Design and Optimization of Lifting Tackle

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ABSTRACT

Lifting of heavy products and machinery's is one of the major causes of injury in the working place or station. One of the incidents which took place in 2001, the Bureau of labor statics reported that over 28-35 percentage of disaster injuries were shoulder & back injuries.

- Musculoskeletal injuries (MSIs) to arms, legs and joints and repetitive strain injuries of various sorts.
- Overexertion.
- Cumulative trauma.

The above stated problems are the biggest factors in the injuries, which are noticed in labours while lifting and moving of heavy parts or machineries.

- For detailed & more information about the injuries caused during lifting of heavy parts is mentioned in the site which is in bibliography.

When an employee makes use of smart lifting practices, which are in means of mechanical gears or elements and electronics configuration which makes ease to lift any heavy products or machineries.

Keyword : - heavy products , smart lifting practices**,** mechanical gears, machinery's *etc*

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1. INTRODUCTION

1.1 Lifting and Material Handling or Problem Statement

Lifting of heavy products and machinery's is one of the major causes of injury in the working place or station. One of the incidents which took place in 2001, the Bureau of labor statics reported that over 28-35 percentage of disaster injuries were shoulder & back injuries.

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1.2 Lifting equipment

Lifting equipment means work equipment for lifting and lowering loads, and includes any accessories used in doing so (such as attachments to support, fix or anchor the equipment).

Examples of lifting equipment include:

- overhead cranes and their supporting runways
- patient hoists
- motor vehicle lifts

- vehicle tail lifts and cranes fitted to vehicles
- a building cleaning cradle and its suspension equipment
- goods and passenger lifts
- Tele-handlers and fork lifts
- Lifting accessories are parts of equipment that are used to attach the load to lifting equipment, providing a link between the two. Any lifting accessories used between lifting equipment and the load may need to be taken into account in determining the overall weight of the load.

Examples of lifting accessories include:

- fiber or rope slings
- chains (single or multiple leg)
- hooks
- eyebolts
- spreader beams
- vacuum devices

2. PROBLEM STATEMENT

Lifting of heavy products and machinery's is one of the major causes of injury in the working place or station. One of the incidents which took place in 2001, the Bureau of labor statics reported that over 28-35 percentage of disaster injuries were shoulder & back injuries.

- Musculoskeletal injuries (MSIs) to arms, legs and joints and repetitive strain injuries of various sorts.
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The above stated problems are the biggest factors in the injuries, which are noticed in labours while lifting and moving of heavy parts or machineries.
If a hook fails there is a huge loss in terms of

a. Life or death chances if a high product land on someone heads it will be a great tragedy.
b. loss of money, cause of damage
c. Material loss/waste.
d. Total time waste.
e. Environment waste like damage to the other surrounding parts. Etc.

3. OBJECTIVE

1. Until now I have researched several published journals from which I have concluded the title and difficulties in lifting of heavy engines. Exhaust. And automotive parts. So
2. In this practice I'm going to design a lifting tackle for automotive engines using CATIA v5 R20 version soft.
3. Study the different Materials suitable for sustaining the load capacity to lift. Move and locate.
4. To study the Finite element analysis of static structural analysis on designed equipment using ANSYS R2020 workbench
5. To evaluate deformation. Von-misses stress. Von-misses strain and its life with factor of safety
6. To redesign the tackle for its weight and cost efficient etc.
7. And also to compare on different materials for feasible selection of material.

3.1 SCOPE

According to the literature review and journals which I have referred there is a huge scope for the lifting equipment in the industries as well as automotive workshop and different types of equipment varies on the basis of requirement and use of conditions for particular applications so our design may help in constructing new terminological equipment based on the load and working capability.
Now day's in India several industries are developing and more automotive infrastructure are growing so as well our design of lifting tackle for automotive engines will be in need. Even this type of lifting tackle can also be use for smaller industries and workshop garages.

4. Material & Process Selection

Rectangular Hollow Section (RHS)

For mechanical and structural applications, rectangular hollow sections (RHS) are popular. This is because the flat surface makes it a more economical structural solution for joining and different types of manufacturing work. For soldering or joining, RHS requires minimal edge preparation. Because of the rectangular shape of this type of hollow section, parts only need to be cut straight when joining to other flat surfaces. We produce good quality of Rectangular Hollow Section with the help of the latest technology and equipment and excellent raw material quality. We do not compromise with the quality of the product in any way. We understand important of the quality of a product is for users in meeting the requirements of the application. To satisfy all of the buyer requirement, we promise that we will deliver the best and top-quality product to the customer so that we can get more deal in the future. We sell the product at the market-leading price, so buyers won't find it hard to buy goods in bulk.

Rectangular Hollow Section Dimensions/Sizes
Table 1

Size mm	kg/m	Size mm	kg/m
40 x 20 x 2.0	1.68	40 x 20 x 2.5	2.03
40 x 20 x 3.0	2.36	40 x 25 x 1.5	1.44
40 x 25 x 2.0	1.89	40 x 25 x 2.5	2.23
50 x 25 x 2.0	2.21	50 x 25 x 2.5	2.72
50 x 25 x 3.0	3.22	50 x 30 x 2.5	2.92
50 x 30 x 3.0	3.45	50 x 30 x 4.0	4.46
50 x 40 x 3.0	3.77	60 x 40 x 2.0	2.93
60 x 40 x 2.5	3.71	60 x 40 x 3.0	4.39
60 x 40 x 4.0	5.72	70 x 50 x 2	3.56
70 x 50 x 2.5	4.39	70 x 50 x 3.0	5.19
70 x 50 x 4.0	**6.71**	**80 x 40 x 2.5**	4.26
80 x 40 x 3.0	5.34	80 x 40 x 4.0	6.97
80 x 40 x 5.0	8.54	80 x 50 x 3.0	5.66

Circular Hollow Section Dimensions/Sizes
Table 2

Nominal Bore	**Outside diameter**	**Thickness**	**Weight**
Mm	**mm**	**Mm**	**kg/m**
15	**21.3**	**2.00**	**0.95**
		2.60	**1.21**
		3.20	**1.44**
20	**26.9**	**2.30**	**1.38**
		2.60	**1.56**
		3.20	**1.87**
25	**33.7**	**2.60**	**1.98**
		3.20	**0.24**
		4.00	**2.93**
32	**42.4**	**2.60**	**2.54**
		3.20	**3.01**
		4.00	**3.79**
40	**48.3**	**2.90**	**3.23**
		3.20	**3.56**
		4.00	**4.37**

50	**60.3**	**2.90**	**4.08**
		3.60	**5.03**
		5.00	**6.19**
65	**76.1**	**3.20**	**5.71**
		3.60	**6.42**
		4.50	**7.93**
80	**88.9**	**3.20**	**6.72**
		4.00	**8.36**
		4.80	**9.90**
100	**114.3**	**3.60**	**9.75**
		4.50	**12.20**

5. CATIA

Computer-aided design (CAD) is the use of computer systems (or workstations) to aid in the creation, modification, analysis, or optimization of a design. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. CAD output is often in the form of electronic files for print, machining, or other manufacturing operations. The term CADD (for Computer Aided Design and Drafting) is also used.

Its use in designing electronic systems is known as electronic design automation (EDA). In mechanical design it is known as mechanical design automation (MDA) or computer-aided drafting (CAD), which includes the process of creating a technical drawing with the use of computer software.

CAD software for mechanical design uses either vector-based graphics to depict the objects of traditional drafting, or may also produce graphics showing the overall appearance of designed objects. However, it involves more than just shapes. As in the manual drafting of technical and engineering drawings, the output of CAD must convey information, such as materials, processes, dimensions, and tolerances, according to application-specific conventions.

CAD may be used to design curves and figures in two-dimensional (2D) space; or curves, surfaces, and solids in three-dimensional (3D) space.

CAD is an important industrial art extensively used in many applications, including automotive, shipbuilding, and aerospace industries, industrial and architectural design, prosthetics, and many more. CAD is also widely used to produce computer animation for special effects in movies, advertising and technical manuals, often called DCC digital content creation. The modern ubiquity and power of computers means that even perfume bottles and shampoo dispensers are designed using techniques unheard of by engineers of the 1960s. Because of its enormous economic importance, CAD has been a major driving force for research in computational geometry, computer graphics (both hardware and software), and discrete differential geometry.

The design of geometric models for object shapes, in particular, is occasionally called computer-aided geometric design (CAGD)

USES

Computer-aided design is one of the many tools used by engineers and designers and is used in many ways depending on the profession of the user and the type of software in question.

CAD is one part of the whole Digital Product Development (DPD) activity within the Product Lifecycle Management (PLM) processes, and as such is used together with other tools, which are either integrated modules or stand-alone products, such as:

- Computer-aided engineering (CAE) and Finite element analysis (FEA)
- Computer-aided manufacturing (CAM) including instructions to Computer Numerical Control (CNC) machines
- Photorealistic rendering and Motion Simulation.
- Document management and revision control using Product Data Management (PDM).

CAD is also used for the accurate creation of photo simulations that are often required in the preparation of Environmental Impact Reports, in which computer-aided designs of intended buildings are superimposed into photographs of existing environments to represent what that locale will be like, where the proposed facilities are allowed to be built. Potential blockage of view corridors and shadow studies are also frequently analyzed through the use of CAD.

CAD has been proven to be useful to engineers as well. Using four properties which are history, features, parameterization, and high-level constraints. The construction history can be used to look back into the model's personal features and work on the single area rather than the whole model. Parameters and constraints can be used to determine the size, shape, and other properties of the different modeling elements. The features in the CAD system can be used for the variety of tools for measurement such as tensile strength, yield strength, electrical or electromagnetic properties. Also its stress, strain, timing or how the element gets affected in certain temperatures, etc.

TYPES

There are several different types of CAD, each requiring the operator to think differently about how to use them and design their virtual components in a different manner for each.

There are many producers of the lower-end 2D systems, including a number of free and open-source programs. These provide an approach to the drawing process without all the fuss over scale and placement on the drawing sheet that accompanied hand drafting since these can be adjusted as required during the creation of the final draft.

3D wireframe is basically an extension of 2D drafting (not often used today). Each line has to be manually inserted into the drawing. The final product has no mass properties associated with it and cannot have features directly added to it, such as holes. The operator approaches these in a similar fashion to the 2D systems, although many 3D systems allow using the wireframe model to make the final engineering drawing views.

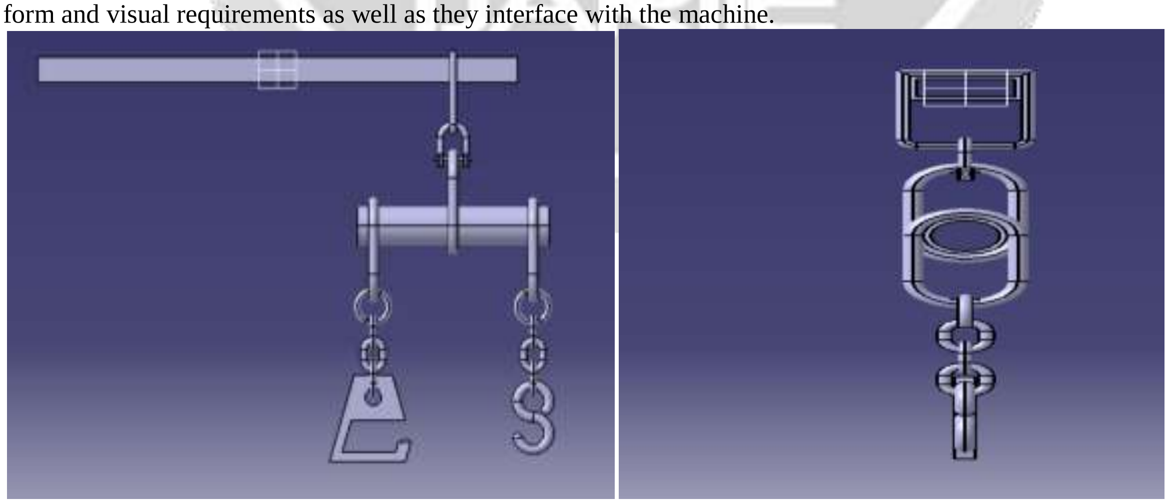
3D "dumb" solids are created in a way analogous to manipulations of real-world objects (not often used today). Basic three-dimensional geometric forms (prisms, cylinders, spheres, and so on) have solid volumes added or subtracted from them as if assembling or cutting real-world objects. Two-dimensional projected views can easily be generated from the models. Basic 3D solids don't usually include tools to easily allow motion of components, set limits to their motion, or identify interference between components.

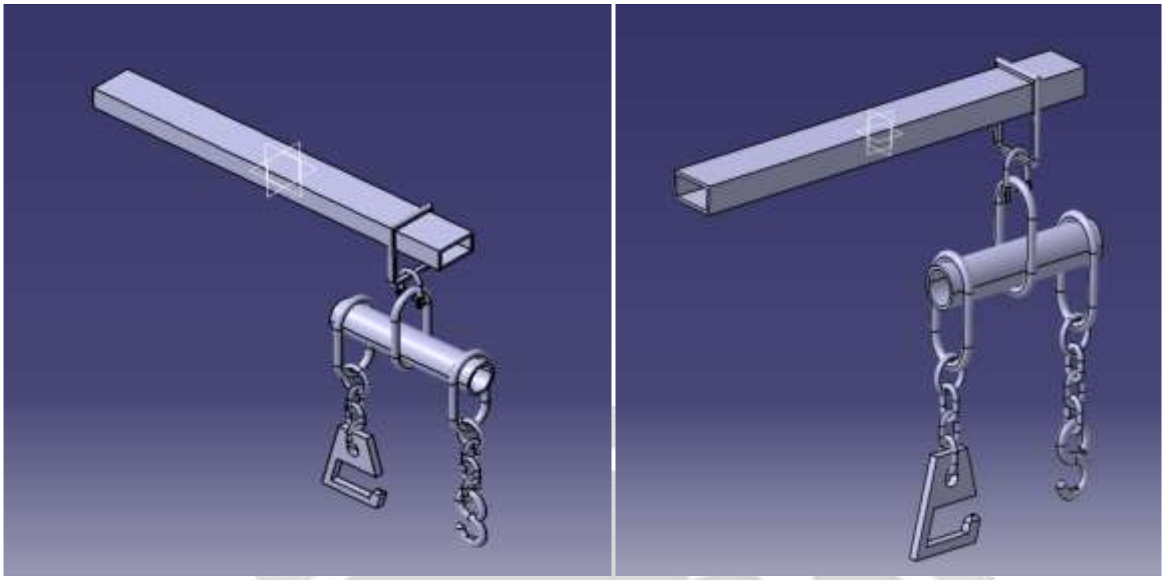
There are two types of 3D Solid Modeling

1.Parametric modeling allows the operator to use what is referred to as "design intent". The objects and features created are modifiable. Any future modifications can be made by changing how the original part was created. If a feature was intended to be located from the center of the part, the operator should locate it from the center of the model. The feature could be located using any geometric object already available in the part, but this random placement would defeat the design intent. If the operator designs the part as it functions the parametric modeler is able to make changes to the part while maintaining geometric and functional relationships.

2.Direct or Explicit modeling provide the ability to edit geometry without a history tree. With direct modeling, once a sketch is used to create geometry the sketch is incorporated into the new geometry and the designer just modifies the geometry without needing the original sketch. As with parametric modeling, direct modeling has the ability to include relationships between selected geometry (e.g., tangency, concentricity).

Top end systems offer the capabilities to incorporate more organic, aesthetics and ergonomic features into designs. Freeform surface modeling is often combined with solids to allow the designer to create products that fit the human form and visual requirements as well as they interface with the machine.





6. ANALYSIS

The finite element method (FEM), is a numerical method for solving problems of engineering and mathematical physics. Typical problem areas of interest include structural analysis, heat transfer, fluid flow, mass transport, and electromagnetic potential. The analytical solution of these problems generally require the solution to boundary value problems for partial differential equations. The finite element method formulation of the problem results in a system of algebraic equations. The method yields approximate values of the unknowns at discrete number of points over the domain. To solve the problem, it subdivides a large problem into smaller, simpler parts that are called finite elements. The simple equations that model these finite elements are then assembled into a larger system of equations that models the entire problem. FEM then uses variational methods from the calculus of variations to approximate a solution by minimizing an associated error function.

Studying or analyzing a phenomenon with FEM is often referred to as finite element analysis (FEA).

BASIC CONCEPTS:

The subdivision of a whole domain into simpler parts has several advantages:

- Accurate representation of complex geometry
- Inclusion of dissimilar material properties
- Easy representation of the total solution
- Capture of local effects.

A typical work out of the method involves (1) dividing the domain of the problem into a collection of sub domains, with each sub domain represented by a set of element equations to the original problem, followed by (2) systematically recombining all sets of element equations into a global system of equations for the final calculation. The global system of equations has known solution techniques, and can be calculated from the initial values of the original problem to obtain a numerical answer.

In the first step above, the element equations are simple equations that locally approximate the original complex equations to be studied, where the original equations are often partial differential equations (PDE). To explain the approximation in this process, FEM is commonly introduced as a special case of Galerkin method. The process, in mathematical language, is to construct an integral of the inner product of the residual and the weight functions and set the integral to zero. In simple terms, it is a procedure that minimizes the error of approximation by fitting trial functions into the PDE. The residual is the error caused by the trial functions, and the weight functions are polynomial approximation functions that project the residual. The process eliminates all the spatial derivatives from the PDE, thus approximating the PDE locally with

- a set of algebraic equations for steady state problems,
- a set of ordinary differential equations for transient problems.

These equation sets are the element equations. They are linear if the underlying PDE is linear, and vice versa. Algebraic equation sets that arise in the steady state problems are solved using numerical linear algebra methods, while ordinary differential equation sets that arise in the transient problems are solved by numerical integration using standard techniques such as Euler's method or the Runge-Kutta method.

In next step above, a global system of equations is generated from the element equations through a transformation of coordinates from the sub domains' local nodes to the domain's global nodes. This spatial transformation includes appropriate orientation adjustments as applied in relation to the reference coordinate system. The process is often carried out by FEM software using coordinate data generated from the sub domains.

FEM is best understood from its practical application, known as finite element analysis (FEA). FEA as applied in engineering is a computational tool for performing engineering analysis. It includes the use of mesh generation techniques for dividing a complex problem into small elements, as well as the use of software program coded with FEM algorithm. In applying FEA, the complex problem is usually a physical system with the underlying physics such as the Euler-Bernoulli beam equation, the heat equation, or the Navier-Stokes equations expressed in either PDE or integral equations, while the divided small elements of the complex problem represent different areas in the physical system.

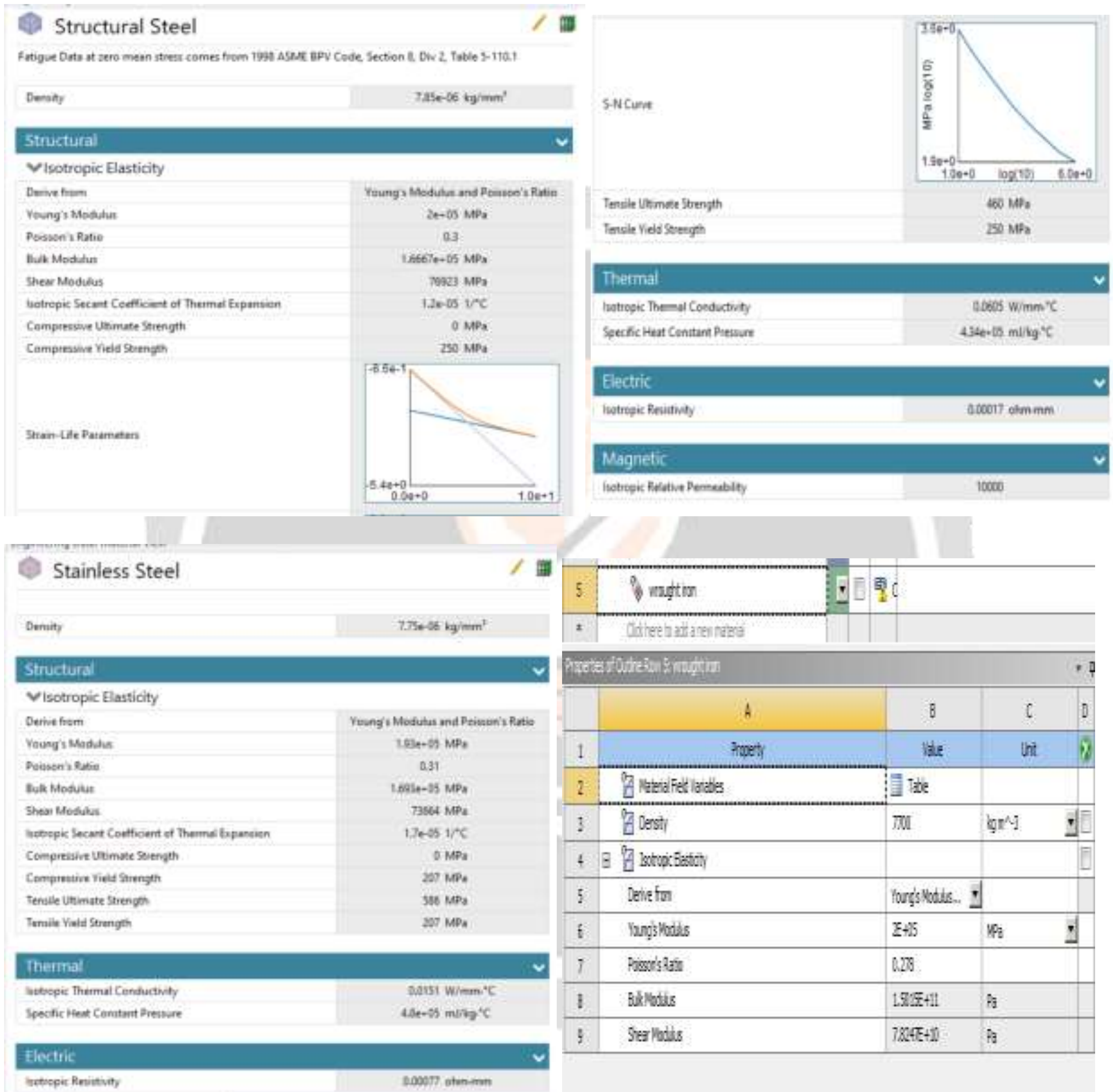
FEA is a good choice for analyzing problems over complicated domains (like cars and oil pipelines), when the domain changes (as during a solid-state reaction with a moving boundary), when the desired precision varies over the entire domain, or when the solution lacks smoothness. FEA simulations provide a valuable resource as they remove multiple instances of creation and testing of hard prototypes for various high-fidelity situations. For instance, in a frontal crash simulation it is possible to increase prediction accuracy in "important" areas like the front of the car and reduce it in its rear (thus reducing cost of the simulation). Another example would be in numerical weather prediction, where it is more important to have accurate predictions over developing highly nonlinear phenomena (such as tropical cyclones in the atmosphere, or eddies in the ocean) rather than relatively calm areas.

PROCEDURE FOR ANSYS SIMULATION

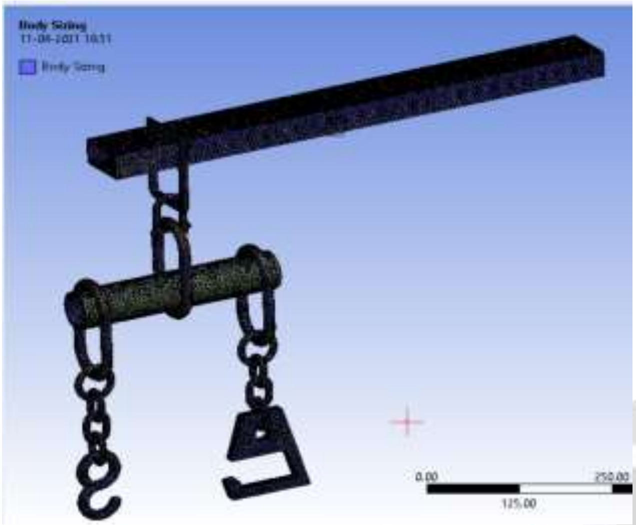
1. To design and test failure sustain 400 N of load on the tackle.
2. I had created the design using CATIA v5 soft and converted the file to stp file to import into the ANSYS soft.
3. This time I will check the failure condition on the micro structure and also record the data at boundary condition.

4. After the simulation on the case results, I will try to minimize the failure by conducting the redesign methodology and again simulate the redesigned one.

In 3rd case I will particularly optimize a part where large failure is occurring and I will study the topology optimization



Materials



Details of "Patch Conforming Method" - Method

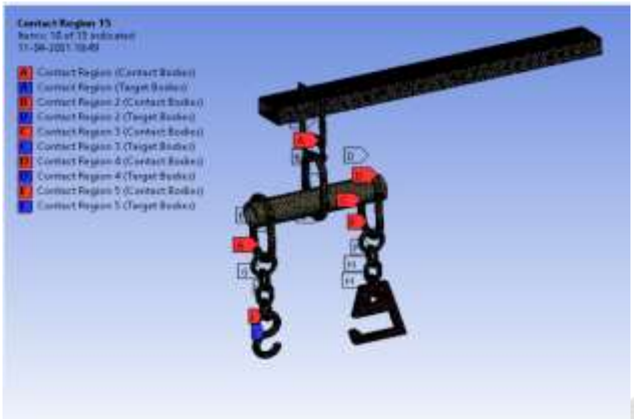
Scope	
Scoping Method	Geometry Selection
Geometry	16 Bodies
Definition	
Suppressed	No
Method	Tetrahedrons
Algorithm	Patch Conforming
Element Order	Use Global Setting

Details of "Body Sizing" - Sizing

Scope	
Scoping Method	Geometry Selection
Geometry	16 Bodies
Definition	
Suppressed	No
Type	Element Size
Element Size	5.0 mm
Advanced	
Defeature Size	Default
Behavior	Soft

Statistics	
Nodes	197373
Elements	108460

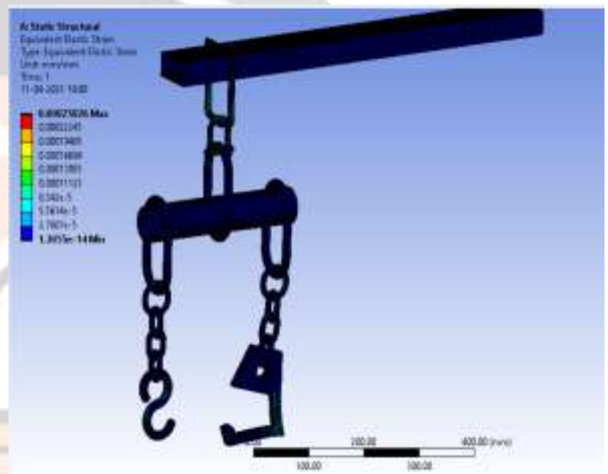
Mesh details



Contact region

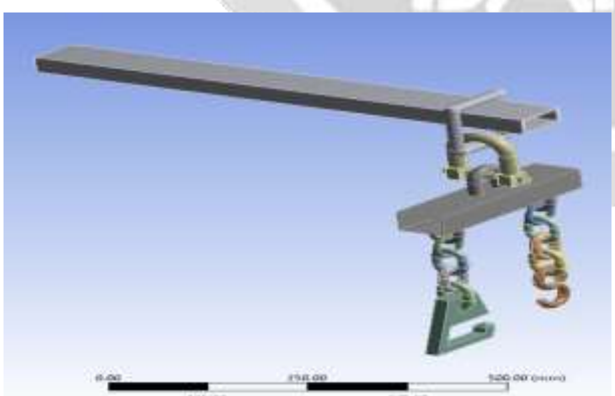
Deformation

Stress

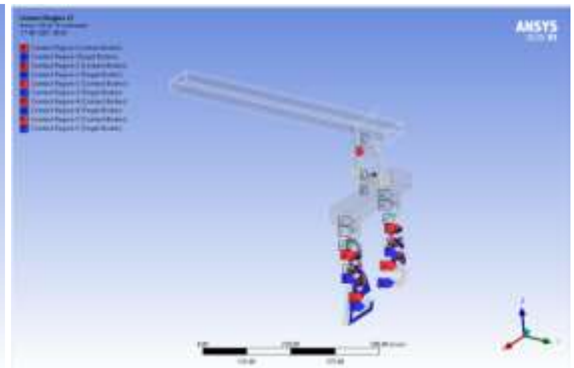


Strain

2nd iteration



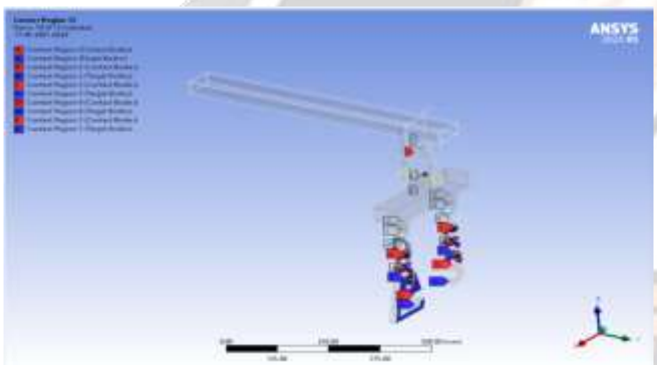
In this geo we have changed the parameters and support shape from circular to rectangular as we can see in the above fig.



Statistics	
Nodes	47569
Elements	23735

Mesh

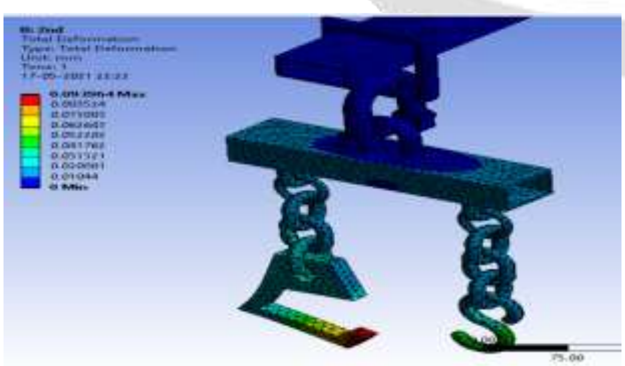
Here patch configuration method with tetrahedron shape is used with a 5 mm mesh size

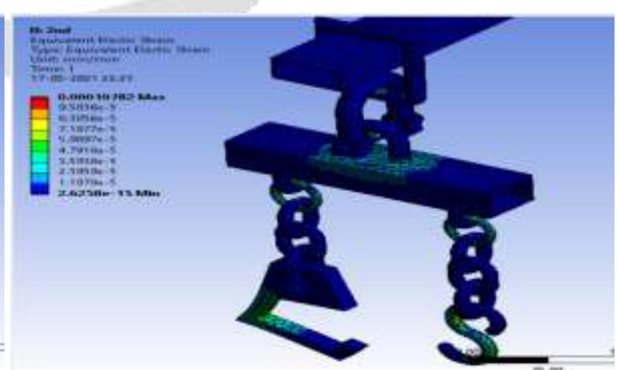


Contact region

Contact region is the main part of the simulation without CR the simulation will be terminated here the surface to one another contact is shown n the fig.

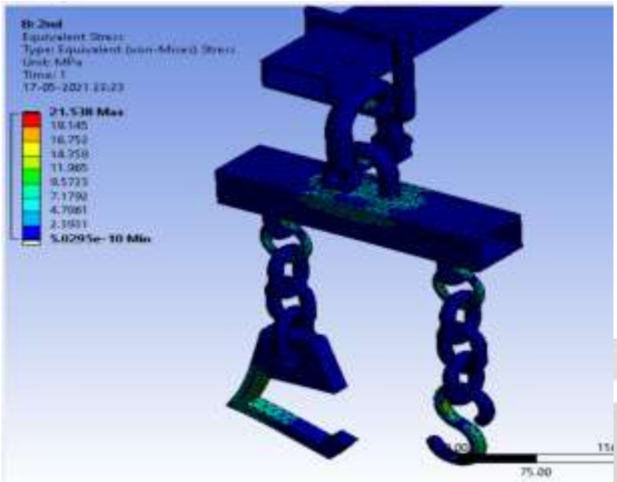
7.RESULT





Deformation Strain

Change in length by its original length after boundary condition of 200 N load at each hook.



Stress

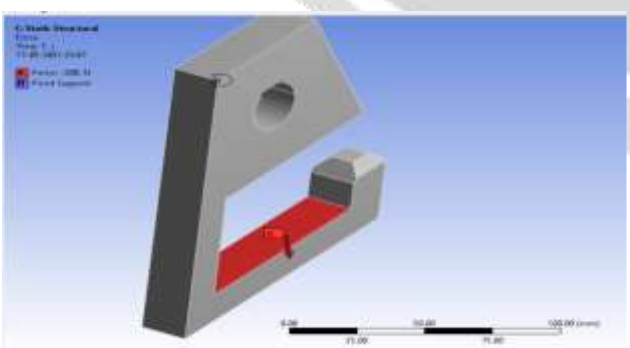
Discussion

In 1st iteration I have designed and simulated a tackle at 200 N load at each of the hooks and condition was good but stress parameter was more.

In 2nd iteration I have varied the size and neglected some of the hard operation and changed the support from circular to rectangular and simulated to FEM solution to study the failure and recorded the much better results than the previous one. But here the failure is more at the hook 2 so in next procedure I will optimize the hook 2 to its required volume by considering the cost factor and simulate it separately to know the failure factor of hook using wrought iron material.

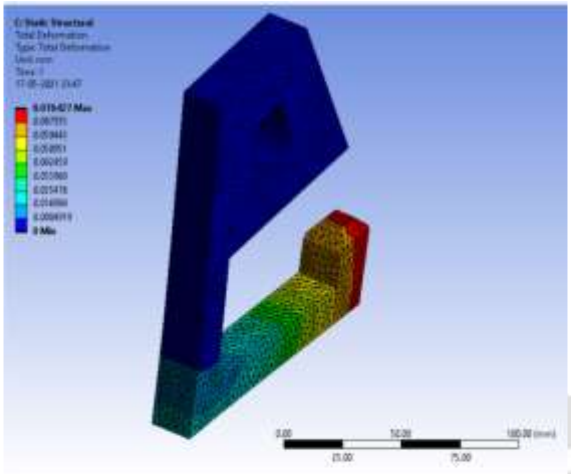
3Rd iteration

In this iteration we will study the failure only in hook 2 and optimize it to weight consideration

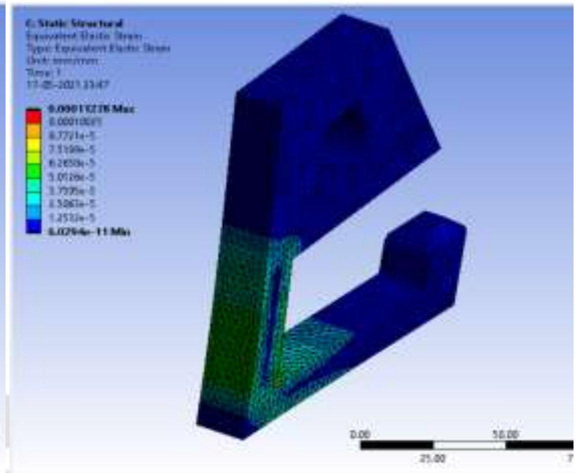


Geometry

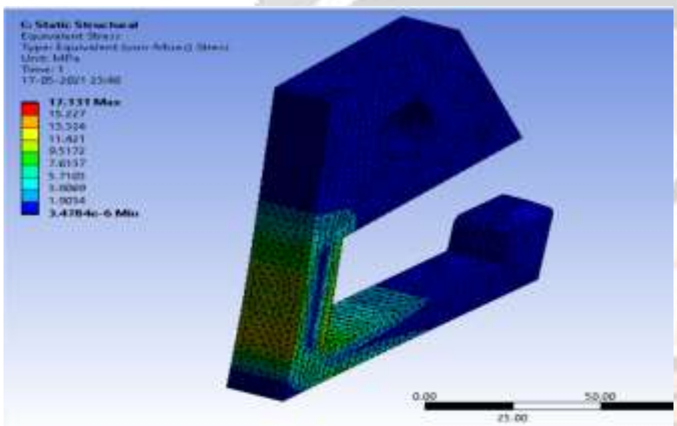
This is the geometry of old hook 2 with the boundary condition



Deformation



Strain

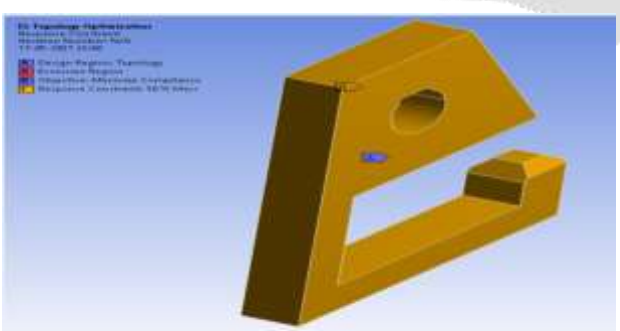


Stress

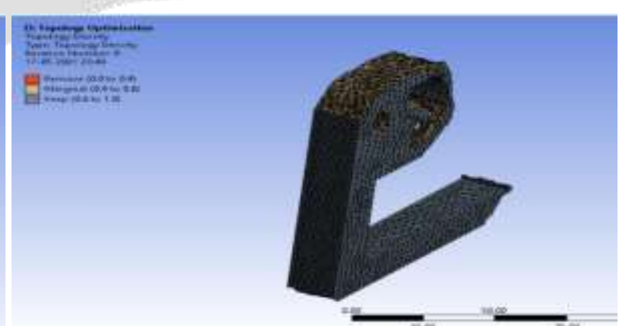
Discussion

As we have simulated the hook the stress factors are more in at the edges max deformation is more as compared to the other hook so we will optimize this hook with the help of topology analysis

Topology optimization



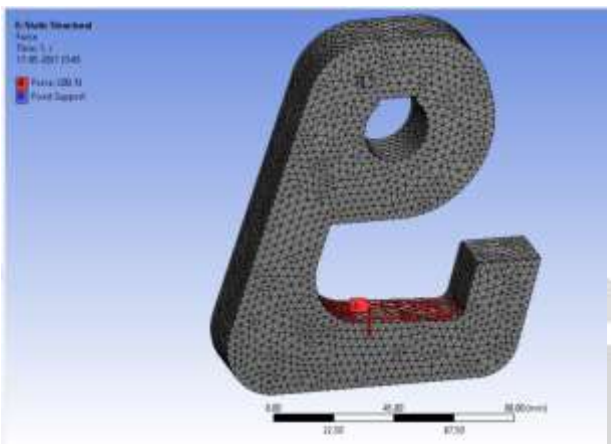
Selection of criteria

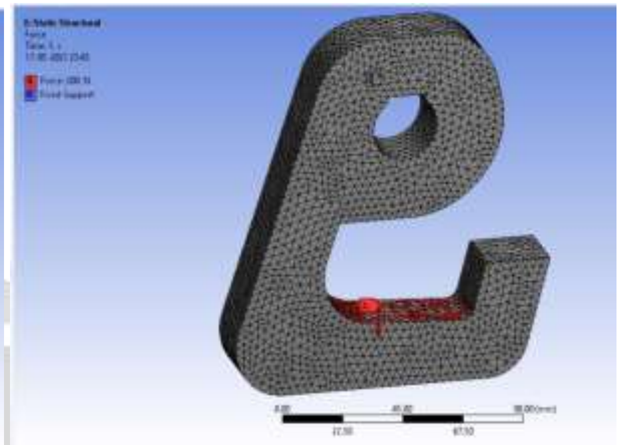


Density formulation optimization

After studying the topology, we will redesign the hook.

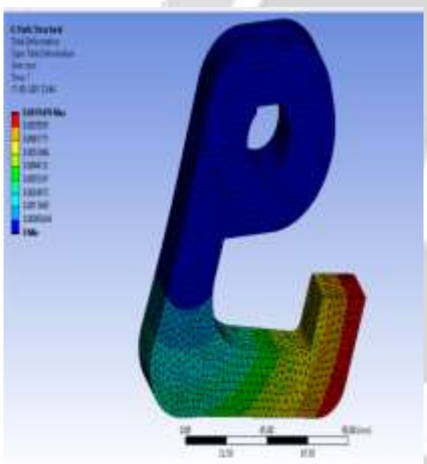
4th iteration

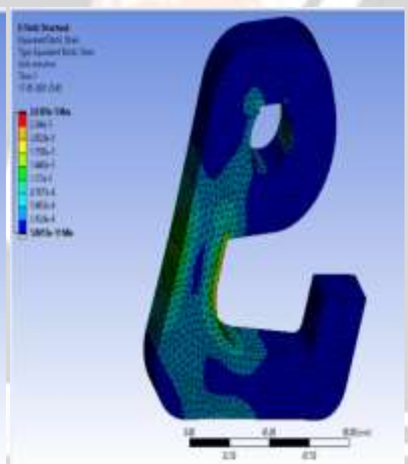


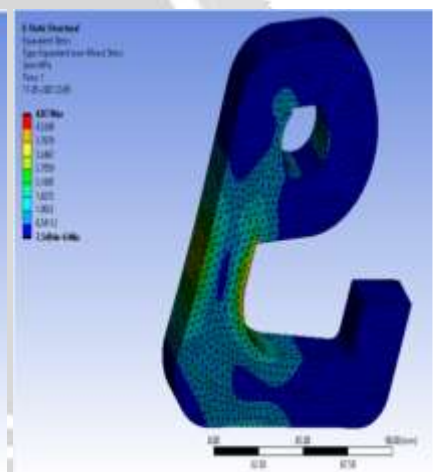


Mesh Boundary condition

Load of 200 N in -Z direction with a fixed support at hole upper surface.





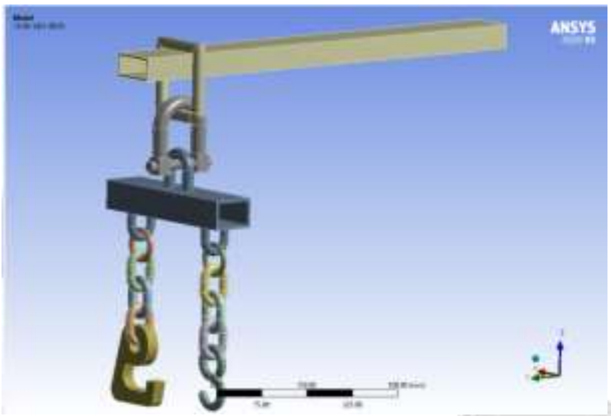


Deformation Strain Stress

Discussion

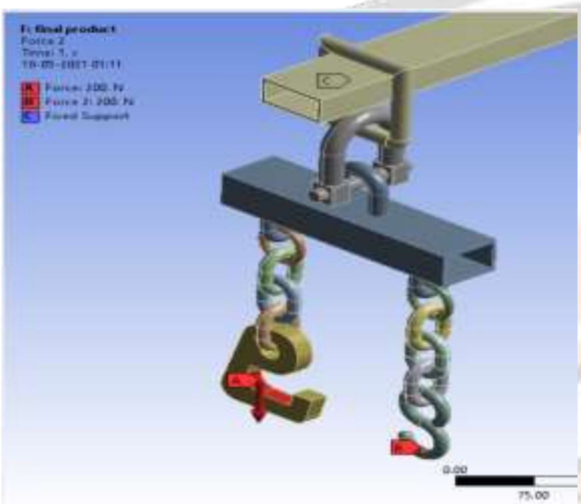
In this simulation I have redesigned the hook according to the topology obtained and again simulated with the same boundary condition and recorded the data. Here the results of the optimized hook are much better than the previous one and the condition is satisfactory.

5th iteration

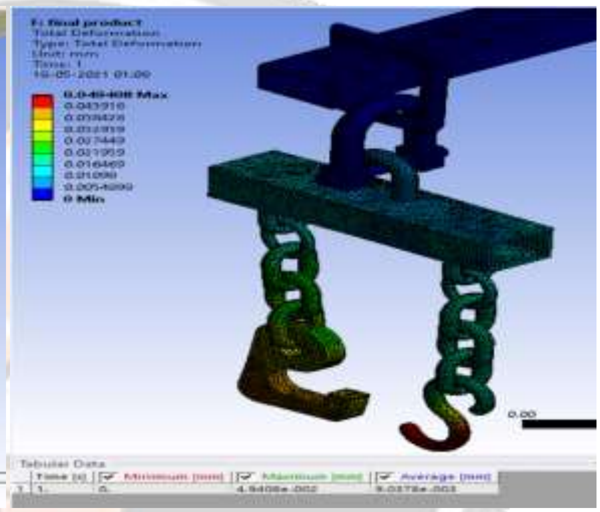


Geometry

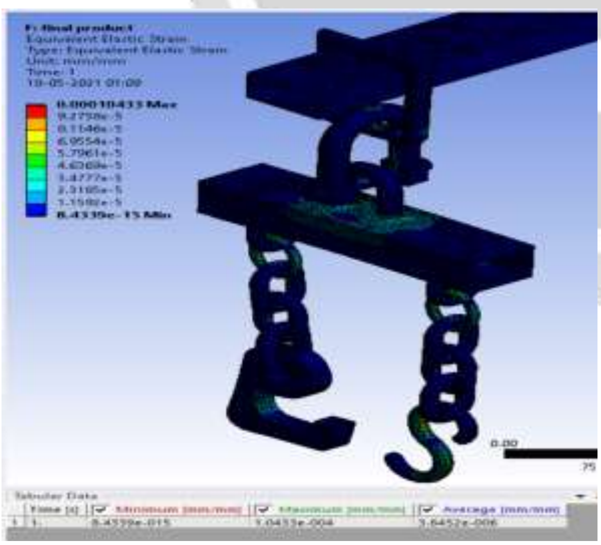
Mesh



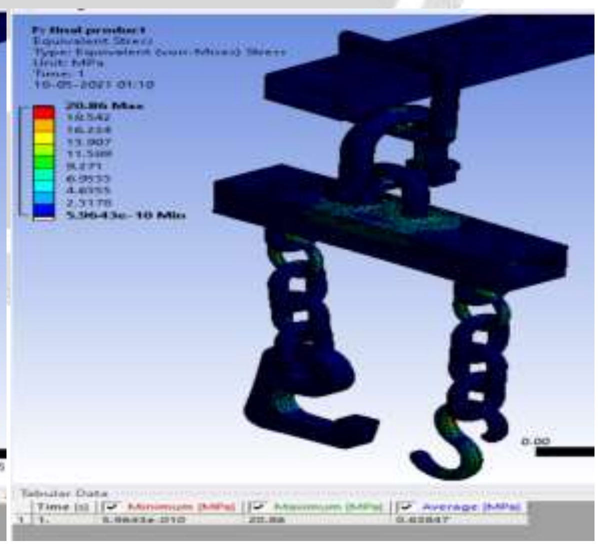
Boundary condition



Deformation



Strain



Stress

Discussion

After topology optimization of the hook I have replaced the hook from old to optimized one and again simulated for final results this time the hook was safely passed with 4 mpa of stress at the whole part. In this simulation we are recording the data from 44 mpa to half of it 22 mpa load failure has bee taken out up to now and can be further simulated for smooth surfaces

Tabular column of results

Sl No	Material	Part	Deformation In MM	Strain In MM/MM	Stress In MPA
1	Structural steel	Assembly	0.1777	0.00025026	42.748
2	Structural stee ad Stainless steel	Increased parameter Assembly	0.09396	0.0001078	21.538
3	Wrought iron	Hook	0.07	0.0001127	17.137
4	Wrought iron	Optimized Hook	0.0079	2.639e-5	4.87
5	All MS+SS+Wi	Assembly	0.049	3.6452e-6	20.86

8.CONCLUSION

In 1st iteration

1. Until now I have researched and selected material to be used for ANSYS to solve in structural analysis.
2. And also designed the lifting equipment or tackle using CATIA v5 R20 software
3. And also solved the FEM solution using ANSYS R1 2020 software
4. Recorded the output obtained from the simulation.
5. In next process ill change the material and observe the output at same boundary condition.
6. Later on, at final requirement ill change the design if required to minimize the weight and cost.

In 2nd iteration I have changed the parameter and reduced some of the parts as shown in the fig. and simulated it and observed the results

In 3rd iteration I have particularly studied the max failure part and the hook for its load condition.

In 4th iteration I have redesigned the hook and again simulated for FEM solution.

In 5thiteration I have replaced the hook 2 and added the optimized one and observed the results which was having better condition then the 1st case with minimum cost effectiveness.

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