A Review on Design, Analysis and Software Development for 100 Tonnes Capacity Overhead Crane

PankajKumar Indramani Mishra[a], Hetalkumar N Shah[b], Chintan Barelwala[c]*

[a] *PG Student, M.E.(CAD/CAM),Gandhinagar Institute of Technology, India*
[b,c*] *Gandhinagar Institute of Technology, India*

Abstract

Equipment for material handling is a vital component of daily living. Without numerous material handling tools, the modern technological era is unimaginable. One piece of material handling equipment with numerous uses in a variety of engineering sectors is the crane.
The current endeavour aims to cover the entire design and analysis of an EOT crane with a 100-ton capacity.
The manual was designed in compliance with the different pertinent IS codes. Since procedural design necessitates laborious calculations, an effort is made to create software using Microsoft Visual Studio 2008 in order to minimise exhausting calculations. Using Solid Edge ST and Ansys 11, modelling and analysis of the whole crane's components and their assembly (based on the manual design) have been carried out, respectively.

Keywords: EOT crane, design, analysis, software development

Nomenclature

Rd	Loads due to the dead weight of the mechanism or component and dead weight of Those parts of the crane acting on the mechanism or the component under consideration
Rh	Loads due to weight of hook load and also it is defined as SWL of the hook
Rhi	Loads due to the weight of the hook load increased by impact factor
Rm	Dynamic loading arising from the acceleration or braking of the motion
Rf	Load arising from the frictional forces
Rw1	Loads due to the service wind acting horizontally in any direction where applicable to IS 875 (part 3)
Rw2	Loads due to the out of service wind acting horizontally in any direction where applicable to IS 875 (part-3)
Fo	Minimum breaking load
S	Maximum rope tension considering inclination of the rope in the uppermost position
Zp	Minimum partial co-efficient of utilization
Ddf	Duty factor for hoist for appropriate mechanism class
Dd	Diameter of drum measured at the bottom of the groove
d	Rope diameter
Crc	Factor depend upon the construction of wire rope
Crr	Co-efficient depending upon the type of receiving system
M	Mass of rated load on the hook plus weight of the hook block and wire rope in tones
V	Specified hoisting speed in m/min
E	Combined efficiency of gears and sheaves
Cv	Service factor depending on type of motors
Camb	Derating factor for ambient temperature
M1	Mass of rated load on the hook plus weight of the hook block and wire rope plus self weight of crane Girder in tones
V1	Specified traveling speed in m/min
F	Overall friction factor
a	Average linear acceleration of the crane or the trolley

* Corresponding author
E-mail address: chintan.barelwala@git.org.in

1. Introduction

Material handling equipment is employed for moving loads in premises or areas, de-partment, factories and plants, at construction sites, point of storage and reloading, etc.
Material handling equipment carries loads over relatively short distances, in contrast to so-called long-distance transport (railway, automobile, ocean, and air), which moves loads over a significant distance. In order to provide a consistent load transfer between two or more places connected by common production activities, these distances are often limited to tens or hundreds of meters and only occasionally reach thousands of meters.
Each business' handling and loading processes are reliant on the external and internal facilities that are available. The business receives its raw materials, semi-finished goods, fuel, auxiliary materials, etc. from outside transportation facilities.

1.1. Types of Material Handling Equipment

- Hoisting Equipment
- Conveying Equipment
- Surface and Overhead Equipment

1.1.1 Hoisting Equipment

It is a group of machines with lifting gear intended for moving loads mainly in batches. It is intended mainly for unit loads - various parts of machines and whole machines, elements of metal structure, hopper and ladles, girders, building blocks and materials, etc.

Types of Hoisting equipments are:
Hoisting Machinery
Cranes
Elevators

1.1.2 Conveying Equipment

It is a group of machines which may have no lifting gear, and which moves loads in a continuous flow. It includes all types of Conveyors.

1.1.3. Surface and Overhead Equipment

It is a group of machines which also may not be provided with lifting gear and usually handle loads in batches. conveying equipment can be used to handle either only bulk or only unit loads while surface or overhead facilities can be used to handle both bulk and unit loads. Materials handled in bulk are composed of a large number of homogeneous particles or lumps, for example: coal, ore, cement, sand, clay.

2. Types of Cranes

2.1 Electric Overhead Traveling Crane

- Single Girder Overhead Traveling Crane (up to 10 tonnes Capacity)
- Double Girder Overhead Traveling Crane (above 10 tonnes Capacity)
- Under slung Cranes (up to 10 tonnes Capacity)

2.2 Gantry Crane

2.3 Jib Crane

2.4 Tower Crane

2.5 Derrick Crane

2.6 Crawler Crane

2.7 Truck mounted Crane

2.1 Electric Overhead Traveling Crane.

Overhead traveling cranes operate using three motorized movements (lifting, trolley traverse, and bridge traverse), which provide handling within the volume of space under the crane.

2.1.1 Single Girder Overhead Traveling Crane Range

Capacity: up to 10 tonnes
Span: 0.5 to 25 meters
Lift: 0.5 to 12 meters

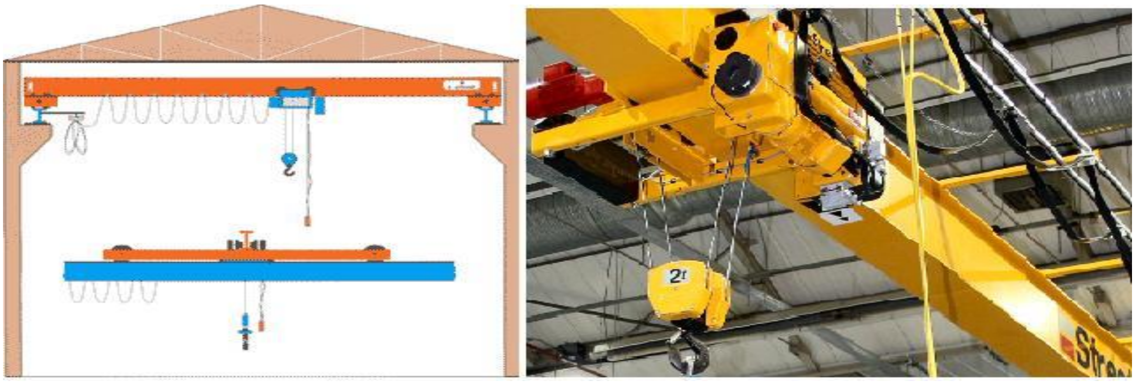

Fig.1 . Single Girder Overhead Traveling Crane

2.1.2 Double Girder Overhead traveling Crane.

When heavy load and wide span are required, double girder Overhead traveling Crane are generally used. They consist of two torsion free box girder. This makes them especially suitable for lifting and transporting load over 10 tonnes and for span of more than 25 meter.

Range

Capacity: above 10 tonnes
Span: 0.5 to 40 meters
Lift: 0.5 to 12 meters

Fig

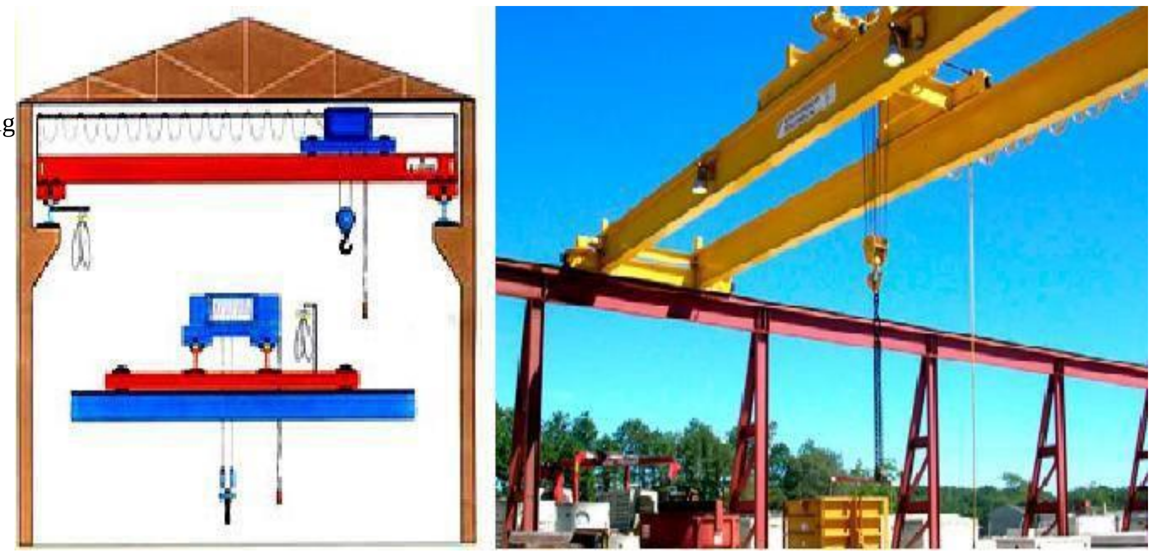

Fig.2. Double Girder Overhead Traveling Crane

2.1.3 Under slung Crane

It is a special type of crane and provides an optimal solution where the building structure makes the normal traveling cranes less suitable. The main feature is that the crane track is not fastened to pillars but to the beams of the building. Over and above these special cranes offer the advantage of very small trolley approach dimensions and as a result an optimal utilization of the building width.

Range
Capacity: up to 10 tonnes
Span: 0.5 to 25 meters
Lift: 0.5 to 12 meters

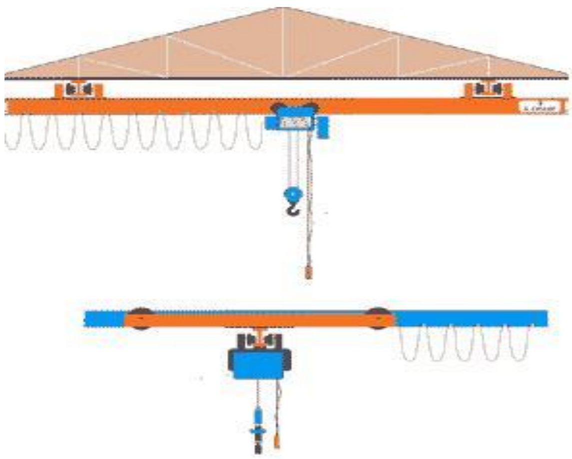

Fig.3. Under slung crane

2.2 Gantry Crane

Unlike EOT cranes, Goliath cranes run on gantry rails mounted on floor level. The bridge girders are supported on a pair of legs which are supported on end carriages. This type of crane is extremely used in shipyards and industrial installation.

Fig. 4. Gantry crane

2.3 Jib Crane

Jib crane is a type of crane where a horizontal member (jib or boom), supporting a moveable hoist, is fixed to a wall or to a floor-mounted pillar. Jib cranes are used in industrial premises and on military vehicles.

Fig. 5. Jib crane

2.4 Tower Crane

It is a crane of fixed type which by virtue of height of its supporting tower frame is capable of hoisting, luffing, and slewing its loads over high obstruction. It is most widely used in the construction of tall building.

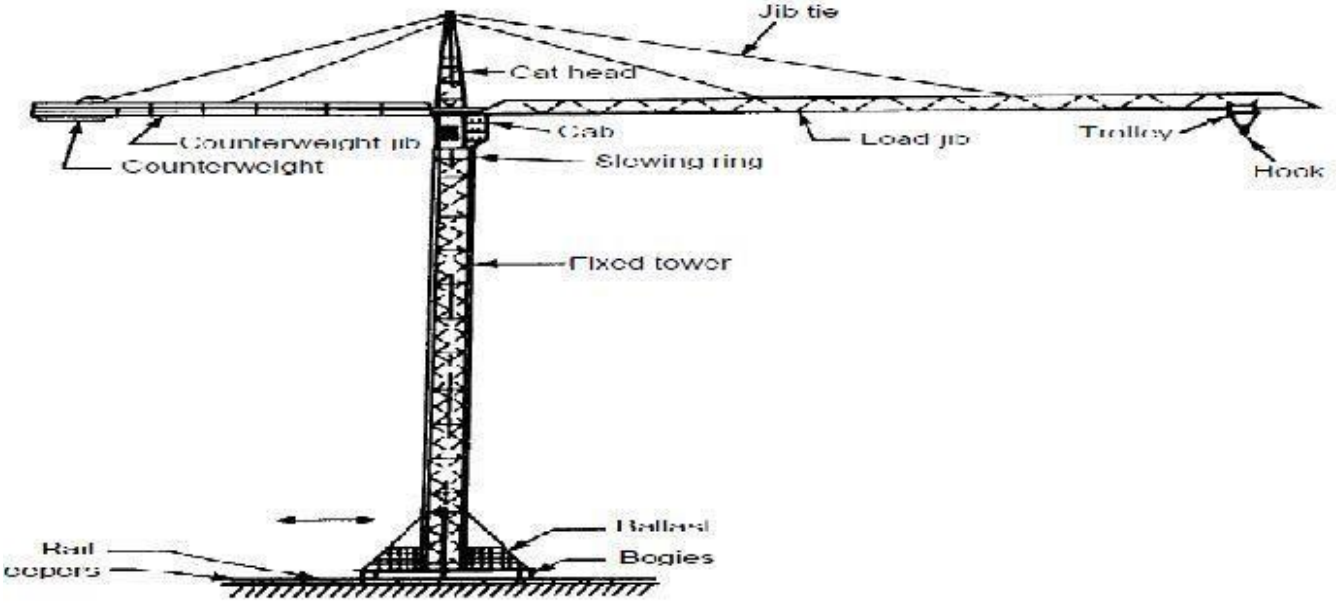

Fig. 6. Tower crane

2.5 Derrick Crane

Derrick is a strut with guys so arranged as to permit of inclination of strut in any direction, the load being raised or lowered by a hoisting mechanism.

Fig. 7. Derrick crane

2.6 Crawler Crane

A Crawler is a crane mounted on an undercarriage with a set of tracks (also called crawlers) that provide stability and mobility.

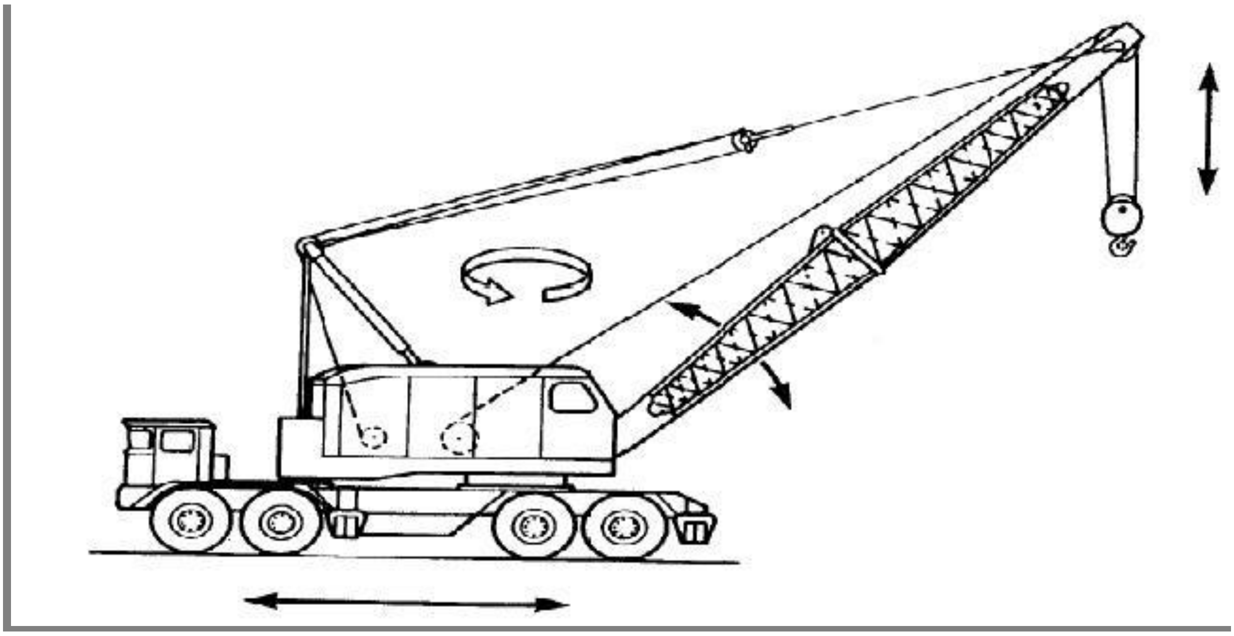

Fig. 8. Crawler crane

3. Literature Review

In the design of EOT (Electric Overhead Traveling) crane, it is necessary to have knowledge of different component used in Electric Overhead Traveling, knowledge of types of material and most important thing is to have a good knowledge of loading condition on different component. Material Handling Equipment by **N Rudenko** is the book for EOT crane design, which covers all aspects of EOT crane design. In this book **Chapter 3** covers construction of wire ropes, lays of wire ropes, which can be preferable for particular application, selection procedure of wire ropes and ho how to calculate fatigue strength (endurance) of steel wire ropes by professor Zhitkov's method. **Chapter 4** covers design procedure of pulley and drum and in this chapter, it also includes the equation which can be used in determination of crunching, shear and bending stress induced in drum. **Chapter 5** gives the idea for hook selection and sets of equation to calculate stress induced in different section of the hook, this chapter also includes crosspieces design for hook and side plate design. **Chapter 6, 8 and 9** gives guideline for selection of arresting gear, hoisting gear, traveling gear and brakes, it also includes crane wheels design. **Chapter 11** include the guideline for selecting the motor rating and determining the braking torque for hoisting motion and traveling motion**. [1]**

EOT crane are designed as per IS 3177: 1999 Code of practice for electric overhead traveling cranes and gantry cranes other than steel work cranes (second revision) **[2].** IS 2266: 2002 Steel wire rope for general engineering purpose- Specification **[3]**
and IS 3973: 1984 Code of practice for the selection, installation and maintenance of wire ropes **[4]** are used for wire rope design. IS 13156: 1991 Sheave pulley blocks for wire rope - Specification **[5]** and IS 4137 Specification for sheave assembly for EOT cranes **[6]** are used in sheave design. IS 15560: 2005 Point hooks with shank up to160 tonnes - Specification (Merging of IS 3815, 6294 and 8610) **[7]** and IS 5749: 1970 Specification for Forged ram shorn hooks **[8]** are used in selection hook.
Design of structure of an EOT crane (design of crane girder and gantry girder) is the very most important and critical things. Chapter 12 of N Rudenko book gives idea on loading condition of crane girder design. Well, depending on crane lifting capacity and length of span the bridge of EOT crane are made up of plate girders, truss gird- ers, box girders, double-web girders, etc. Design of Steel Structure by S K Duggal **[9],** Design of Steel Structure by N Subramanian **[10]** are the two books to design of steel structure, chapter 6, 7 and 8 of Design of Steel Structure by S K Duggal covers design procedure of plate girder and gantry girder. The design of crane girder is satisfying the IS 807:2006 Design, Erection, and Testing (structural portion) of Crane **[11]** and also IS 800:1984 Code of practice for general construction in steel **[12].**

Dynamic study of an Overhead crane system is very interesting part of crane design. D. C. D. Oguamanam and J. S. Hansen performed a parametric study and de- rived a set of coupled, non-linear equation of motion via Hamilton principle and it was observed that location and the value of maximum beam deflection for given set of carriage and payload masses is dependent upon the carriage speed., J. S. Hansen **[13]**

At very fast speed carriage speeds, the maximum beam deflection occurs to the end of the beam where the carriage stops as a result of inertial effects and at very slow speeds occur near the middle of the beam because the system reduces to quasi-static situation. investigated the dynamics of a beam with intermediate point constraints subjected to a moving load via the method assume modes. Lee **[14]**

It was observed that point constraints resulted in a significant reduction in the deflection of the beam for slow moving loads. M. M. Stanisic is departure from the above because the position of the moving load is included in mode shapes derivation thus ensuring satisfaction of both bound- ary and transient conditions. This technique is based on use of operational calculus. M. M. Stanisic **[15]**

Muhammad Abid et al. in is paper by this study has the study arrived at a generalisation methodology that connected all the characteristics to the box girder's capacity. The created generalisation process just requires capacity knowledge as an input and outputs all of the optimised dimensions. The optimised deflection steadily rises with decreasing box girder capacity, from 40.12 mm for 100 tonnes to 47.30 mm for 50 tonnes.As the capacity decreases, the camber may be increased in accordance. On the other hand, no consideration of camber was made during the analysis. Each optimised girder showed at least a 22% mass reduction. The study came up with a generalisation methodology that linked all the traits to the capacity of the box girder. Only capacity knowledge is needed as an input for the constructed generalisation process, which then produces all of the optimal dimensions. With a reduction in box girder capacity, the optimum deflection slowly increases, rising from 40.12 mm for 100 tonnes to 47.30 mm for 50 tonnes.The camber may be raised in response to a decline in capacity. On the other hand, camber was not taken into account when doing the analysis. Each improved girder displayed a mass reduction of at least 22%.[16]

Akihito Otani et al. in investigated in this study In this study, the 1/8 scale model excitation test and the simulation analysis were used to examine the vertical scismic response of a typical 150 tonne overhead crane.The excitation test confirmed and offered a simple equation for the prediction of the overhead crane's leap. The test proved that, despite the collision occurring after the overhead crane's leap, the response force at the wheels could be predicted using linear analysis.If the leap of the overhead crane is anticipated, it is inferred that a large margin (about 30% recommended) is required to analyse the reaction force at the wheels in the design of the overhead crane.The simulation study was performed using a nonlinear model with gap elements. [17]

Ph.D. Ya. Slavchev et al. in demonstrated in their study. A 3-D model of a double girder overhead crane's metal construction, known as model 1, has been created. Comparing the FEA model to the well-known Euler-Bernoulli model demonstrates the correctness of the FEA model. Due to the crucial influence of the connections between the main girders and end trucks as well as rotations of the supports, the carrying metal construction of model 1 is in a 3-D strained condition. The model 1's metal construction is generally well-built. It satisfies many of the requirements for contemporary double girder overhead cranes, including contemporary hoist, driving units, etc. The model 1 bridge crane's mass might still be further lowered, though.Various tests are performed on the new design models, model2 and model3, to demonstrate their adherence to theoretical considerations and demonstrate that their static reaction is comparable to that of the original crane. The majority of the types of tests involve conducting stress analysis and bridge horizontal and vertical deflection measurements. The models were found to follow theory, and their static structural reaction keeps the original crane structure's response intact. [18]

I.Gerdemeli et al. in evaluated in general, The main beam of a gantry crane's design and analysis using a numerical method are provided. In various load combination instances, analytical stress calculations and stress analysis using numerical approach are investigated. Table compares the outcomes of the analytical calculations with those of the analysis.

Table 1. Load Combination & Stress

Load Combination	SW	ST1	ST2	ST3	DY1	DY2	DY3
σ_{eqv} (MPa)	52	92	129	88	106	152	101
σ_{eqv} (MPa)	47	78	124	84	89	147	97

All of the stress results, as shown in Table 6, are less than the maximum stress that St 37-2 steel can withstand. For static loading and dynamic loading, St 37-2 steel can withstand stresses of 160 MPa and 180 MPa, respectively.
In general, it is anticipated that there will be a maximum 20% variation between analytical calculation results and analysis results. Therefore, the study's findings are acceptable.However, it is clear that the outcomes of the ST1 and DY1 cases differ from one another more than the other differences. [19]

Lasinta Ari et al. in evaluated in The simulation findings demonstrate that the gantry crane's structure has a minimum fatigue life of up to 11.770 x 10, 1.055 x 10, and 0.494 x 10 6 cycles, respectively, for loads of 7, 8, 9, and 10. While the gantry crane's framework has a safety factor of 1.296, 1.134, 1.008, and 0.907 for its 7, 8, 9, and 10 Tonne models, respectively. The minimal fatigue life of a gantry crane is fewer than 1 million cycles with a payload of 10 tonnes. [20]

Heikki Sjömanet al. in investigated ability to create products while objectively researching the case's project or process, which serves as the research's primary data source. This establishes high criteria for comprehensively documenting the project because there is a lot of information flowing in. Participatory action research has similar restrictions. [21]

International Journal of Engineering Research and General Science in is paper by public was It design necessitates putting design concepts to use in real-world business situations. The burden to be lifted was the primary factor taken into account when solving the challenge. Accordingly, hoisting speed was taken into account. The essential components in this part design are what make up any overhead automobile. This design is for a general-purpose overhead crane that is frequently used in machine shops, warehouses, and companies that remove metal. possess a lifting capacity of roughly 50 tonnes.[22]

Kamal A. F. Moustafa et al. in evaluated the motion of an overhead crane is proposed to be controlled using fuzzy logic. The research is based on an overhead crane model that incorporates cargo lifting and lowering, trolley travel and transverse cable vibration. To regulate the motion of the trolley, the motion of the cable hoisting and lowering, and the swing of the cargo, the considered model is simulated under the influence of three fuzzy logic controllers. The outcomes of the simulation provide a logically sound interpretation of the characteristics of the suggested fuzzy control approach. There are two distinct obstacles to the current issue, it should be recognised. The first step is to develop and simulate a mathematical model that describes the overhead crane. The creation of an experiment that validates the developed model presents the second hurdle. Only the first issue is addressed in the current work. However, future research will be taken into account to overcome the second issue of adapting the current work to a genuine overhead crane. Future research will also focus on the optimisation of the parameters of the membership functions of the controllers' variables as well as the consideration of transverse cable vibrations in two dimensions.[23]

Thomas Morstyn et al.in investigated This study looked into a novel solution for repurposing defunct deep mine shafts called gravity energy storage employing suspended weights. Given a mine shaft's physical specifications, it has been demonstrated how to size the suspended weight to maximise the energy storage capability. Additionally, it has been demonstrated that quicker ramp-rates raise the system's necessary short-time power rating. This means that while sizing the motor and power electronics, designers must take into account the variety of power system services to be offered. In order to examine the potential energy storage capacity that the technology could give a former coal mining region, the United Kingdom's Midlands have been used as a case study. It has been determined that there are 340 mine shafts that could be turned into gravity storage units with energy capacities exceeding 1 MWh, offering 0.804 GWh of energy storage, using information from the United Kingdom Government Coal Authority Abandoned Mine Catalogue. This is predicated on the notion that the hung weights are made of iron ore and have a maximum weight of 3,000 tonnes. Analysis has also been done on how sensitive the predicted energy storage capacity is to these presumptions. Surveys and feasibility studies will be necessary to compare the price of the technology to other energy storage solutions and to have a better understanding of the difficulty involved in redeveloping abandoned mines. When there are chances to relieve local distribution network congestion or to store locally generated renewable energy to lower imports/exports and to boost local asset utilisation, the case for redeveloping certain mines could be further bolstered.[24]

Ibrahim A. Hameed et al. in evaluated The following are some benefits of GWO over other algorithms: ease of implementation due to its straightforward structure; reduced storage and processing needs; faster convergence due to continuous search space reduction and fewer decision variables (i.e.,,, and); ability to avoid local minima; and only two control parameters (i.e., a and C) to tune the algorithm's performance, leading to better stability and robustness.
The combination of two competing individual aim functions into a single fitness function in this study raises the possibility that enhancing one objective degrades the other and vice versa. Multi-objective GWO is suggested as a future project to simultaneously optimise each objective function separately.[25]

Mohamed Al-Hussein et al. in evaluated on job sites, a database system has been introduced to automate the crane selection process. The built data- base offers a variety of intriguing features, such as the ability to accommodate various crane kinds and measuring systems. The database's storing and querying skills are also strong. It has a useful, user-friendly interface that is backed up with graphics in a multiplatform setting. The utilisation of the suggested database system and an illustration of its key components and capacities have been shown using an actual example involving a large and critical lift. The system gets rid of hunches and the penalties of making bad decisions throughout the selection process. The technology can cut down on both the expense and the amount of time needed for the selecting process. Additionally, it offers a variety of workable options that provide the decision-maker more flexibility.[26]

4. Conclusion

Manual design of EOT cranes was carried out using IS codes, after which 3-d modelling of all components and crane assembly was carried out using Solid Edge ST. Finite element analysis of the parts and assembly was performed using An- sys 11, and the resulting stresses are well below the allowable stress limits. To minimize the time-consuming calculations of crane design (based on multiple IS codes), a software was created using Microsoft Visual Studio 2008. A full dynamic analysis was performed with the EOT crane modelled as a simply supported uniform Euler-Bernoulli beam. The pendulum's motion is believed to be flat, with minimal angular displacements and displacement rates from the vertical. It was discovered that the location and magnitude of the maximum beam deflection for a given set of carriage and payload masses are affected by carriage speed. At very rapid carriage speeds, the maximum beam deflection occurs near the end of the beam where the carriage stops due to inertial effects, whereas at very slow speeds, it occurs near the middle of the beam because the system reduces to a quasi-static state.

References

Book and BIS Standards:

1. Rudenko N, Material Handling Equipment, Mir Publisher, Moscow, 1981
2. IS 3177 Code of practice for electric overhead travelling cranes and gantry cranes other than steel work. cranes (second revision)
3. IS 2266:2002 Steel wire ropes for general engineering purpose- Specification.
4. IS 3973:1984 Code of practice for the selection, installation and maintenance of wire ropes.
5. IS 13156:1991 Sheave pulley blocks for wire rope Specification.
6. IS 4137 Specification for sheave assembly for EOT cranes.
7. IS 15560:2005 Point hooks with shank up to 160 tonnes - Specification (Merging of IS 3815, 6294 and 8610)
8. IS 5749:1970 Specification for Forged ram shorn hooks.
9. Duggal S K, Design of Steel Structure, Tata Macgraw Hill, 1960
10. Subramanian N, Design of Steel Structure, Oxford University Press, USA (oct- 2008)
11. IS 807:2006 Design, Erection, and Testing (structural portion) of Crane
12. IS 800:1984 Code of practice for general construction in steel.
13. Oguamanam D. C. D. and Hansen J. S, Dynamics Response of an Overhead Crane System, Journal of Sound and Vibration 213(5), 889-906, (1998)

14. Lee H. P., Dynamic response of a beam with intermediate point constraints subjected to moving load, Journal of Sound and Vibration 171, 369-395, (1994)
15. Stanisic M. M, on a new theory of the dynamic behavior of the structure carrying moving loads, Ingenieur - Archiv 55, 176-185, (1985)

Journal articles:

1. 9th International Conference on Fracture & Strength of Solids by Muhammad Abid Shahbaz Mahmood Khan, Optimization of Box Type Girder of Overhead Crane for Different Capacities with Fixed Span, June 9-13, 2013.
2. Vertical Seismic Response of Overhead Crane by Akihito Otani, Takeshi Yoshitomi, Osamu Komori Keisuke Nagashima, Junya Suzuki, Kazuhide Enoo , Structural Mechanics in Reactor Technology,1999.
3. Modelling and simulation Research on the metal structure of bridge cranes by Ph.D. Ya. Slavchev Javier Izurriaga Lerg, Sofia 2011.
4. Design and analysis with numerical method of gantry crane Main beam by I.Gerdemeli, G.Akgun , S.Kurt , International Conference on Innovative Technologies, 2013.
5. The fatigue life prediction of gantry crane with load capacity variation using Ansys Workbench by Lasinta Ari, Nendra Wibawa, Jurnal Sains DanTeknologi (2020).
6. Using Low-Cost Sensors to Develop a High Precision Lifting Controller Device for an Overhead
    a. Crane—Insights and Hypotheses from Prototyping a Heavy Industrial Internet Project by, Juuso Autiosalo,
    b. Heikki Sjöman, Jari Juhanko , Petri Kuosmanen , and Martin Steinert , Sensors 2018
7. Basic component design consideration of overhead Crane International Journal of Engineering Research and General Science,2015, B.Tech in Mechanical Engineering, Department of Mechanical Engineering , Zakir Hussain College of Engineering And Technology, 2015.
8. Fuzzy control of flexible cable overhead cranes with load hoisting by Kamal A. F. Moustafa Mohamed I. S. Ismail, Emil H. Gad, Ahmed M. A. El-Moneer, Transactions of the Institute of Measurement and Control, 2006.
9. Gravity Energy Storage with Suspended Weights for Abandoned Mine Shafts by Thomas Morstyn, Martin Chilcott, Malcolm D. McCulloch, Department of Engineering Science, University of Oxford.
10. Grey wolf optimizer (GWO) for Automated Offshore Crane Design by Ibrahim A. Hameed, Robin T. Bye, Ottar L. Osen, Software and Intelligent Control Engineering LaboratoryFaculty of Engineering and Natural Sciences Norwegian University of Science and Technology., http://blog.hials.no/softice/
11. D-CRANE: A database system for utilization of cranes by Mohamed Al-Hussein, Sabah Alkass, Osama Moselhi, Canadian Journal of Civil Engineering, 2011

Acknowledgement

It is indeed a pleasure for me to express my sincere gratitude to those who have always helped me throughout my paper publishing journals work. First of all, I would like to thank my project guide Prof. Dr. H N Shah & Prof Chintan Barelwala who helped me, understanding of the subject, stimulating suggestions, encouragement and publishing paper. I am sincerely thankful for his valuable guidance and help to enhance my skills.

I would also like to thank our Head of the Department for providing valuable guidance and also to the Gandhinagar Institute of Technology, Gandhinagar for providing excellent infrastructure and facilities whenever and wherever required.

I am highly indebted to Mr. Dipak Joshi (Director – Cransoul Engineering Private Ltd.) for his constant support and motivation throughout the period.

I am Grateful to Mr. Kunal (Computer Engineer) for his invaluable help during the development of software knowledge.

Last but not least, I would like to thank Almighty, my parents, my family mem- bers and friends for their love, support and excellent co-operation to build my moral during the work.