel, for their guidance, encouragement and support during a project.

I take this opportunity to give sincere thanks to **Mr. Ganesh Mahale** , Manager in "*JSW Steel Ltd. - Vasind"* , for all the help rendered during the course of this work and their support, motivation, guidance and appreciation.

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Last but not the least I would also like to thank all the staffs of Kalsekar Technical Campus (Mechanical Engineering Department) for their valuable guidance with their interest and valuable suggestions brightened us.

Thanking,

Mr.Hitesh Gopal Awate

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Mr.Faiz Zulfikar Don

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1.INTRODUCTION

Material handling is a crucial department in any manufacturing industry which involves bulk movement of materials from one place to another which changing the nature of the materials. It is the most attractive and major areas where cost can be reduced. If labours are employed for moving such bulk materials, it involves cost and does not have enough safety for them. When the costs are reduced, it ultimately results in less cost for a finished good. Thus, **EOT (Electronic overhead travelling)** crane is essential industrial equipment involved in material handling job.EOT crane is one of the most common types of Overhead Crane, or called Bridge Crane which consist of parallel runways with a traveling bridge spanning the gap. As obvious from the name, EOT crane is operate by electric, generally there is an operator cabin or a control pendant along with the EOT crane.EOT crane is extensively used in the warehouse, workshop, and stock ground of pilining, unloading or relocating heavy load. EOT crane is equipped with the mechanical means to realize the traveling not only in both directions but also can raise or lower the heavy load easily. Also, EOT crane is forbidden to used in the explosive, combustible or corrosive environment, and the working temperature is approximately from -20 to 40.

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. Some of the most popular reasons for using an overhead crane include:

- Loading or unloading materials from a truck
- Moving materials around a facility more efficiently than a tow motor or manpower can
- Flipping or pulling dies in and out of stamping machines at a manufacturing facility
- Feeding raw material into a machine at a manufacturing facility
- Moving pieces or parts down an assembly line in a controlled fashion
- Moving containers around a shipyard or railyard

In addition to simplifying some of the processes described above, there are two main reasons why a company would want to install an overhead crane, or a series of overhead cranes, in their facility:

1. **Efficiency**- Overhead cranes are more efficient than using a group of workers or tow motors to lift and move material and can work up to 2-3 times faster. Think about how a manufacturer, mill, or warehouse can streamline their processes and procedures by introducing an overhead crane to automate the lifting, maneuvering, and unloading of materials at their facility.
2. **Safety**- Another advantage of installing an overhead crane in a manufacturing, assembly, or warehousing facility. Cranes can be used to lift and move materials in extreme environments and can handle corrosive or dangerous materials like hot metals, chemicals, and heavy loads. A workstation or jib crane can be put in place to help workers move heavy objects in a controlled manner and help cut down on repetitive motion injuries and muscle strains.

   Other benefits to using an overhead crane system include:

- Reduction in workplace accidents
- Reduction of product or material damage
- Improved workflow
- Lowered costs
- Green solution that reduces environmental impact

There are assortments of types of overhead cranes with many being extremely specialized, but the vast majority of installations fall into one of three categories:

a) Top running single girder bridge cranes,

b) Top running double girder bridge cranes and

c) Under-running single girder bridge cranes.

- **Single Girder EOT crane** -The crane consists of a single bridge girder supported on two end trucks. It has a trolley hoist mechanism that runs on the bottom flange of the bridge girder.

Fig 1.1 : Single Girder EOT Crane

- **Double Girder EOT Crane** -This type of EOT crane consists of two bridge girders supported on two end trucks. The trolley runs on rails on the top of the bridge girders.

Fig 1.2 : Double Girder EOT Crane

- **Gantry Cranes** -These cranes are essentially the same as the regular overhead cranes except that the bridge for carrying the trolley or trolleys is rigidly supported on two or more legs running on fixed rails or other runway. These "legs" eliminate the supporting runway and column system and connect to end trucks which run on a rail either embedded in, or laid on top of, the floor.

Fig 1.3 : Gantry Crane

- **Monorail** -For some applications such as production assembly line or service line, only a trolley hoist is required. The hoisting mechanism is similar to a single girder crane with a difference that the crane doesn't have a movable bridge and the hoisting trolley runs on a fixed girder. Monorail beams are usually I-beams (tapered beam flanges).

Fig 1.4 : Monorail Crane

2.PROBLEM DEFINITION

Overhead Travelling Cranes, Gantry Cranes, Jib Cranes and Monorail Hoists are used widely for material handling. Safe operation of such cranes requires operators to have the knowledge and competence to avoid accident.

The purpose of this report is to raise awareness of the hazards in lifting operations and to provide the basic knowledge in the safety devices(brakes) overhead travelling cranes, gantry cranes, jib cranes and hoists.

This report is intended to be used by company managements to promote safe lifting operations in the handling of Overhead Travelling Cranes, Gantry Cranes, Jib Cranes and Hoists. Please see following Figure-

Fig 2.1 : Crane Failure

Most accidents related to gantry cranes, overhead travelling cranes, jib cranes and hoists occur during the lifting activity. The consequences of an accident can be serious, and fatal at times. Adopting the right method and using the right equipment will greatly minimize potential accidents during lifting operations.

Statistics say that accidents, incidents are very common on cranes. It may be during shifting of material or during maintenance work. Considering the hazards and associated risks involved, it has been felt necessary to formulate some basic guidelines for safe working on EOT cranes (are formulated & specified in this report for compliance).

This report will be applicable to all EOT cranes in operation or during maintenance. The subject has been addressed from the following three different aspects and adherence to the requirements evolving thereof shall ensure better control of and protection from foreseeable hazards:

· Relevant Statutory Provisions

· Engineering Controls to Ensure Safety

· Standard Work Practices

3.LITERATURE REVIEW

Emergency braking mechanism is working based on the wedge braking methods. In any EOT crane designed with two sides that is drive and non-drive sides. The drive side is called high speed end and non-drive side is called slow speed end. Drive end was connected with gear box, coupling and shafts. A thruster brake system was available at high speed end to retard the lifting speed and hold the load. There were no brakes provided at slow speed end because high rate of torque is applied in this side. Indian standards are not enforcing to provide the braking system at slow speed end. But United States made mandatory to provide the same by the EN 14492-2. Electrical motor is the propellant device of Electrical Overhead Crane it can provide high speed with low torque. Thruster brake system was provided after the electric motor for holding the load during operation as well as stopping. According this arrangement, Thruster never saves the load drop/accident in case of any damages occurred in the gear box or shaft. This is very rare but catastrophic.

Emergency braking mechanism consists of brake drum, shaft, brake block and wedge. The arrangement was newly added to slow speed end of hoist mechanism ie., rope drum. A centrifugal switch was provided for monitoring the rated RPM of rope drum. The switch was elected based on the operational RPM. A solenoid switch was fixed under the wedge and linked with centrifugal switch. When the solenoid valve receives the signal from centrifugal switch, it can eject the wedge. The wedge will entangled between brake drum and brake block resulted brake force applied at slow speed end. Rotation of brake drum and wedge was located to induce brake at lowering motion only. It does not disturb the operational function. The braking system will be actuated if any accidental load drop occurred due to failure of shaft/gear box/couplings.

After the operation of emergency braking system we must replace the wedge. Because the wedge may plugged due to impact load of brakes. Reuse of wedge is not advisable for efficient function of emergency braking system. Emergency braking system is very essential for warehouse containing explosive materials. More than 150 starts operational cranes are have high probability to get mechanical failure. Emergency braking system will enhance the reliability of EOT crane as well as safety.

➢ General Arrangement of EOT Crane Hoist

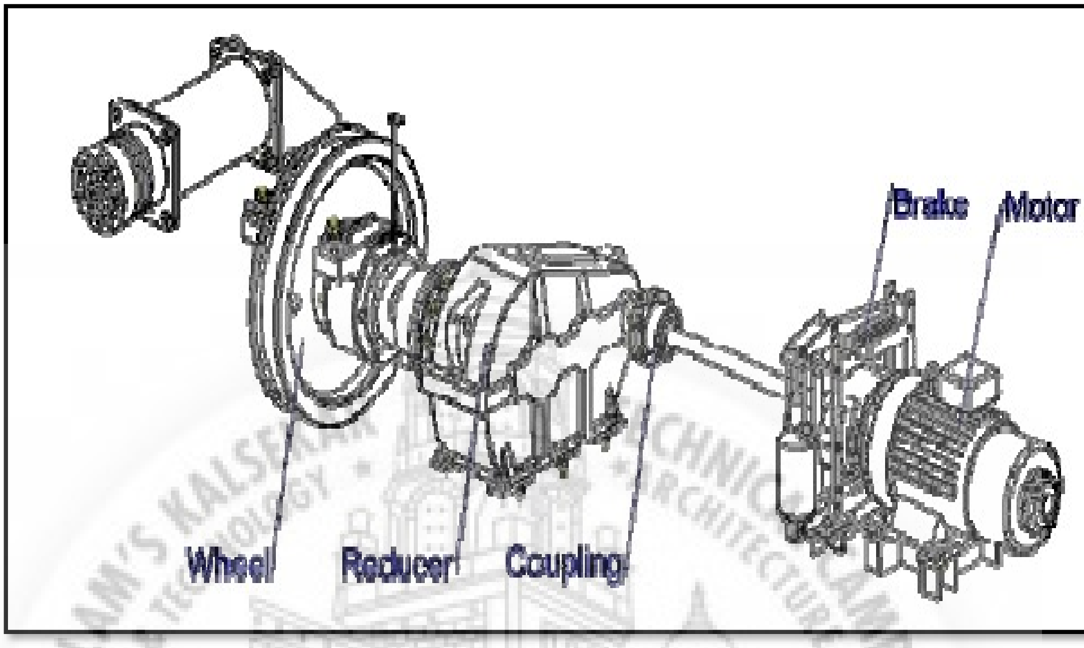


Fig 3.1 : Existing Hoist Arrangement

There are two sides mentioned in the hoist mechanism one is high speed end and another one is slow speed end. High speed electric motor is used as propellant in the crane hoist. The motor can deliver the high-speed rotational motion with low rate of torque. Motor torque referred is an electrical formula that lift maximum load. The below formula for calculating motor torque, which uses the horsepower and rpm of the motor being used and is expressed in foot-pounds / Newton meter:

Torque = (hp x 5,250)/rpm in ft-lb

Torque = (hp x 5,250)/rpmx0.73756 in Nm

The mechanical torque produced by the brake must be greater than full-motor torque. Service factor must be considered during calculating motor power. According to AIST (Association for Iron and Steel Technology) Technical Report No. 6, "Brake sizes shall be as recommended the following:

1. 150% when only one brake is used.
2. 150% when multiple brakes are used and the hoist is not used to handle hot metal; failure of any one brake shall not reduce total braking torque below 100%.
3. 175% for hoists handling hot metal; failure of any one brake shall not reduce total braking torque below 125%

Gear box can convert the high-speed rotation to high torque but RPM became low. Mostly heavy multigrade gearbox has been used in cranes like 1:100, 300 rates. All equipments are linked with rigid shaft. Thruster brake system was provided between motor and gearbox because low rate of torque being observed that location which is uncomplicated for braking.

Hoist of EOT crane was constructed as above arrangement. Propellant power (motor) has been received from electric motor. Speed of the motor was converted to useful torque by multi grade gear box. Load was attached to the lifting hook which is hanged to the sheaves. Sheaves are arranged as a simple mechanism. Existing braking setup is enough for regular operation. Hoist Brake is applied at high speed only but no braking mechanism was provided at slow speed end i.e., near the rope drum. So, if any failure occurred after the location of thruster brake, total load will be dropped. Some of case studies were available for this type of failure causes accident. These types of accidents are very rare but cause catastrophic result.

3.1 Thruster Brake System

Thruster brake is a device to retard the speed of moving machinery and to stop it to the desired position. Brake is applied always by pretension spring. Energy or power is required for releasing the braking force during lifting or lowering of hoist. Electrical or electro hydraulic motor was used to release the braking force. The shoes press on the rotating brake drum retarding its speed and finally stopping it. The releasing of the brake and compressing of the spring is done by the Thruster. The pre-tension in this spring decides the braking torque. When the thruster is not energized, the brake shoes are pressed on the brake drum fitted on the drive motor shaft. When the thruster motor is energized, the thrust provided by the thruster lifts up the crank lever which moves the arms and the shoe brakes away from the brake drum, and releasing the braking force.

In addition to the thruster braking system, European Standard EN 14492-2 has enforced to provide braking system at slow speed end. Probability of accident due to load drop is common because thruster brakes never controls the slow speed end of hoist. So Electrical Overhead cranes using for handing of explosive material are recommended to provide additional braking system in that country.

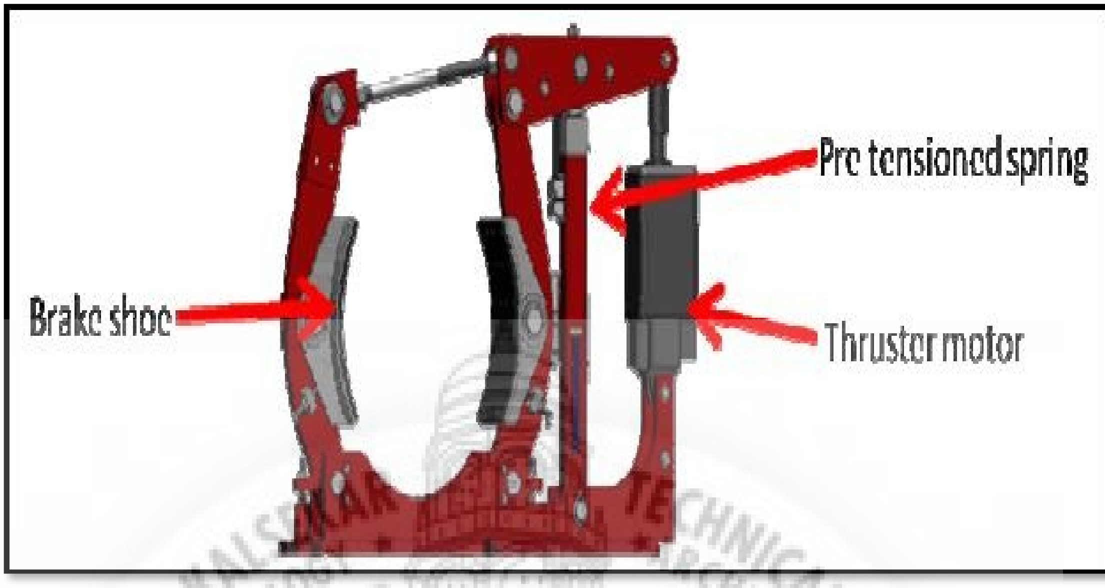


Fig 3.2 : Thruster Brake System

3.2 Need for emergency brake

Gear box of the hoist get gradual diminution due to function of thruster brake system. Improper alignment of thruster brake shoes, time clip between actuation of motor & thruster and high starts per hour can lead the mechanical damage to the crane equipments. These damages of gearbox /shaft / coupling are resulting accidents which is very rare but catastrophic. The following points are noticed for needs of emergency braking system,

1. Thruster brake was installed before the gear box. So, it is incapable to hold the load if the gearbox get failure.
2. Thruster brake system has inability to hold the load drop in case failure of couplings.
3. Thruster brake system can't hold the load drop if the connecting shaft got broken
4. Improper brake shoe alignment in thruster can't provide adequate braking force. So load drop may occur even-though thruster in working condition (accident).
5. Entire crane brake is only depends on the thruster brake system. There is no fail safe arrangement available.

6. Reliability level related with safety of EOT crane is petite.

Overhead cranes are located typically above 20ft level so access to overhead crane also not easy. Additional safe arrangements must be needed for accessing the overhead crane and duration of maintenance also minimized for safety of workers. These are the factors were considered for failure of overhead cranes as well as crane accidents by means of load drop.

4. METHODOLOGY

4.1 Emergency Braking Mechanism

Emergency braking system is an electro mechanical device consists of brake drum, brake block, wedge, rpm sensor and solenoid switch. The braking system was affixed with another end of rope drum by flange coupling. During normal operation the system doesn't work. When the rotational speed of rope drum reaches higher than normal, the system will be activated to stop and hold the rope drum with crane loads. The rope drum never reaches above the normal speed until any failure occurred in hoist mechanism.

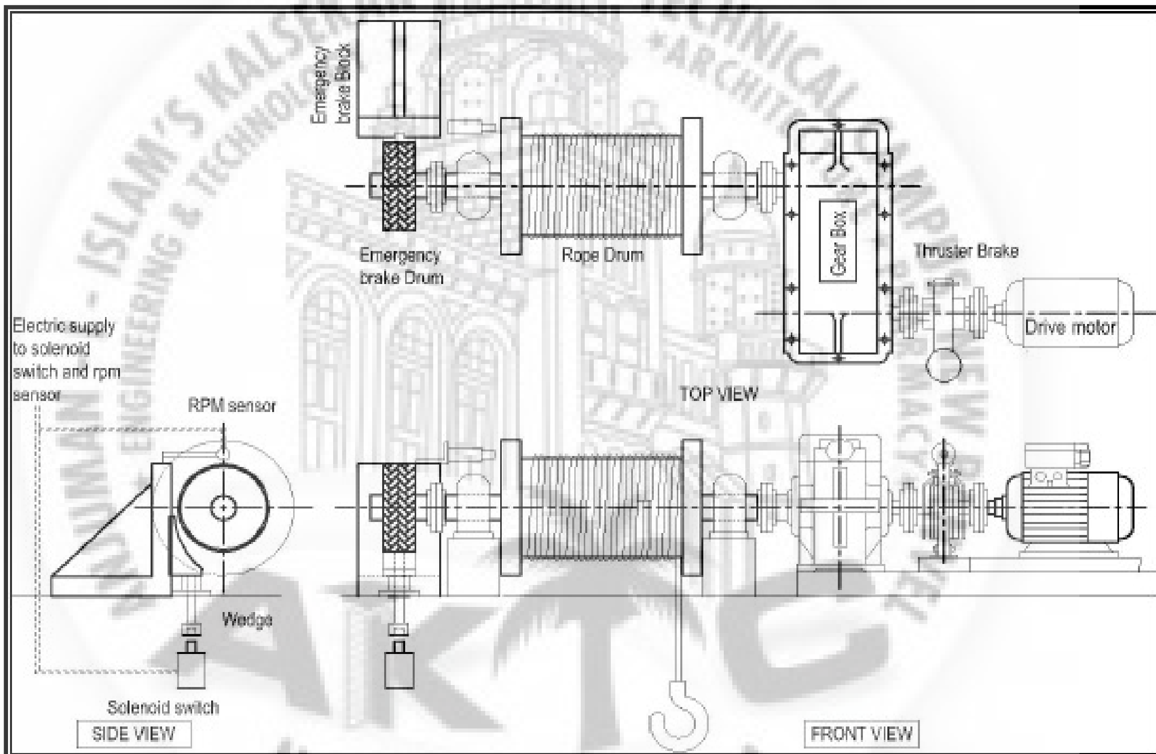


Fig 4.1 : Layout of Emergency Braking System

Brake drum was fixed on the extended shaft. Brake block was located closer to rope drum and it has key way for guiding the wedge while applying brake. Wedge was inserted in guide bush located at bottom and correlated with key way of brake block. Long pin has been attached under the wedge. Always the brake drum rotates along with rope drum. Long stroke solenoid switch was linked with rpm sensor which is monitored the rotation of rope drum. When the rope drum reaches higher than normal speed, signal will be sent to solenoid switch. Immediately wedge will be lifted to lock the brake drum with brake block by solenoid switch. Finally, wedge will be entangled between brake drum and brake block. This event causes braking effect to the rope drum. Factor of safety maintained overall crane shall be 2.5. Rope and hook must be maintained at 8. Other than rope and pulley, we can't see the level of depreciation. In this connection we recommended that wedge should be replaced after using of emergency brake because wedge may get plugged / deformed while applying brake. Original wedge gives effective result.

At first glance, we must provide bigger brakes torque provides better braking. Smaller diameter brake can generate as much torque as a larger by simply increasing the coefficient of friction linings applications. Total amount of torque shall be calculated as given below for hoist arrangements.

Lifting Torque at Rope drum = (Motor torque) x (gear box ratio) x (service factor)

Motor Torque = (hp x 5,250)/rpmx0.73756 in Nm

Gear box ratio= Times of reduction in speed

Service factor = Service factor 0.95 – 1.2 as per IS 3177

During load drop, the torque may develop up to 125% due to hold the full load. So we must design the braking torque greater than 150%.

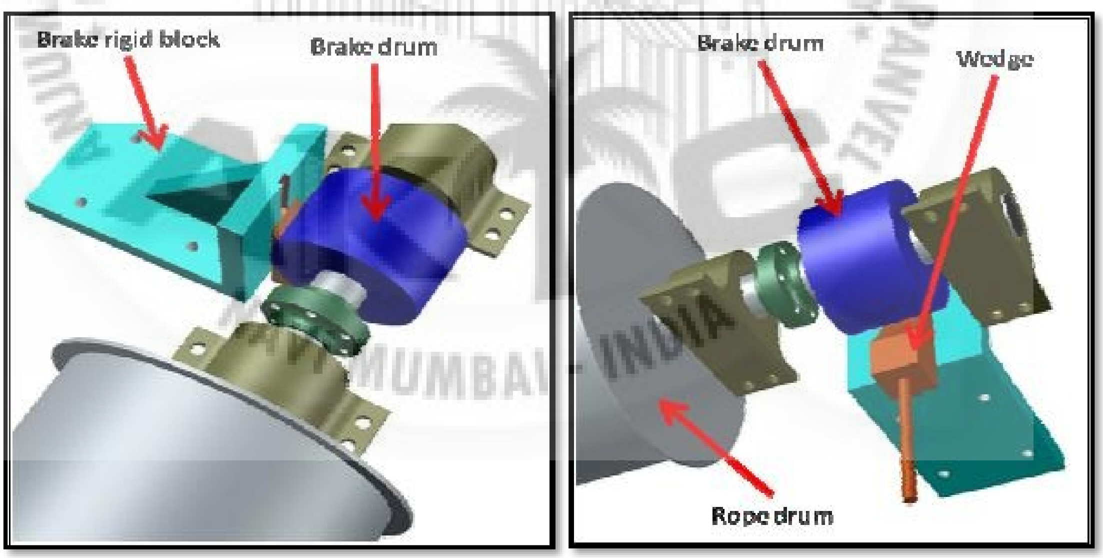


Fig 4.2 : 3D View of Emergency Braking System

a) Maximum force acting on the brake drum

Acceleration due to gravity causes the falling object to increase speed as it travels.

Falling object's speed is constantly changing based on the height of the drop and weight of load. These factors affect the performance of emergency braking. Gravitational force must be calculated at maximum height of the crane.

Impact velocity $v=\sqrt{2gh}$

Kinetic energy K= 1/2mv2

Max force acting on the brake drum = (mgh)/d Newton

Electrical overhead crane typically provided at 6m elevation and works with heavy loads.

b) Maximum Braking Torque (M_{bmax})

As hoist application, lowering the load can induced max torque by load. Total load may differ based on the elevation. Stopping energy is even higher due to system inertia. It is calculated as follows:

Braking torque $M_{bmax} = (J_{tot} \times N \times 2 \pi J_m /60) - M_{load}$

Inertia of mass $J_m = \frac{1 .wr^2}{2. g^2}$

Where,

J_m - Mass moment of inertia for motor — J = inertia (kgm²)

M_{load}= - Load induced by mechanism — W = weight (Kg)

J_{tot} - Combined moment of inertia — R = radius (m)

N - Speed — g =gravitational force by height

Torque produced by the brake must be greater than lifting torque of crane. Friction factor shall be considered while calculating braking torque. According to AIST (Association for Iron and Steel Technology) Technical Report No. 6, Brake capacity shall be as recommended for greater than 150 – 175% based on the normal material to explosive material.

5. DATA COLLECTION

- **Crane No. 401 – 30 T**

- Load mass: 31,000 kg (consider SWL, bottom block, wire rope weight)

- No of reevings line: 8 (As per the specification)

- Drum diameter: 480 mm

- Flange diameter: 1000mm

- No of strands per rope drum: 2 per drum (As per the drawing given)

- Safety factor: 2

- Axial movements of the brake disc +/- 0.15 mm

- Brakes will function as emergency and parking brakes, not as operation brakes

- Max. 4 meters pipe length from brakes to hydraulic aggregate

- Braking system painted in KATEEL Brakes' standard colors

- Ambient temperatures min. 0º C and max. +60º C (if not, please contact us)

- Max. opening time of the brakes 2 seconds (balance pressure of the brakes)

- Braking system will be installed in non-corrosive environment

- No water or grease on the brakes or brake disc

- **Quotation description for crane no. 401 – 30 T**

1. Hydraulic disc brakes-spring applied hydraulically released Type KDAF/ 70-DS with Brake on/off switch Make: Kateel
2. Single Motor Hydraulic power unit with manual release hand pump See description later in this quotation with enclosure
3. PLC Based Electrical Control Panel for operating single motor Hydraulic power pack.
4. Hallo Shaft Encoder for measuring the rope drum RPM
5. Flange OD 1000mm X 25mm thick
6. Brake Mounting Bracket with Hoses & Fittings including Sole Plate for the above Model
7. Installation & Commissioning the Brakes.

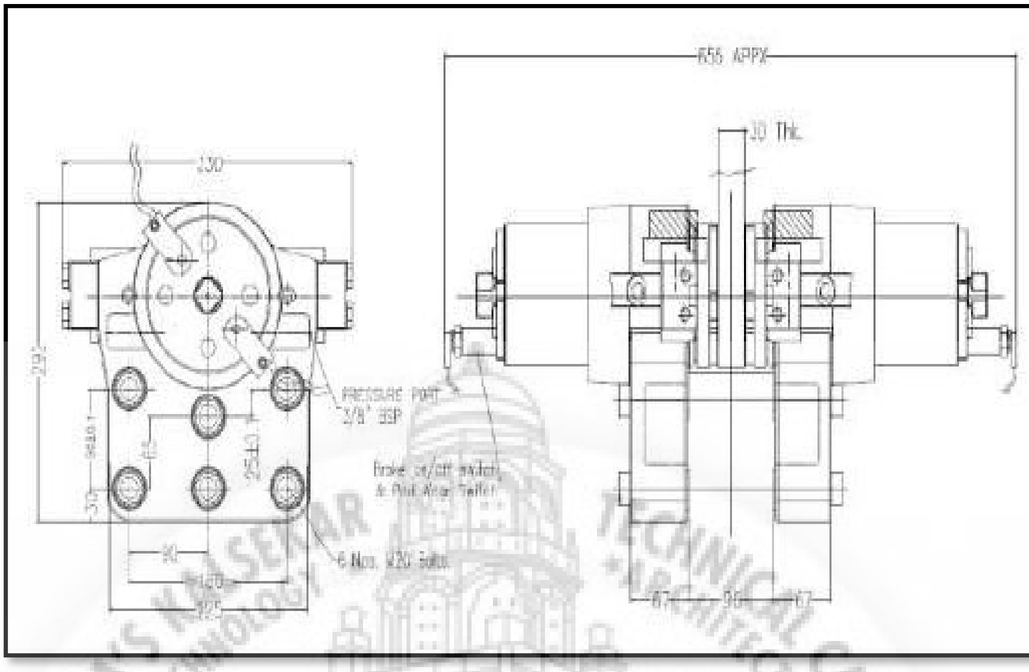


Fig 5.1 : Hydraulic Fail-Safe Disc Brake

- **Brake Specifications -**

Weight	: 120kg
Brake Pad Width	: 130mm
Area per brake pad	: 20,000mm^2 - sintered material
Max wear of each Brake Pad	: 3mm
Total Piston Area	: 138.2cm^2
Oil volume - 1mm stroke	: 13.8cm^2
Pressure Connection Port	: 2 ports - 3/8" B.S.P.
Drain Connection Port	: 2 ports - 1/8" B.S.P
Min Recommended Pipe Size	: 10/8 - Ø 10mm (OD) ; Ø 8mm (ID)
Max Operating Pressure	: 230 bar
Temperature Range	: -20^{o}C to 80^{o}C
Min Outer Disc Diameter	: 480mm
Max Outer Coupling Diameter	: 300mm
Disc Thickness	: 20-30mm
Clamping Force	: 1,40,000N
μ (coefficient of friction)	: 0.4

- **Hydraulic Power Pack Description -**

1 No., 3 HP, 415 VAC motor,

24 VDC coils, 19 watt

4.8 L/M gear pump

Flexible coupling between motor and gear pump

0.15 litre accumulator

Pressure switch for motor on/off, max. 230 VAC

10 micron pressure filter

Check valve

Solenoid valve etc.

➢ General description of the hydraulic system:

-The hydraulic system is driven by a single motor. 415 VAC, 50 Hz electric motor

-Each motor is operating a 4.8 L/M gear pump, which provides pressure to the system.

-A 10 micron air breather is mounted on top of the oil tank. – it prevents oil and air from dirty particle coming from the ambient environment. Air in the hydraulic system will cause a slower reaction of the braking system.

-The hydraulic system is equipped with one accumulator which reduces the starts and stops of the motor in case of small leakage in the hydraulic system.

- **Brake Function Description -**

-To open the brakes, hydraulic pressure is required from the hydraulic system. The pressure is built-up by means of the gear pump and the electric motor. The power supply to the motor is constantly controlled by the PLC, which will receive a signal from the pressure switch.

-For opening of the brakes, the PLC has to give a signal to the motor, which will build up the pressure in the brakes. However, the accumulator is filled first, and after reaching its pressure setting, the lifting of the brakes continues. Before entering the accumulator and brakes, the oil passes through the 10 micron pressure filter where the oil is cleaned to avoid particles in the system.

-The solenoid valve must be energized for the oil to pass through to the brakes.

-The solenoid valves must also be energized to prevent the oil from running directly to tank.

-When the hydraulic pressure in the brakes reaches the operating pressure, the pressure switch gives a signal to the PLC that the brakes are fully opened, and the PLC must then stop the motor.

- **Brake Sequence -**

-The system is designed for emergency and parking application only, and not for operation braking.

-The oil is dumped immediately to the tank, by de-energizing the solenoid valves. This means that full braking force will be achieved as fast as possible, giving full emergency braking.

-The dumping of oil to tank continues until no more oil is left in the system, and 100% braking force thereby is achieved.

-As soon as the hydraulic pressure at the brakes drops below the preset pressure for the pressure switch, the signal from the pressure switch will disappear, indicating that the brakes are not totally opened anymore.

- **Brake Caliper -**

Fig 5.2 : Brake Caliper

-Brake system will include one fail-safe brake calipers, spring applied and hydraulically released. The calipers must be able for installation on the drum on the brake disc center line as shown in fig. 5.1.

-Brake calipers will include electronic indicators, micro switch or inductive type, to give signal when the calipers are released.

-Fig 5.1.Brake calipers on the disc center line

-The brake calipers will be supplied with brake pads, with an average coefficient of friction of minimum 0.4. The width of the brake pads will be sufficient to remove the heat generated during the stopping sequence without exceeding the operating limits of the friction material.

-The brake pads will include pad retraction springs to retract the brake pads, in order to event unnecessary wear on the friction material when the brake is not engaged.

Fig 5.3 : Hydraulic Safety Brake System

Fig 5.4 : Brake Caliper

Fig 5.5 : Hydraulic Power Pack

- **Brake Disc -**

-The brake disc must be manufactured from steel quality st 52.3 or equal

-Face specifications for the brake disc shall be according to fig.2 below. Disc surface specification

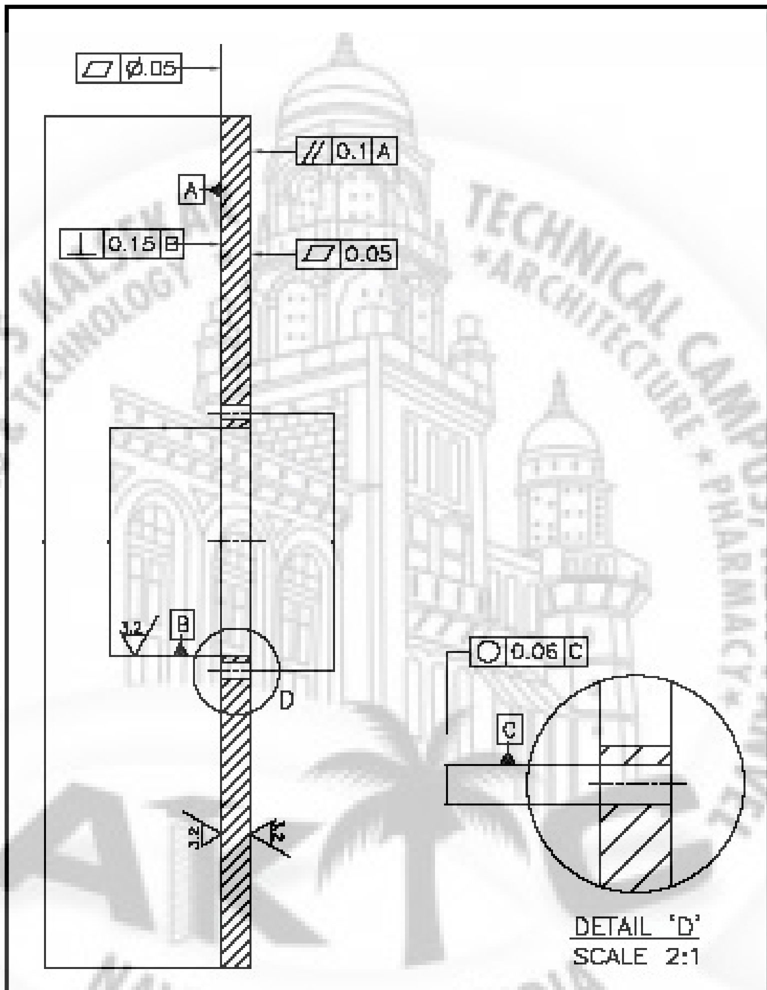


Fig 5.6 : Brake Disc Specification

6. CASE STUDY

Crane accident

Date of accident: 02/05/2019

Time of accident: 1:50pm Rakesh Kumar was operating an EOT crane to move a Hot Rolled Sheet from an storage area to dispatched area in order to dispatching the product to customer.

JSW Steel Ltd. history

With the largest product portfolio in steel, JSW Steel Ltd. is India's largest steel exporter, shipping to over 100 countries across 5 continents. Over the last 35 years, they have been at the forefront of science and cutting-edge technology. Starting with a single plant in 1982, they are now India's leading manufacturer of value-added and high-grade steel products. With plants in Karnataka, Tamil Nadu and Maharashtra, they have the capacity to produce 18 million tons per annum (MTPA). By staying on the cusp of change, and maintaining the best-in-class standards, they aim to revolutionize steelmaking. JSW Group is a major player in steel industry with a formidable presence in Steel, Energy, Cement and Ports. JSW Steel Ltd has become a single largest steel plant in India through speed and innovation in short span of time. JSW Steel Coated Products Limited (JSWSCPL) is a 100 % subsidiary of JSW Steel Ltd., having state of the art manufacturing facilities at Vasind, Tarapur & Kalmeshwar in Maharashtra. JSWSCPL is India's largest manufacturer and exporter of Coated Steel with a total capacity of 1.8 MTPA with the capability to produce 0.69 MTPA of Colour Coated Steel. The manufacturing facilities at Vasind & Tarapur plants are located near major ports & Kalmeshwar plant is centrally located near Nagpur to serve customers across the nation.

Accident Investigation

There have been two very serious accidents involving cranes in the JSW Steel Ltd.-Vasind so far. The first incident occurred on Dec 10,2018 when a crane failed due to overloading and killed two workers. Suresh Ramdas Kumavat is the operator of the crane. This accident had been investigated successfully, the main cause of this accident is that the crane was poorly maintained and that mechanical failure contributed to the accident.

The second serious accident occurred on May 2,2019. This event was same as the first accident in that the operation of a crane factor into the accident. The apparent cause of this accident was the Brake Failure of the crane. One worker was killed and three others were seriously injured. Rakesh Kumar is the operator of the crane.

Fig. 6.1 : Hoist Mechanism

Fig 6.2 : Failure of Girder

Fig. 6.3 : Failure of Rope

Fig. 6.4 : Bending of Trolley Frame

Summary

As we can see, crane accidents can be very serious. Equipment failure or human error can lead to death. We believe the most significant finding of our analysis is that riggers appear to be at the greatest risk during crane operations. The above analysis could also lead you to believe that equipment failures cause more crane incidents than human error. However, the workgroup believes that human error likely played significant contributing roles in those incidents listed as being caused by equipment failure. We found that almost 75% of the reports listed the cause of the accidents as mechanical failure (several incidents are still under investigation and the specified causes could change).

Recommendation

Based on the information discussed above, the workgroup believes that the following recommendation could help improve the safety of crane operations:

1. Installation of Hydraulic Safety Braking System

7.PREDICTED ANALYSIS

- **Theoretical** -

Brake calculation for Crane:

Load mass :31,000 kg(consider SWL , bottom block, wire rope weight)

No of reevings line : 8 (As per the specification)

Drum diameter : 480 mm

Flange diameter : 1000mm

No of strands per rope drum : 2 per drum (As per the drawing given)

Safety factor: :2

M_b = Load × (Drum Diameter / 2) × 9.81 = 31,000 × (0.48 / 2) × 9.81

= 72,986 × 2 (2 is F.O.S.)

= 1,45,972 NM

Also, Braking Torque = 1,45,972 / No. of reeving

Braking Torque= 18,246 NM

But, Number of strands per rope drum is 2

Therefore, 18,246 x 2 = 36,493 NM

Braking Torque= 36,493NM

Braking force needed:

$F_b = M_b \times 2 / D_o - w$

$$= \frac{36,493 \times 2}{1 - 0.13}$$

= 83,891N

F_B = Braking force (N)

M_B = Braking torque (Nm)

D_0 = Disc outer diameter (meters)(1m)

w = Pad radial width (meters)(0.13m)

Clamping force (Fc) needed using the coefficient of friction μ= 0.4:

$F_c = F_b / (2 \times \mu)$

$= 83,891 / (2 \times 0.4)$

$= 1,04,863$N

"Suitable Brake Model giving the clamping force of 1,04,863 N considering the air gap of 2mm per side"

Hence selected Brake model is OK.

- **Software** -

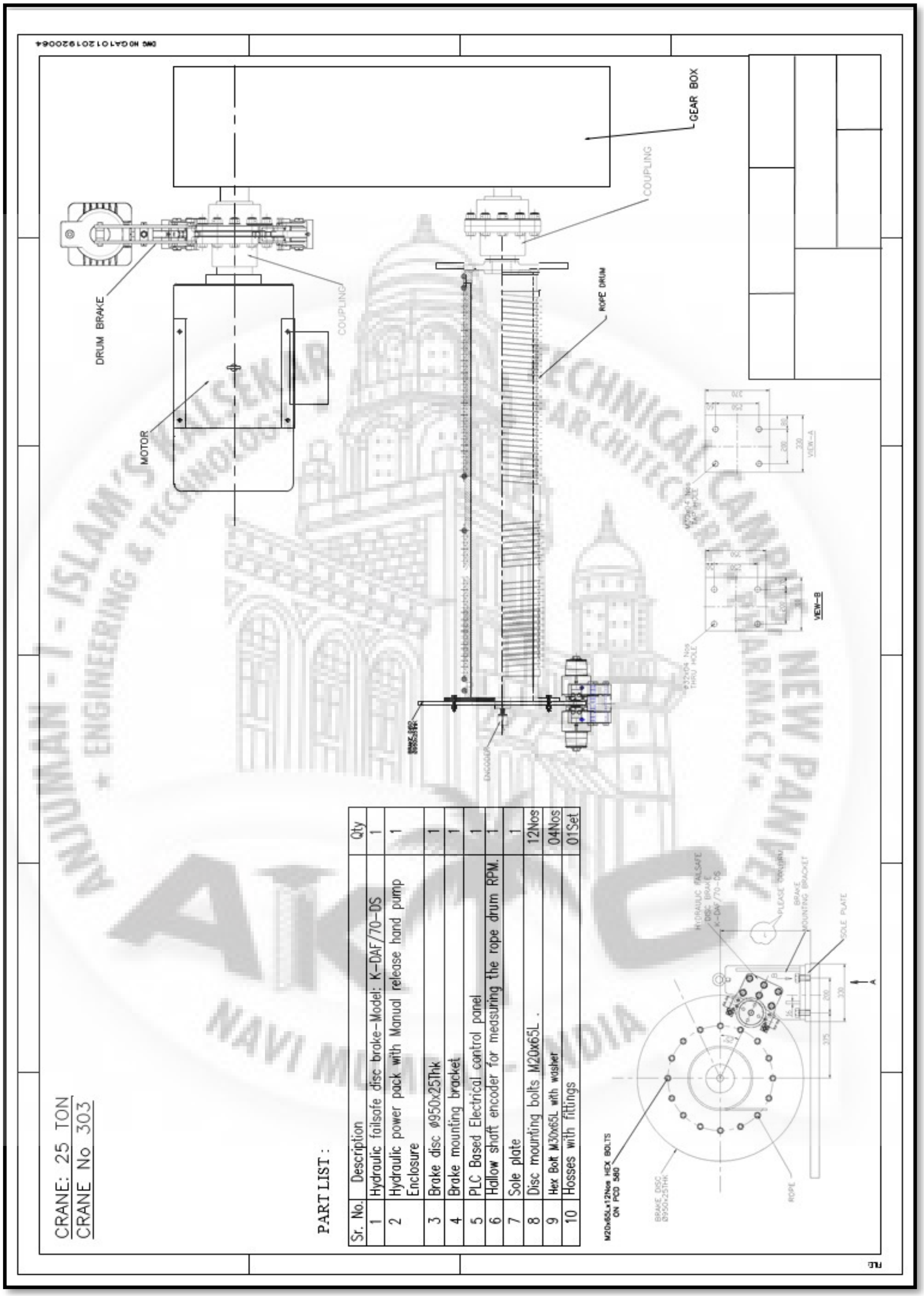


Fig. 7.1 : Crane Assembly

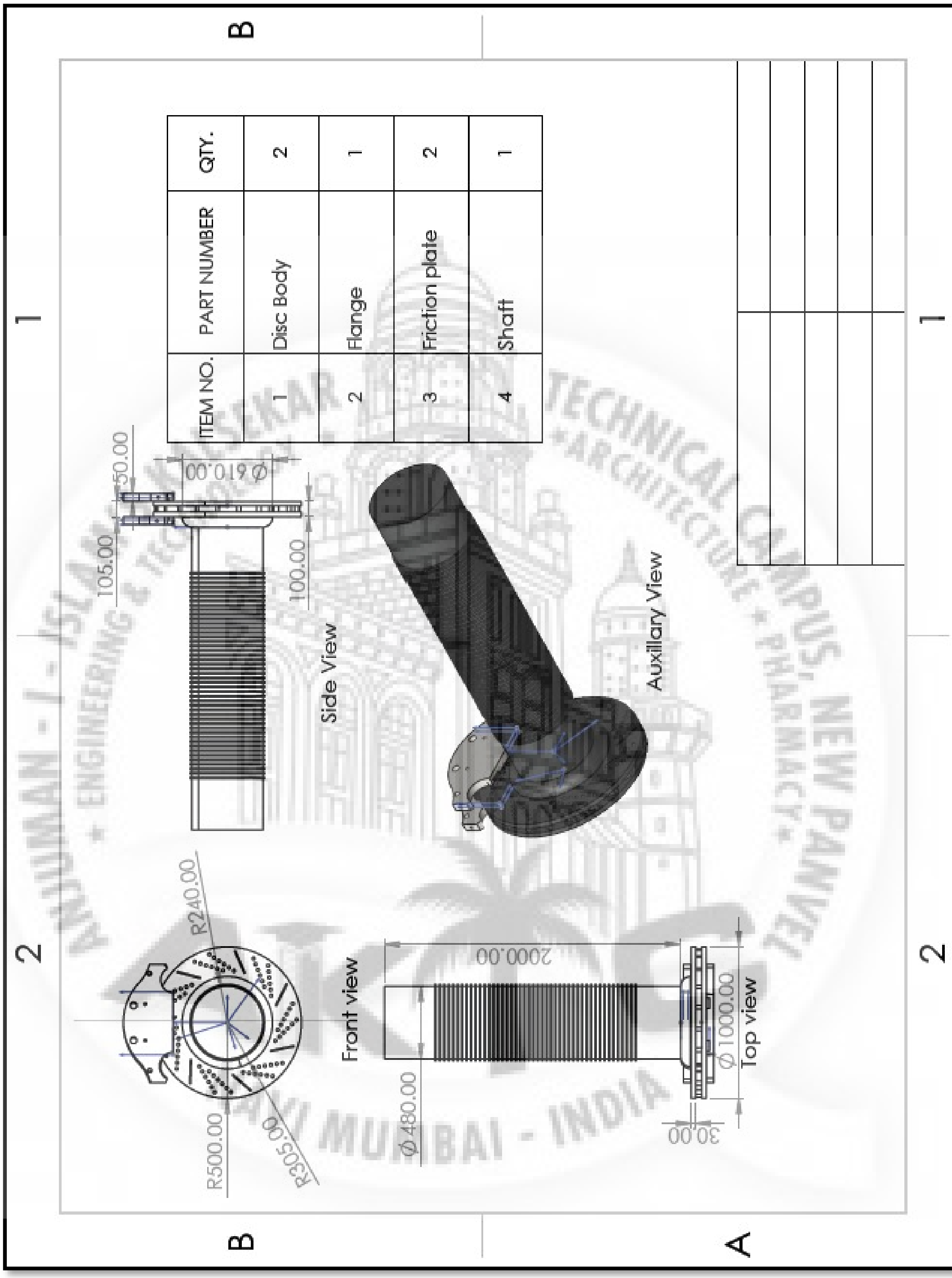
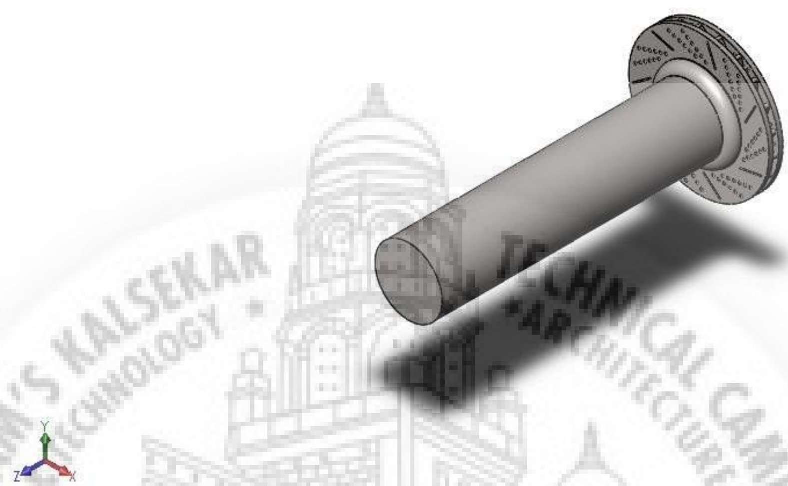


Fig. 7.2 : Safety Brake Assembly

➢ Model Information



Model name: final-assem-sim
Current Configuration: Default

Solid Bodies

Document Name and Reference	Treated As	Volumetric Properties	Document Path/Date Modified
Flange.stp[1] 	Solid Body	Mass:124.145 kg Volume:0.0159161 m^3 Density:7800 kg/m^3 Weight:1216.63 N	E:\eotigs\eotigs-updated\Flange.SLDPRT May 18 16:37:56 2020
Flange.stp[2] 	Solid Body	Mass:236.457 kg Volume:0.0303151 m^3 Density:7800 kg/m^3 Weight:2317.28 N	E:\eotigs\eotigs-updated\Flange.SLDPRT May 18 16:37:56 2020
Saft.stp 	Solid Body	Mass:2813.72 kg Volume:0.360733 m^3 Density:7800 kg/m^3 Weight:27574.5 N	E:\eotigs\eotigs-updated\Saft.SLDPRT May 18 16:40:00 2020

Table 7.1 : Model Information

➢ Study Properties

Study name	Static 1
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SOLIDWORKS Flow Simulation	Off
Solver type	FFEPlus
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off
Result folder	SOLIDWORKS document (E:\eotigs\eotigs-updated)

Table 7.2 : Properties

➢ Units

Unit system:	SI (MKS)
Length/Displacement	Mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

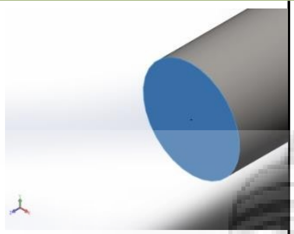
Table 7.3 : Units

➢ Material Properties

Model Reference	Properties	Components
	Name: **Plain Carbon Steel** Model type: **Linear Elastic Isotropic** Default failure criterion: **Max von Mises Stress** Yield strength: **2.20594e+08 N/m^2** Tensile strength: **3.99826e+08 N/m^2** Elastic modulus: **2.1e+11 N/m^2** Poisson's ratio: **0.28** Mass density: **7800 kg/m^3** Shear modulus: **7.9e+10 N/m^2** Thermal expansion coefficient: **1.3e-05 /Kelvin**	**SolidBody 1(Flange.stp[1])(Flange-1), SolidBody 2(Flange.stp[2])(Flange-1), SolidBody 1(Saft.stp)(Saft-1)**
Curve Data:N/A		

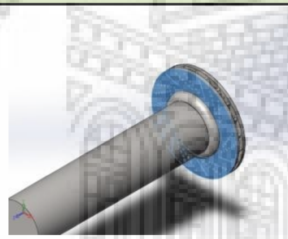
Table 7.4 : Material Properties

➢ Loads and Fixtures

Fixture name	Fixture Image	Fixture Details
Fixed-2		**Entities:** **1 face(s)** **Type:** **Fixed Geometry**

Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	1158.42	1156.72	0.00360107	1637.05
Reaction Moment(N.m)	0	0	0	0

Fixture name	Fixture Image	Fixture Details
Fixed-5		**Entities:** **1 face(s)** **Type:** **Fixed Geometry**

Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	0.00153351	-0.000518799	-238000	238000
Reaction Moment(N.m)	0	0	0	0

Load name	Load Image	Load Details
Torque-1		**Entities:** **1 face(s)** **Reference:** **Face< 1 >** **Type:** **Apply torque** **Value:** **78308 N.m**

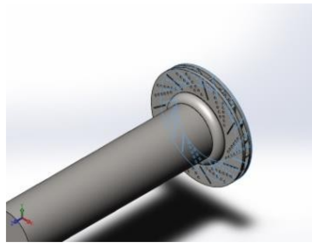
Force-1		**Entities:** 1 face(s) **Type:** Apply normal force **Value:** 238000 N

Table 7.5 : Loads & Fixtures

➢ Contact Information

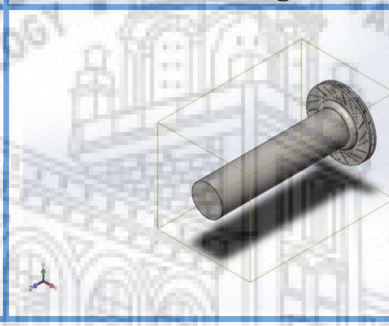
Contact	Contact Image	Contact Properties
Global Contact		**Type:** Bonded **Components:** 1 component(s) **Options:** Compatible mesh

Table 7.6 : Contact Information

➢ Mesh information

Mesh type	Solid Mesh
Mesher Used:	Curvature-based mesh
Jacobian points	4 Points
Maximum element size	85.2242 mm
Minimum element size	17.0448 mm
Mesh Quality Plot	High
Remesh failed parts with incompatible mesh	Off

Table 7.7 : Mesh Information

➢ Mesh information - Details

Total Nodes	103880
Total Elements	61508
Maximum Aspect Ratio	34.881

% of elements with Aspect Ratio < 3	88.2
% of elements with Aspect Ratio > 10	0.439
% of distorted elements(Jacobian)	0
Time to complete mesh(hh;mm;ss):	00:00:14
Computer name:	

Table 7.8 : Mesh Information Details

- **Resultant Forces**

Reaction forces-

Selection set	**Units**	**Sum X**	**Sum Y**	**Sum Z**	**Resultant**
Entire Model	N	1158.42	1156.72	-238000	238006

Reaction Moments

Selection set	**Units**	**Sum X**	**Sum Y**	**Sum Z**	**Resultant**
Entire Model	N.m	0	0	0	0

Table 7.9 : Resultant Forces

➢ **Study Results**

Name	Type	Min	Max
Stress1	VON: von Mises Stress	0.004 N/mm^2 (MPa) Node: 81727	11.419 N/mm^2 (MPa) Node: 83893

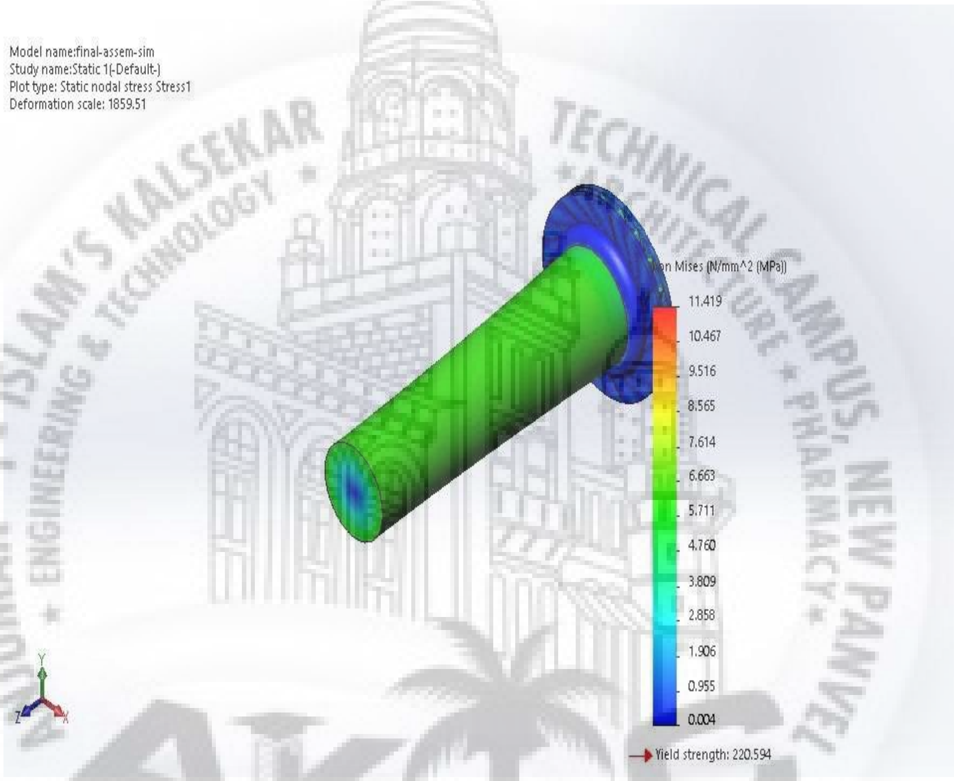


Table 7.10 : Stresses

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0.000 mm Node: 9549	0.119 mm Node: 1494

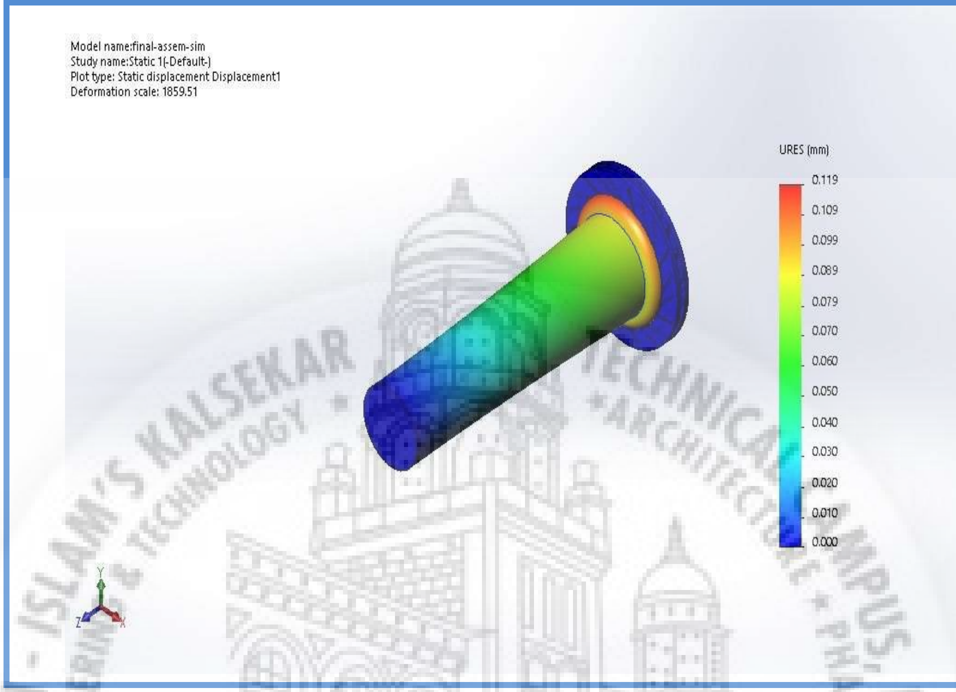


Table 7.11 : Displacement

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	0.000 Element: 30089	0.000 Element: 47073

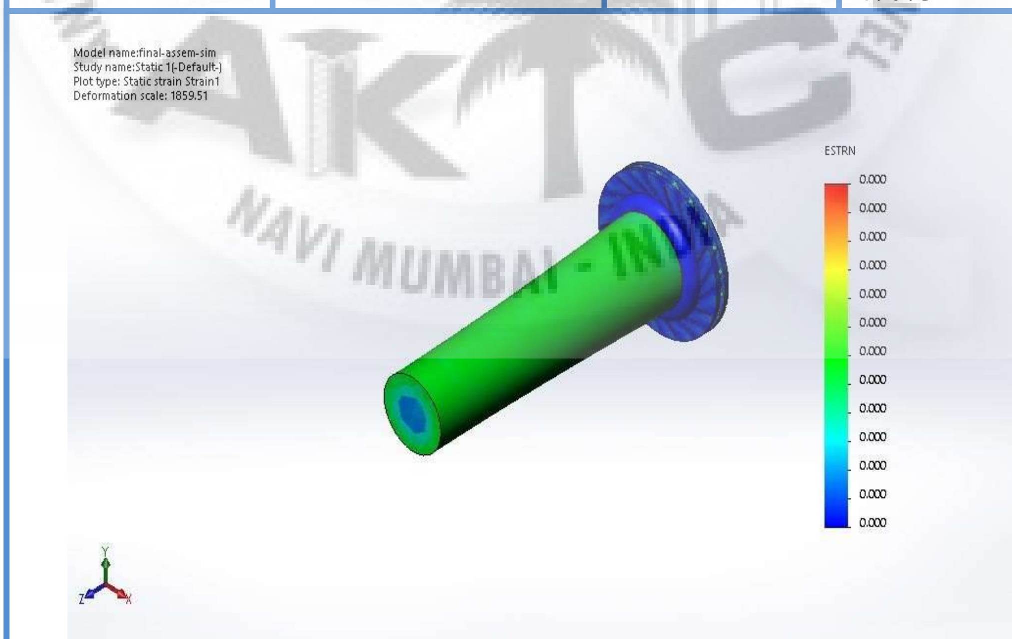


Table 7.12 : Strain

Name	Type	Min	Max
Factor of Safety1	Max von Mises Stress	19.319 Node: 83893	55,340.207 Node: 81727

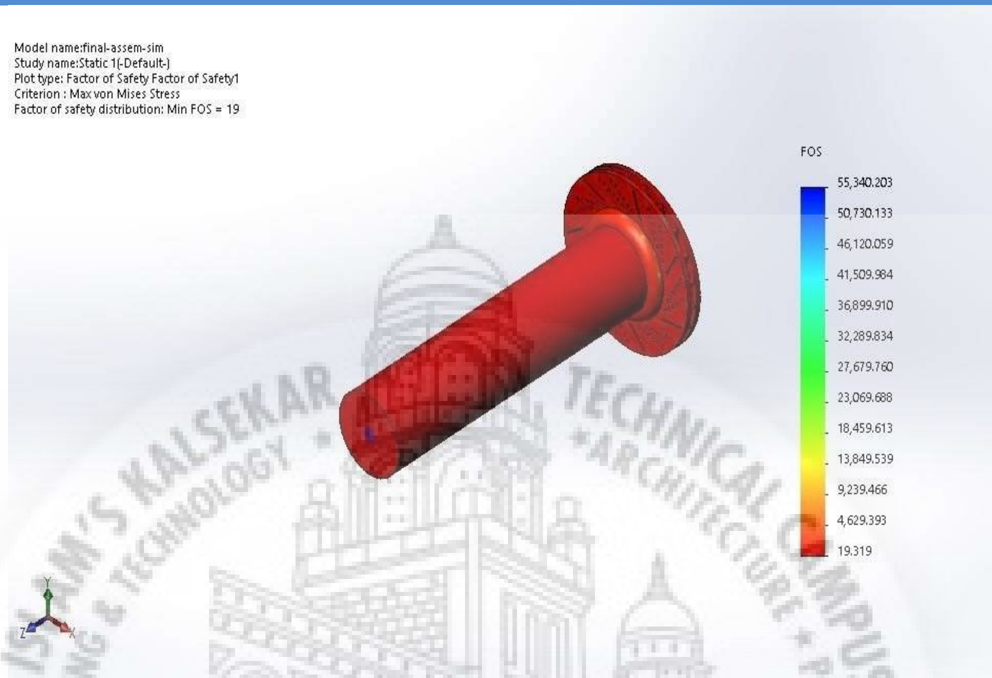


Table 7.13 : Factor of Safety

- **<u>Conclusion</u>** -

From the data obtained by Simulation Work the brake selected is much more capable than their given application. As from above analysis it has been seen that selected assembly can be perfectly work under the condition which could be 19 times higher than required working conditions which implies greater safety & reliability. Thus the proposed Braking Mechanism can be applied to given problem statement without a worry.

8.COSTING

Costing is the classifying, recording and appropriate allocation of expenditure for the determination of the costs of products or services; and for presentation of suitably arranged data for the purposes of control, and guidance of management.

Table below shows the expected costing for complete project work-

Sr.No.	Specification	Qty	Unit Price	Total Price
1.	Hydraulic disc brakes-spring applied hydraulically released Type K-DAF/70-DS with Brake on/off switch Make: Kateel	1 No	2,36,000.00	2,36,000.00
2.	Single Motor Hydraulic power unit with manual release hand pump See description later in this quotation with enclosure	1 No	1,90,000.00	1,90,000.00
3.	PLC Based Electrical Control Panel for operating single motor Hydraulic power pack.	1 No	1,96,000.00	1,96,000.00
4.	Hallo Shaft Encoder for measuring the rope drum RPM	1 No	63,500.00	63,500.00
5.	Flange OD 950mm X 25mm thick	1 No	92,500.00	92,500.00
6.	Brake Mounting Bracket with Hoses & Fittings including Sole Plate for the above Model	1 Set	1,05,000.00	1,05,000.00
7.	Installation & Commissioning the Brakes.	1 No	75,000.00	75,000.00
		Total Price	**Rs. 9,58,000.00**	

Table 8.1 : Costing

9. EXPECTED OUTCOME

Safety braking system has been added to the crane hoist at slow speed end. One end of rope drum was linked with drive shaft from gearbox and now another end has been fastened to emergency braking mechanism. The braking system doesn't work during normal running. When the rope drum reached greater than rated speed it will be activated automatically with help of rpm sensor. Brake force has been transferred to rope drum to stop the hoist without help of thruster. The arrangement has fulfilled the requirement of EN14492-2 standards. Braking system has been installed at slow speed end can prevent load drop even any mechanical damages occurred in the hoist. If the safety braking system will be successfully installed in an EOT Crane the occurrence of the accidents will be less as compared to before. As the crane can be controlled easily even if the thruster brake fails to handle the load when some of the component is damaged. Therefore, by installing the safety braking mechanism the safety of the EOT crane is increased.

10. FUTURE SCOPE

Safety Braking System is an important system in EOT Cranes but besides to this there are some "Statutory Provision" in order to increase the safety upto its extent & Organizations should consider these to standardize work practice.

- **Relevant Statutory Provisions -**

1. **Fencing of Machinery** - Unless they are in such position or of such construction as to be safe to every person employed in the factory as they would be if they have securely fenced the following namely

a) Every part of an electric generator or rotary convertor

b) Every part of a transmission machinery and

c) Every dangerous part of any other machinery

Shall be securely fenced by safe guards of substantial construction which shall be constantly maintained and kept in position while the parts of machinery they are fencing are in motion or in use.

2. **Work on or near machinery in motion** – Where in any factory, it becomes necessary to examine any part of machinery referred to in while the machinery is in motion, such examination or operation shall be made or carried out only by a specially trained adult male worker wearing tight fitting clothing whose name has been recorded in the register prescribed in this behalf.

No woman or young person shall be allowed to clear, lubricate or adjust any part of any machine if the cleaning, lubrication or adjustment there of would expose the woman or young person to risk of injury from any moving part either of that machine or any other adjacent machinery.

3. **Self-acting machines** – No traversing part of a self-acting machine in any factory and no material carried there on, shall, if the space over which it runs is a space over which any person is liable to pass whether in the course of employment or otherwise be allowed to run on its outward or inward traverse within a distance of 50 cm from any fixed structure which is not part of the machine.

4. **Lifting machines, chains, ropes and lifting tackles** – In any factory, the following provisions shall be complied with in respect of every lifting machine (other than a hoist and lift) and every chain rope and lifting tackle for the purpose of hoisting or lowering persons, goods or materials.

a) All parts including the working gear, whether fixed or moveable of every lifting machine and every chain rope or lifting tackle shall be:

i) of good construction, sound material and adequate strength and free from defects.

ii) Properly maintained and

iii) Thoroughly examined by a competent person at least once in every period of 12 months or at such interval as the Chief Inspector may specify in writing and a register shall be kept containing the prescribed particulars of every such examination.

b) No lifting machine and no chain rope or lifting tackle shall, except for the purpose of test, be loaded beyond the safe working load (SWL) which shall be plainly marked thereon together with an identification mark and duly entered in the prescribed register and where this is not practicable, a table showing the safe working loads of every kind and size of lifting machine or chain rope or lifting tackle shall be displayed in prominent positions in the premises.

c) While any person is employed or working on or near the wheel track of a travelling crane in any place, where he would be liable to be struck by the crane, effective measures shall be taken to ensure that the crane does not approach within six meters of that place.

5. **Floors, stairs and means of access** – In every factory, all floors, steps, stairs, passages and gang-ways shall be of sound construction and properly maintained and shall be kept free from obstructions and substances likely to cause persons to slip and where it is necessary to ensure safety, steps, stairs, passages and gangways shall be provided with substantial handrails. There shall, so far reasonably practicable, be provided and maintained safe means of access to every place at which any person is at any time required to work. When any person has to work at a height from where he is likely to fall, provision shall be made, so far as reasonably practicable, by fencing or otherwise to ensure the safety of the person so working.

- **Engineering Control -**

1.Identification number and SWL to be painted in bold letters on the crane itself in such size and clarity that it is easily visible, readable from Floor Level.

2. One **portable** CO_2 fire extinguisher **of suitable capacity** is to be kept in the crane operator's cabin.

3. Safety switches, preferably of lockable push button type shall be provided on four corners of the crane near the ladder so that it can be operated either from Gantry or from the bridge platform. In addition, one such switch shall be provided in the operator's cabin also.

4. An audible warning device shall be provided in the operator's cabin to warn people working below, while operating the crane.

5. All drive couplings and protruded extended shafts etc are to be securely guarded.

6. Sufficient light shall be hung from the girder of the crane so that the working area under the crane is properly illuminated.

7. There shall be at least two plug points of voltage **220 AC** and 24 volts ac respectively fitted in the crane girder to facilitate during maintenance work.

8. Panel nomenclature to be painted on the outer side of individual panel doors and all circuit components to be adequately labeled and all **control cables** properly.

12.REFERENCES

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Glossary

catastrophic : a moment of tragic [see 6]

cusp : a point of transition [see 22]

entangled : to wrap or twist together [see 6]

girder : a horizontal main structure member that supports vertical loads [see 2]

hoist : act of raise or lift something [see 4]

pilining : a structure of piles [see 1]

reeving : to pass a rope through [see 26]

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Declaration

We declare that this written submission represents our ideas in our own words & where other's ideas or words have been included. We have adequately cited & referenced the original sources. We also declare that we have adhered to all principles of academic honesty & integrity & have not falsified any data in my submission. We understand that any violation of the above will be cause for disciplinary action by the Institute & can also evoke penal action from sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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