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Design, Analysis And Optimization Of A Lifting Tong

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Abstract

A suitable lifting tong mechanism has been established for the lifting of heavy steel roll coils. The simulation analysis of lifting tong mechanism was carried out with Ansys. A 3-D model of lifting tong mechanism was established with Catia V5. The design of the mechanism was optimized in Catia/Mechanical based on the findings from simulation analysis, which may guide and improve the further design. The design was proved to be scientific and reasonable and could serve as the theoretical guidance and reference for the design of lifting tong mechanism of other uses.

Keywords: *Lug design, Link design, Grab tong.*

1. Introduction

The tong grab has been used in the steel and iron industry for the last two centuries and by early civilizations as far back as the Roman Empire. Because of the tong's simplicity, suitability for use in the worst mill duty environments, and long term reliability, the tong has a wide appeal to a large spectrum of users. Steel mills utilize tongs because they can be designed to withstand significant heat, are not affected by electromagnetic interference, have low maintenance requirements and can withstand significant shock loading. Service centers or fabricators like the fact that the tong requires few operators, and can be used at various locations around the plant without concern for electrical or special hook needs. The small end-users embrace the tong for its low cost, flexibility and durability. With minimum down time on the process line a major goal of most organizations, the design characteristics of the tong grab make it an appropriate tool for many applications.

Lifting device is an important tool for many production line processes, the wrong application or improper use of a tong grab can cause significant property damage and even the loss of life.

2. Simulation of Mechanism

2.1 Configuration of lifting tong mechanism

In Catia V5, the 3-D model of lifting tong mechanism was established. The configuration of scissor lifting mechanism is Shown in Figure.1. The scissor lifting mechanism is composed of outer cover plate, inner kinematic links and lug plate and other parts.

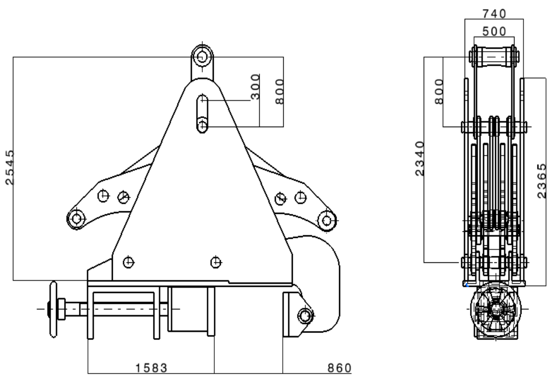

Fig.1 2D Model of lifting tong

2.2 Lifting tong lug strength design

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Lifting equipment is required to transport members from one place to another place. In the present work, a tong is required to lift the heavy roll coils from one place to another place. But due to the heavy load, a grab tong is required to be designed and analyzed properly for lug design.

(1)Lug strength calculations

Lug, Bushing, and Pin Strength under Uniform Axial Loading Lugs must be analyzed for bearing and net-section strength while pins are analyzed for shear and bending load. See Figure.2 below for an overview of basic lug geometry.

(2)Lug Geometry for Uniform Axial Loading

Lug Bearing Stress under Uniform Axial Load to calculate bearing stresses in the region of the lug and/or link forward of the net section, on must first determine the allowable load coefficient (K) which is related to the ration of e/D. When e/D is less than 1.5, lug failures are likely to result from shear tearout or hoop tension while when e/D is greater than 1.5, failure due to bearing is more likely. In the majority of cases, failure depends on the interaction of several failure methods; however, K takes into account these interaction effects. Figure.3 depicts the relationship between e/D and K.

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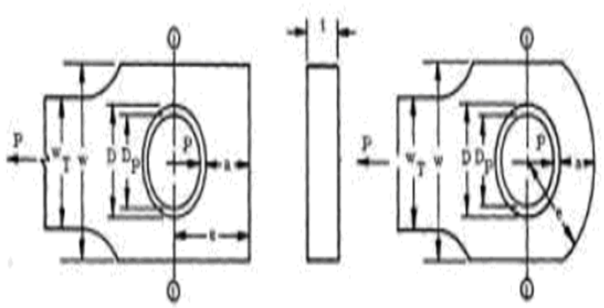

Fig 2- Lug Geometry for Uniform axial loading

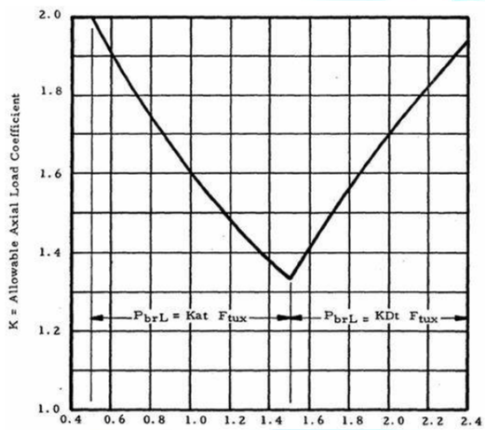

Fig.3 - e/d ratio

Bearing stress in lug plate $\sigma_b = K a \sigma_u / d$

Bearing yield stress $\sigma_y = K\ a\ \sigma_y / d$

The allowable lug bearing load = σ_b x d x t

Bending moment on the lug pin

M_{max}= P ($t_1/2 + t_2/2$ + g

Ultimate loading capacity or failure moment of the pin is

$M_U = \pi\ k_{bp}\ d_p^3\ \sigma_u / 32$

3. Modeling of the lifting tong

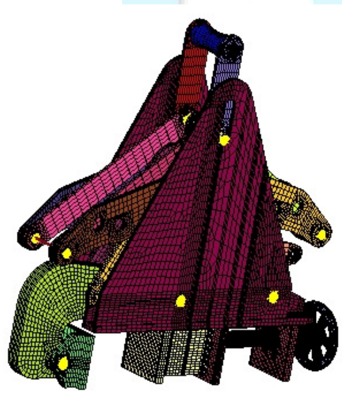

Fig.4 – 3D Meshed model of lifting tong mechanism

The figure.4 shows meshed geometry of the cad model. Brick meshing through hypermesh is used for more accurate results. Initially the members are surface meshed and later extruded to get three dimensional mesh. Pins are represented with one dimensional beam elements.

4. Results and discussion

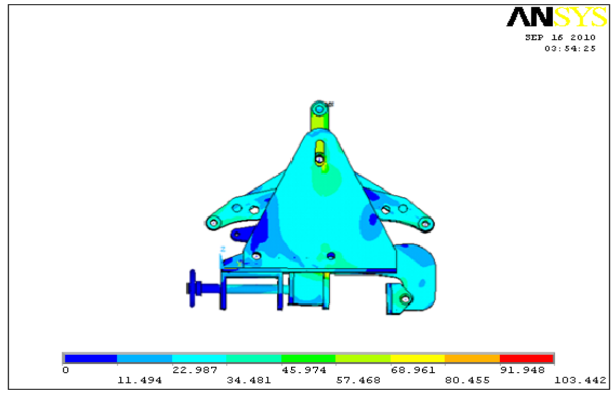

Fig.6 – Von misses stresses in the model

The figure.6 shows developed vonmises stress in the structure. Maximum vonmises stress is around 103.42 Mpa which is less than the allowable stress of 140Mpa of the material. The major stresses are concentrated around the hole regions as they are the potential zones of stress concentration due to the sharp geometrical variation of geometry.

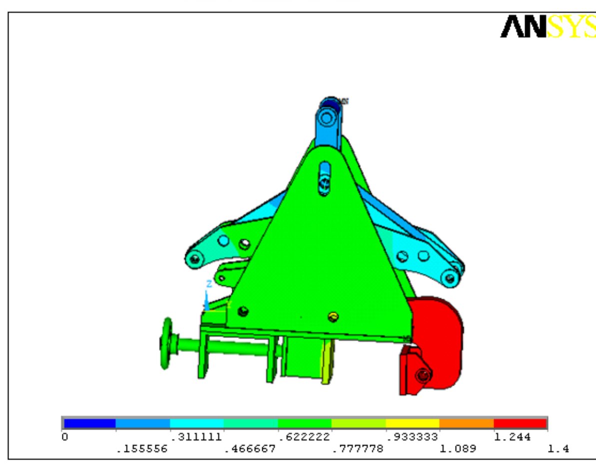

Fig.7 – Displacement in the model

The figure.7 shows displacement in the structure due to 75 tons load. Maximum displacement value is around 1.4mm taking place at the bottom link plate. The displacements are less at the top which are away from the loading regions and also linked to the constrained parts.

By running the simulated model the data of acting force with the change of thickness of link mechanisms can be got (as shown in table.1) which may make preparation for further optimized design.

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5. Optimal Design

There are several advantages to the use of Optimization modules. The use of modules decreases the needed evaluation and modification time for each design option. It also allows for quicker and easier comparison of similar models that fit within the specified requirements. Once the parameters are defined, their values are easily changed both by the computer module and the user. Multiple models that fit within the stated specifications can easily be created and evaluated to determine which could work best under the necessary circumstances. Graphical displays of the results such as stress, temperature gradients and deflection help the user understand the reactions of the model to different conditions so that adaptations can be made to better-fit desired use of the design. With complex models problems start to arise, due to the numerous possible parameters, it is difficult to determine every possible parameter that might be considered when the model is initially created. The analysis results should not be trusted completely, as the analysis is only as accurate as the model used. The mathematical models that are utilized in each program vary in the degree of their accuracy and thus the computerized results should be checked.

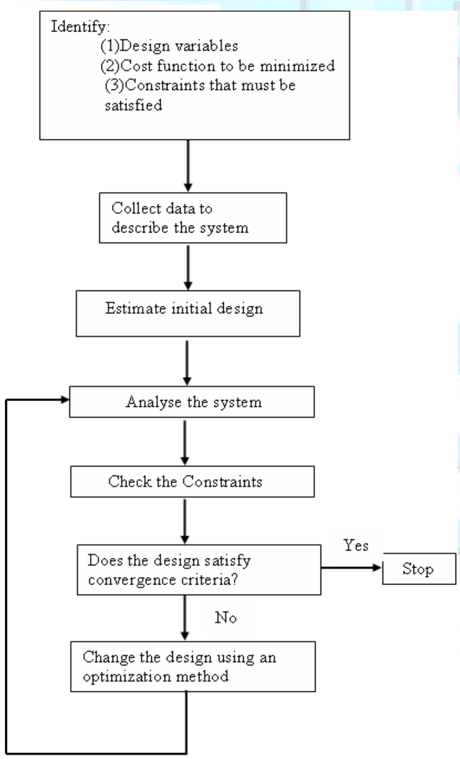


Fig.8 - Optimization Process

Based on Catia/Mechanical, the 3-D model of the lifting tong mechanism can be optimized to minimize the total quality of lifting tong links mechanism parts.

Table.1 Results of optimal design

Si. no	Parts name	Original Design, mm	Optimized Design, mm
1	Links Plate	35	25
2	Outer jaw holding Plate	75	45
3	Inner holding jaw	80	57
4	Vertical connecting link	32	30
5	Outer jaw holding lug	63	45
6	Base plate bracket	30	25
7	Cover Plate	40	35
8	Connecting lever	50	25
9	Outer jaw	140	100
10	Connecting links	35	25
11	Hub Plate	40	28
12	Main extension link	50	32
13	Main extension link-2	50	32
14	Suspension Lever	50	32
15	Toggle Lever	50	28
16	Carrier links	140	90

The iteration results of optimized design can be got by running the program, as is shown in Table.2.

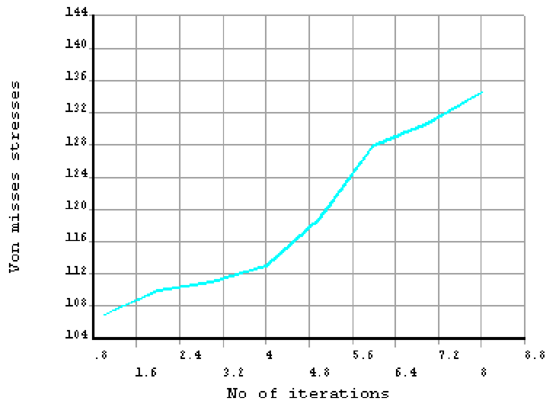
Table.2 Results of optimal design

Iterations	Weight	Vonmisses stresses, N/mm^2	Displacement, *mm*
1	9430.284	107.2	1.461
2	9262.136	110.8	1.506
3	8885.572	111.288	1.547
4	8515.602	112.2	1.601
5	8287.088	119.33	1.625
6	8160.154	128.599	1.686
7	7461.346	130.7	1.77
8	7096.076	134.5	1.889

Table.2 shows variation of weight, vonmises and deformation with increased number of iterations. As iterations increases weight is reducing but the stress and deformation both are increasing linearly. This can be understood from basic strength of materials, as the cross section reduces moment of resistance will reduce, thereby increases the stress but reduces the weight.

Weight reduced = 9430.284-7096.074/9430.284

Weight reduced =24.8%



The figure.9 shows von misses stress variation with number of iterations.

The vonmises stress is increasing linearly with the iterations. The maximum stress of 134.5 is near to the allowable stress. So iterations are stopped and the results show almost a saving of almost 24% material. The stress will increase as the resistance of the structure will reduce for loading as the cross section reduces.

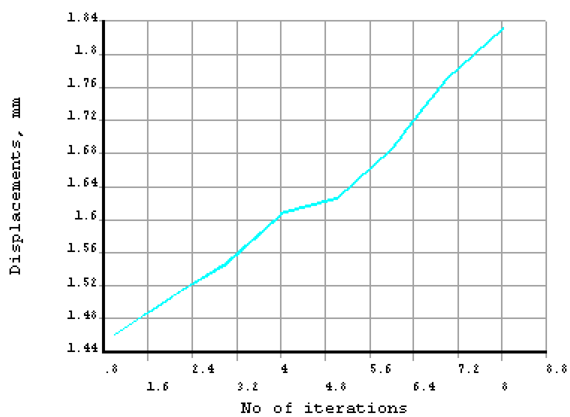
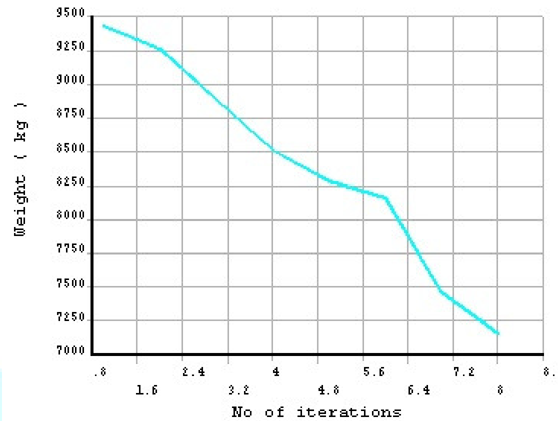


Figure.10 shows the displacement variations with iterations. The deformation is increasing with along with iterations. With the iterations, the section modulus values are reducing, so deformation in the structure will increase.



The figure.11 shows weight variation with reference to number of iterations. The weight is dropping linearly with reduction in weight.

5. Conclusion

The kinematic simulation analysis of lifting tong mechanism for lifting steel roll coils at high altitude work was carried out with Ansys. The Design calculations for link and pin are carried out taking into account force acting on them. A 3-D model of lifting tong mechanism was established with Catia V5. By using catia/Mechanical the design was optimized based on the simulation analysis results. The quality of lifting tong mechanism is effectively reduced in the premise of ensuring the intensity. The proposal can be easily put into operation and provide reference for engineering application.

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