A Review on Design, Selection of Material, Analysis and Failure of Hooks used in Material Handling Equipment

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Abstract

Acrane hook is an accessory used with hoists or cranes to lift objects and move them from one location to another. A crane is used for continuous loading and unloading. This could eventually lead to the crane hook's fatigue failure. The crane hook, which lifts the weight, is a crucial component of the crane itself. Due to the High Concentration of Stresses, they are Subjected to, Hook on the Crane are Always at Risk of Failure. The goal of this study is to improve the crane hook's performance based on stress, geometry, and material choice. Analysed cross sections include square, round, and trapezoidal, all of which are subject to a concentric load. The curving inner surface of a crane hook constantly experiences concentrated load, where the greatest strains are created. This inner surface's curve is thought to be a significant area where failure could happen. Through the use of SOLIDWORKS Simulation, the analysis takes the shape of theoretical calculations and finite element analysis. Variations in the cross-sectional characteristics are used to optimise the weight and stress of the trapezoidal cross section, which is found to be the most effective. SOLIDWORKS software is used to create a solid model of the crane hook in order to examine the stress, strain, and deformation of the crane hook under load.By giving loading conditions, supports, and the relevant material parameters, ANSYS software is used to determine the stress distribution, strain distribution, and total deformation in the 3D model of the crane hook. In order to have improved qualities and achieve the best results, high strength material is chosen and heated. According to the investigation, trapezoidal-shaped crane hooks manufactured of alloy steel that has been hardened and tempered are ideal for use as crane hooks. By choosing the appropriate material in accordance with IS: 15560:2005 and lowering the number of patterns needed to forge each capacity of hook.

Keywords:Alloy1.2367(X38CrMoV53),Crane,Hook,Finite Element Method(FEM); lifting hook; topology optimization; fatigue analysis Solid works Software

1. Introduction

In industries, crane hooks are used for loading, unloading, and transferring big goods. The lower inner curve of the hook, which distributes the produced stress to the remaining portion of the hook, is typically loaded. In this work, analysis is carried out by altering the hook's cross section while maintaining a constant static stress. First, a SOLIDWORKS model of a 3D hook is created. Second, FEM software ANSYS is used before the static study on the hook. In order to reduce hook failure, it is important from a safety standpoint to analyse the stress placed on crane hooks. Hooks come in a variety of area cross sections. In this paper, design and analysis are done using the Hook trapezoidal cross section.

The load can be applied at the hook's bottom-most inner curvature point and the hook's highest point of support. Three important design factors that have a significant impact on the strength and weight carrying capacity of crane hooks are the material composition, cross sectional form, and moment of inertia. This work forges various capacity hooks using fewer patterns than the traditional method. For more than one capacity hook forging, we apply the same pattern by using material selection in accordance with IS 15560: 2005. After forging, we do a model-based stress study and comparison with an analytical method.

2. HOOK

A lifting hook is a device used for lifting loads by means of a device such as a hoist or crane.

Hook Manufacturing Methods:

1. Forging Hooks
2. From Sheet Metal Cutting (IS: 6216)
3. Fabricated Method

2.1. Types of Hooks

Fig. 1. Eye Hook

Fig. 2. Crane Hook

Fig. 3. Ramshorn Hook

Fig. 4. Single Hook

2.2. Design of hook assembly List of components to be used in hook assembly.

1. Hook
2. Cross bar (Cross piece)
3. Pulley
4. Shaft pin
5. Side plate
6. Bearing
7. Bearing cover
8. Bearing spacer

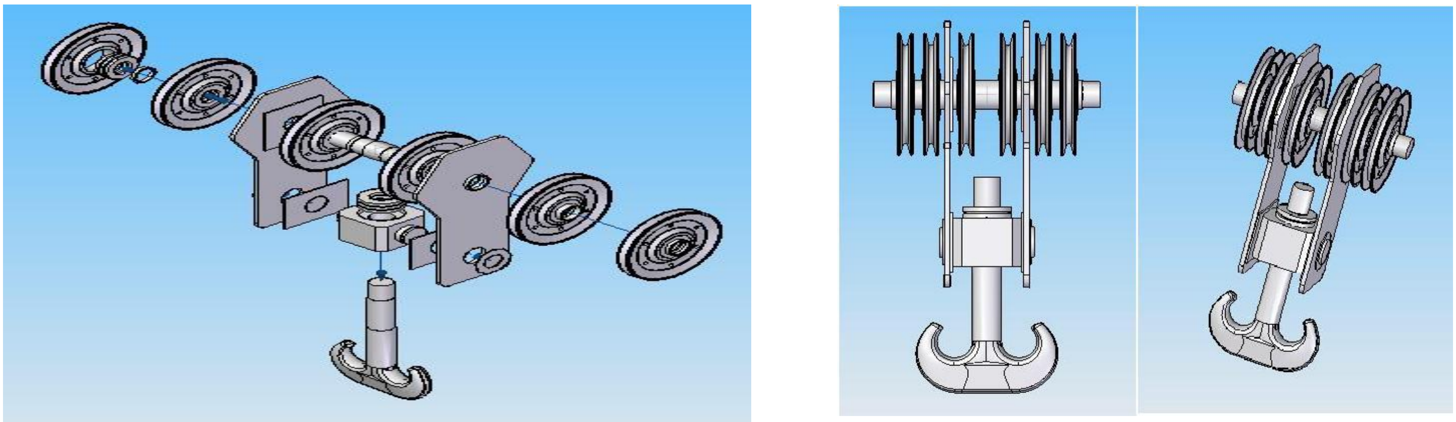

Fig. 5. Hook Assembly

2.3. Hook Failure

The crane is continuously loaded and unloaded. The crane hook becomes fatigued as a result; however, the fatigue cycle is quite short. The crane hook may shatter if a crack forms, which could result in a serious accident. In contrast to brittle fracture, ductile fracture prefers continuous crack propagation and easier detection. In brittle fracture, the crack spreads rapidly and the hook abruptly fails. Due to the difficulty in detection, this form of fracture is quite deadly. Continuous loading and unloading causes strain, which modifies the microstructure. Tensile and bending stresses, hook deterioration from use, and plastic deformation

Excessive heat strains and overloading are a few more causes of failure. Crane hooks may experience increased levels of these stresses over time, which could eventually cause the hook to break.

Fig. 6. Hook Failure

3. Literature Review

Bhimsen Shrestha et al in is the crane hook is successfully designed using the curved beam principle for five distinct cross sections, including circular, rectangular, trapezoidal, triangular, and t-section. The different sections of hooks were designed using the SOLID WORKS 2019 software, and the study of stress-induced deformation in the inner and outer profile was done using ANSYS WORKBENCH. According to the analysis, the stress induced in the trapezoidal cross section is smaller than that of the other four cross sections, indicating that crane hooks with trapezoidal cross sections are more resilient and have a better capacity to absorb and store displacement caused by vertical load (Fig. 7,8,9).[1]

Fig. 7. Circular Cross section

Fig. 8. Trapezoidal Cross Section

Fig. 9. Rectangular Cross Section

Ibrahim T. Teke et al in paper by Public Numerical analysis showed that the number of cycles to failure depending on the geometry of the hook.Among these studies, the most appropriate model is the third model. Fatigue life, damage, and safety factor; equivalent stress, and also total deformation having best result in the third optimized one.The first and second models are not appropriate at least for the loading of 5 tons (49050 N). The stress values of the models increase by about 30% when the first and second optimised models are employed. (Fig. 10) A conventional crane hook's fatigue life is reduced by around 70% by drilling holes behind the area of greatest stress and behind the weight. The third optimised model weighs 285 grammes less than the regular model but has a similar fatigue life to the actual model, which is a significant advantage from an economic standpoint.[2]

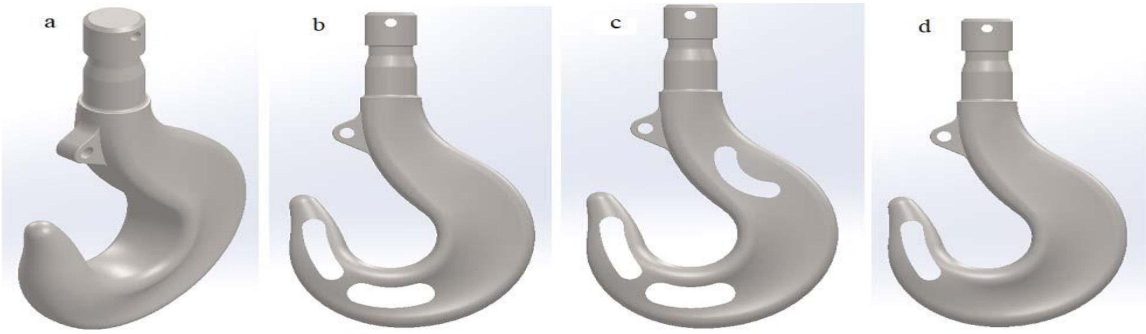

Fig. 10. (a) standard hook model; (b) first optimized model; (c) second optimized model; (d) third optimized model.

V Chandran et al in demonstrated in their in study The study examined crane hooks made of AISI 4340 alloy steel with vanadium at various concentrations. The findings showed that by enhancing crane hook material for more effective lifting and loading with proof of strong mechanical qualities and prolonged lifespan, failure can be minimised. The AISI 4340 alloy steels contain 99.95% AISI 4340 alloy steel and 0.05% vanadium, which together play a crucial role in creating the fine grain structure that improves mechanical qualities(fig.11). The study's findings suggest that using a crane hook made of 99.99% AISI 4340 alloy steel and 0.05% vanadium will result in high strength, dependability, and sustainability. When shipping heavy loads, it could beused.[3]

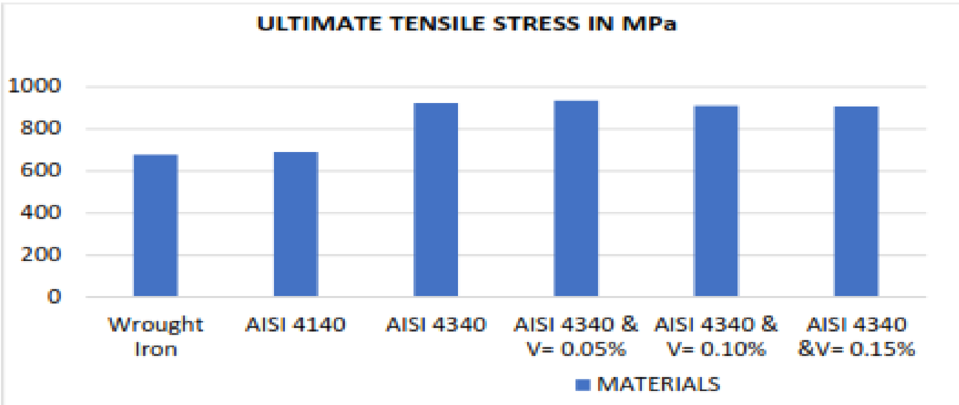

Fig. 11. Ultimate tensile stress in different composition of alloy materials

G Bhagyaraj et al. In is shown We could deduce from this study that Alloy 1.2367 (X38CrMoV53), which can withstand at the same rating and standards and provide significantly greater load capacities than the other hooks, can be used to manufacture crane hooks in place of traditional materials. reduces weight and allows mounting to a variety of cranes and hook blocks without altering the hook's design (Fig. 12, 13) [4]

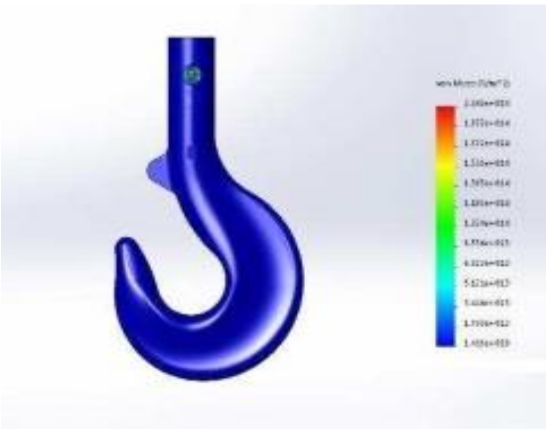

Fig. 12. Von Mises Stress

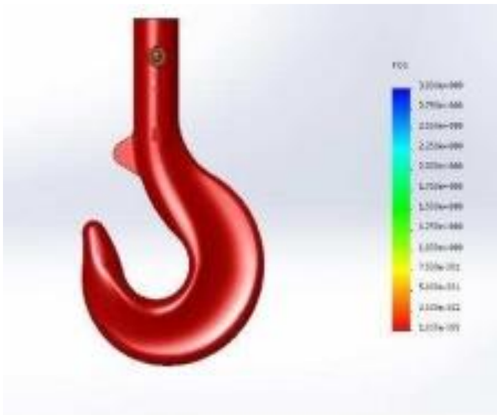

Fig.13. Factor of Safety

Nikhil R. Patel, Nilam kumar , S. Patel et al. In is shown Design of 50 Ton Hook with Analytical Method and Then Create Solid Works model and Analysis on Ansys. Result will compared.The entire work is an effort to develop a FEA process for measuring stresses by validating the outcomes. Estimating stresses, their magnitudes, and potential locations is crucial for lowering hook failure rates. The major goal of this study is to increase the crane hook's ability to endure structural and bending stresses while simultaneously lowering the crane hook's stress concentration. Therefore, the additional scope of work involves optimising the crane hook design by adjusting variables like the inner and outer thickness of the crane hook cross section. [5]

Fig. 14. Solid Works Model of Crane Hook

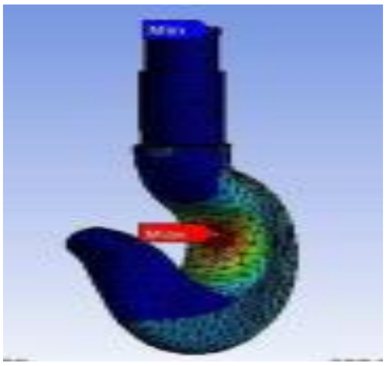

Fig. 15. Maximum Shear Stress Formula

Suman Pathak, et al in paper by to determine the maximum stress, strain, and deformation, a linear static structural analysis has been done after looking at the computation above. Peak stress of 4.017 10 Nm2 is discovered. With a safety factor of 2.64, it can withstand loads up to 2.64 times greater than those used in the experiment. The same calculations and analyses can also be performed using FEM and ANSYS, which is useful for studying stress, displacement, strain fracture point, and numerous other minor calculations at each location. The load can be applied at the hook's bottom-most inner curvature point and the hook's highest point of support. Three important design factors that have a significant impact on the strength and weight carrying capacity of crane hooks are the material composition, cross sectional form, and moment of inertia. This work forges various capacity hooks using fewer patterns than the traditional method. For more than one capacity hook forging, we apply the same pattern by using material selection in accordance with IS 15560: 2005. After forging, we do a model-based stress study and comparison with an analytical method. [6]

Pappuri Hazarathaiah et al. In evaluated Results of stress analysis derived from FEA analysis for a variety of materials, including Forged Steel, Wrought Iron/MS, and Aluminium Alloy. When using different material topologies with the same tone, it is apparent that the results will vary. However, the forged steel material, which is described in the table below, is determined to give the least amount of stress in the above table (Fig.16).[7]

Material	**Analytical stress** (N/mm2)	**Tone**	**Max.Equivalent Stress (N/mm2)**
Forged Steel	98.5	5 tone (49050 N)	103
Wrought iron	125.1	5 tone (49050 N)	113
Aluminium alloy	128.6	5 tone (49050 N)	124

Fig. 16. First Trial Of Hook Design For Forged Steel

Mukesh Sonava et al. In is shown the research we conducted here provides a review of earlier works in journals and publications that are based on various concepts that have been modified using analytical and computational techniques. Here, in this section, we draw a conclusion about the key factors that we examined through research into earlier work. 1. The major portion concentrates on the several crane hook cross sections (trapezoidal, T section, I section, and triangular section).2. The force placed on the crane hook when it is loaded was also a point of emphasis. 3. The literature also demonstrates the usage of various materials in crane hook production. 4. Work is also being done to lighten the hook. 5. The solid model of a hook is subjected to certain experimental methods in order to determine the deformation under stress. [8]

Yadav Bhola Chunkawan et al in paper by determine in order to determine the highest levels of stress, strain, and deformation at the blade, disc, and fillet regions, linear static structural analysis has been done. It is discovered that the hook experiences a peak stress of 310.45 Mpa and total deformation of 2.423 mm. discover Crane hooks' initial modes and accompanying natural frequencies (Fig.17). Crane hook fatigue analysis was done for 1000000 startup and shutdown cycles, and the design was found to be safe because the fatigue life findings were beyond 100000 cycles. Crane hook optimisation reduces weight by 12.1 kg, extending crane hook life and improving efficiency. [9]

Sl.no	Equivalent stress	Maximum principal stress	Minimum principal stress	Weight
Chrome steel	310 mpa	296 mpa	62 mpa	18.614 kg
Aluminum	311mpa	297mpa	63 mpa	6.5682 kg

Fig. 17 Material Comparison

E.Sai Krishna, Dr. S .Suresh kumar et al. In is shown The research We have successfully optimized the material of the crane hook study the structural stresses of hook by ANSYS R15.0 & concluded that the material which is having less deformation will have more stability if less failure of crane hook.Final we got the material SAE-AISI 1040 with less deformation.so it is the material suitable for crane hook.[10]

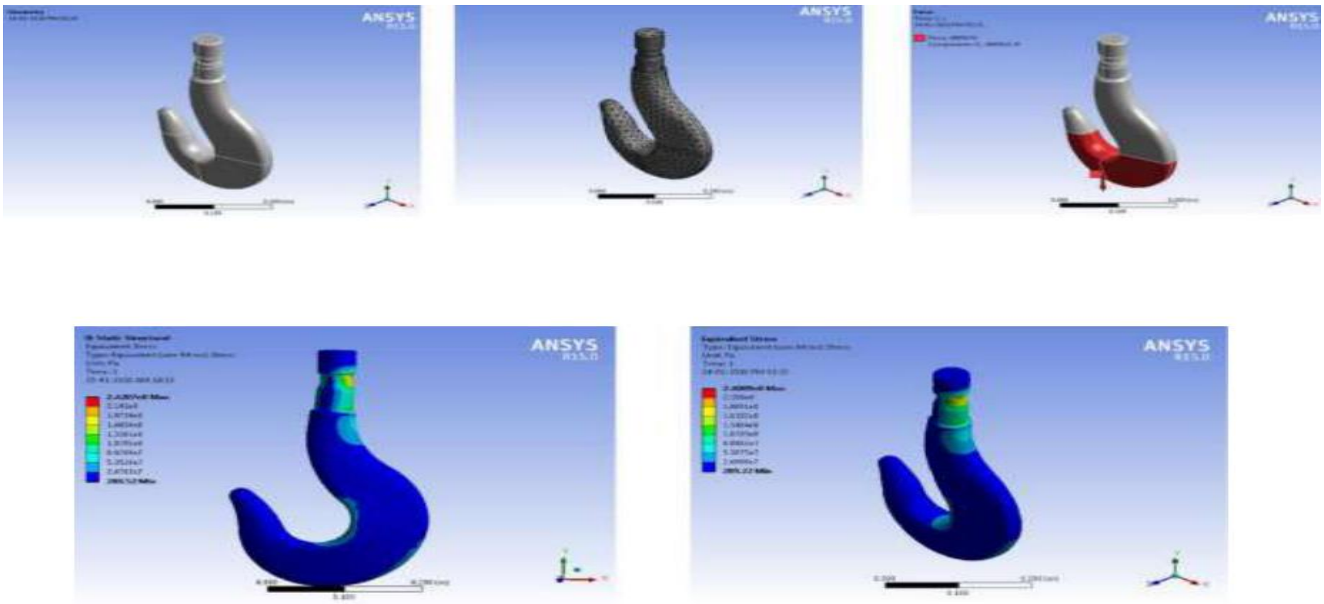

Fig.18. Design and Analysis of Different Grade Materials

Osman Ashraf Ansari et al. In is shown the research that The Pro/Engineer wildfire 5.0 model that was examined with Ansys V12.1. Ansys receives the model developed in Pro/Engineer in IGES (Initial Graphics Exchange Specification) format. The model has undergone a structural analysis using the suggested material parameters, boundary conditions, and loads. By looking at the findings that were covered in the first chapter, it can be concluded that the crane hook model can support the suggested loads while taking a factor of safety into account of 1.2. So, after considerable testing, the planned model can be produced or constructed [11].

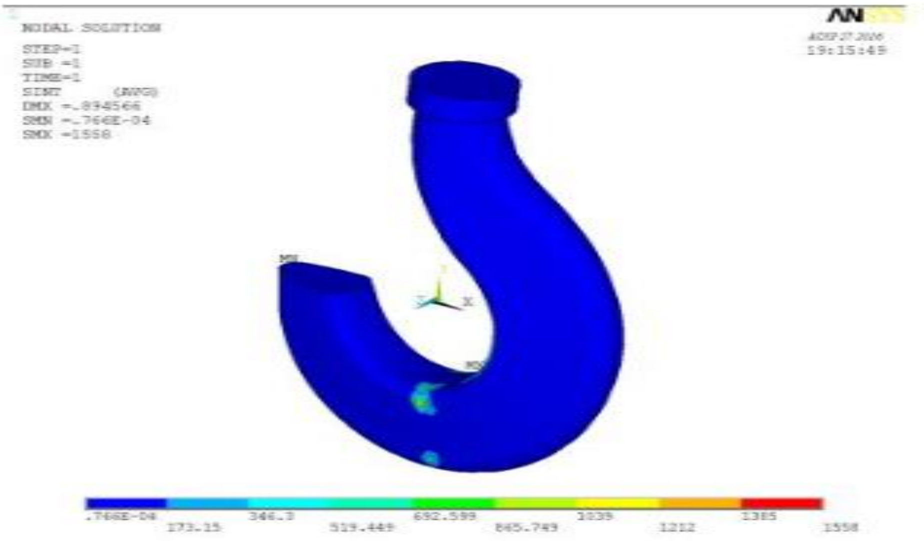

Fig. 19. Stresses in Crane Hook

MOH Ahtesham Mansuri, et al. In is shown the research that Stress concentration criteria are frequently used, among other things, to gauge the sturdiness and durability of machine parts. By examining the strains produced on the crane hook, one can reduce the likelihood of a failure. Since there haven't been many studies in this field, it is acceptable to conclude from an analysis of earlier works that curved beams, such as crane hooks, require additional study. The Finite Element Method (FEM) is one of the best and most potent techniques for stress analysis of the crane hook among those that are accessible, according to the literature review [12].

Fig. 20. Single Crank Hook

Santosh Sahu,Ritesh Dewangan,Manas Patnaik,Narendra Yadav et al. In is shown the research that on the basis of the findings from the Finite Element Analysis and Design of Experiment carried out for the trapezoidal cross section crane hook, we have come to the following conclusions: The site where the maximum tension was produced and its magnitude. The Figure (21) illustrates how the amount of energy held within the crane hook reduces when the outer parallel length (b) of the trapezoidal section is increased. The crane hook's energy storage capacity reduces as inner parallel length (B) of the trapezoidal section increases, as shown in Figure (22).[13]

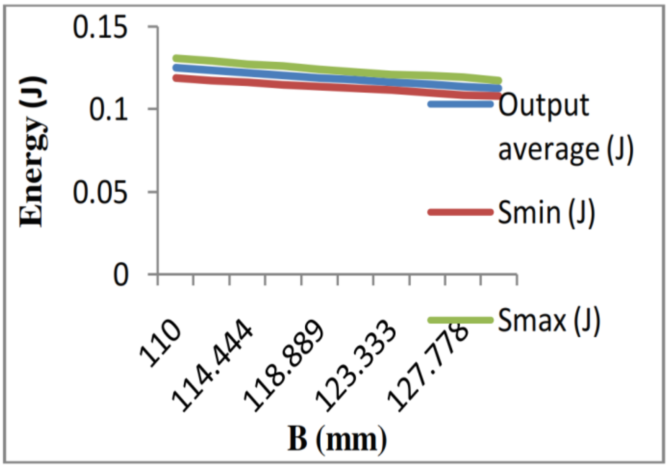

Fig. 21. Graph Plotted Between Energy Stored

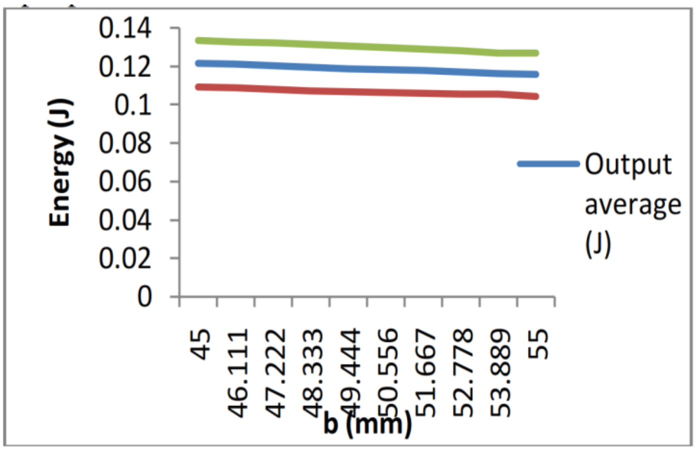

Fig. 22. Displacement Graph

Sumit Bundela, Ashish Kumar Shrivastava et al. In is shown the research that FEA software has been used to analyse the crane hook. The hook model is created using ANSYS, and its maximum primary stresses and deformation are examined. On the hook, a load of around 4 tonnes is applied. The load is applied using cross sections including circular, triangular, trapezoidal, and rectangular. A study was conducted using these models to examine how stresses and the material's flow behaviour were affected by changes in cross sections, and the following conclusion was reached:Trapezoidal cross sections were produced with a main stress of 140.13 MPa as the lowest possible value.Additionally, a trapezoidal cross section is observed to have a relatively lesser material flow[14].

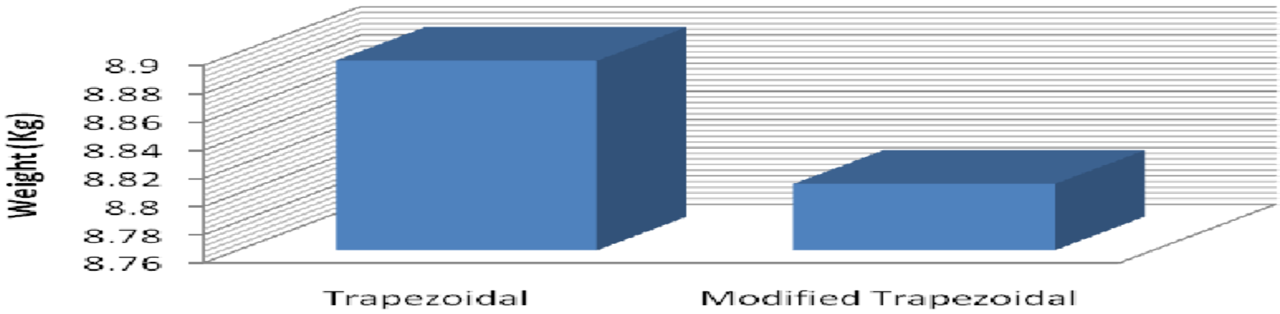

Fig.23. Graphical Comparison Between Trapezoidal and Modified Trapoidal Cross Section

4. Selection of Material

4.1. Chemical Property

Industrial Hook are Designed as per IS: 15560:2005.
Generally, In Hook Manufacturing 4 Grade of Hook are available in Market.

1. Grade L
2. Grade M
3. Grade S
4. Grate T

Grade L and Grade M not Need Hardening Process but in Grade S and Grade T has to Follow Hardening Process after Process.

Here I have Selected Class II IS: 1875 and Class III IS: 1875

Class 1A and class 3 steels of IS: 1875 may be used for Grade L and Grade M hooks.

IS 4367 may be used for Grade Sand Grade T hooks. This standard applies to the drop-forged and open-die forged eye hooks up to a safe working load from 0.63 to 160 tonne.

Table 4. IS :1875 :1992 Tensile Property and Hardness

(*Clauses* 1.1, 6.1, 6.2-1, 6.3 *and* 12.1.1)

Class	Designation [*See* IS 1762 (Part 1) : 1974]	Constituent, Percent				
		Carbon	Silicon	Manganese	Sulphur *Max*	Phosphorus *Max*[1]
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	14C6	0·10—0·18	0·15—0·35	0·40—0·70	0·04	0·04
1A	15C8	0·10—0·20	0·15—0·35	0·60—0·90	0·03	0·04
2	20C8	0·15—0·25	0·15—0·35	0·60—0·90	0·04	0·04
2A	25C8	0·20—0·30	0·15—0·35	0·60—0·90	0·04	0·04
3	30C8	0·25—0·35	0·15—0·35	0·60—0·90	0·04	0·04
3A	35C8	0·30—0·40	0·15—0·35	0·60—0·90	0·04	0·04
4	45C8	0·40—0·50	0·15—0·35	0·60—0·90	0·04	0·04
5	55C8	0·50—0·60	0·15—0·35	0·60—0·90	0·04	0·04
6	65C6	0·60—0·70	0·15—0·35	0·50—0·80	0·04	0·04

CHEMICAL PROPERTIES					
	C	Mn	Si	S	P
Designation	*%*	*%*	*%*	*% (max)*	*% (max)*
20C8	0.15-0.25	0.60-0.90	0.05-0.35	0.050	0.050
25C8	0.20-0.30	0.60-0.90	0.05-0.35	0.050	0.050
30C8	0.25-0.35	0.60-0.90	0.15-0.35	0.050	0.050
35C8	0.30-0.40	0.60-0.90	0.15-0.35	0.050	0.050
40C8	0.35-0.45	0.60-0.90	0.15-0.35	0.050	0.050
45C8	0.40-0.50	0.60-0.90	0.15-0.35	0.050	0.050
50C8	0.45-0.55	0.60-0.90	0.10-0.35	0.035	0.035
55C8	0.50-0.60	0.60-0.90	0.15-0.35	0.050	0.050

4.2. Material Selection Justification

In General Class 1A, Class II and Class III Material are Used in Industry. Reason of that is Class 1A Class II and Class III Material EN Equivalent Chemical Composition is Available in Market easily.

For Prize Comparison these Class Material are easily available in Market and available at Forging Industry for Forging Hooks**.**

5. Conclusion

Further all Research are dealing with Stress Analysis by Numerical Method,Stress Analysis by Various Finite Elements Method. Hook Modeling by Various Soft wares like Solid Works Solid Modeling. Stress Developed on Various Cross section Like Circular Cross Section, Trapezoidal Cross Section, T Section, I Section, Circular Cross section. Among These all-Cross Section

Trapazoizal Cross Section having Less Stress induced and having More Load Carrying Capacity compared to all other Cross Section. By Use of Vanadium in AISI 4340 Alloy Steel used for reducing Weight of Hook as Compared to all other Material used for Hook Forging. Stress induced in Material Wrought Steel, Forged Steel, Alloy Steel, Aluminium Alloys we can conclude that Alluminium Alloy Steel is more durable than other Material so most Versatile used material is Alloy Steel. Stress Developed during Operation most versatile numerical method used is Numerical Method and FEA Method.

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