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Design and Structural Analysis of Mast Member of Hydraulic RIG

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***Abstract**: Drilling rig is a machine that creates holes in the earth subsurface. Mast, a key part of hydraulic drilling rig, is a large steel structure with box section which loads all kinds of workforces. This paper focuses on the design and structural analysis of mast members of hydraulic rig. Stress analysis is conducted on mast structure under different loading conditions. The main aim of this paper is to make mast structure to withstand different load conditions i.e. Lifting drill condition, drilling condition and maximum load condition. The existing mast design is studied and found that stresses and deformations are high. Hence the mast is redesigned using SOLID WORKS and analyzed by FEA. It is found that stress and displacement levels are reduced and the design is made robust. Further, the stress and displacements are also calculated theoretically and compared with results obtained using FEA.*

***Keywords**: Hydraulic rig, Mast member, structural analysis of mast, stress analysis, deformation analysis.*

I. Introduction

Drilling rig is a machine that creates holes in the earth subsurface. These are massive structures used to drill water wells, oil wells, or natural gas extraction wells. Drilling rigs can also be used for providing samples for subsurface mineral deposits, test rock, soil and to find groundwater physical properties.

Fig. 1.1: Pictorial view of Drill rig

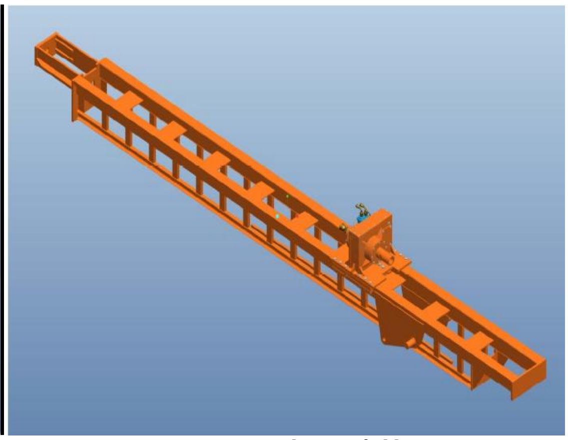


Fig.1.2: pictorial view of old mast

The main component of drilling rig is mast. A Mast is a structural tower which is made of mild steel comprised of one or more sections assembled in a horizontal position near the ground and then raised vertical to the operating position. The mast structure supports the parts of rig, such as drilling tools, gear box, adjusting mechanism, pressure mechanism and so on.

There are many conditions to be considered which influence the failures of mast structure. The main cause for failure of mast is due to drill rod load. Maximum stress on the mast structure depends on the number of drill rods inserted to drill the earth crust. [1]

If, the maximum deformation of a mast under working conditions is high then the rotating drill rod which moves along the track of mast will also bends, therefore it leads to catastrophic failure of rod and bore deviation takes place from actual drilling hole [1,2].

II. Modified Design of mast

The main problem with existing mast design (Fig 1.2) is; the stress intensity is higher as the cross section is varying from top to bottom. Stress is very high under a load of 25tons which is nearly equal to yield stress which is not a safer condition. Further, the stiffness of mast structure can influence directly the construction of drilling rig. Hence the mast design is modified (Fig 1.3) with uniform cross section throughout its length so thatit can provide great strength to withstand the load.In the modified design rectangular hollow rods are replaced by ‘x’ members and ‘C’ frames are replaced by rectangular long rods.

The mast structure is designed using Pro-Eand analyzed in Solid works software. Individual parts are designed and assembled with necessary constraints. Figure1.3 shows assembly model of mast structure of height which is equal to 8000 mmand table 1 shows the various parts of a new design mast. The CAD model is converted into PARASOLID model using xt file format which is then imported into SOLIDWORKS to examine the structural results. The analysis is carried out under different load conditions.

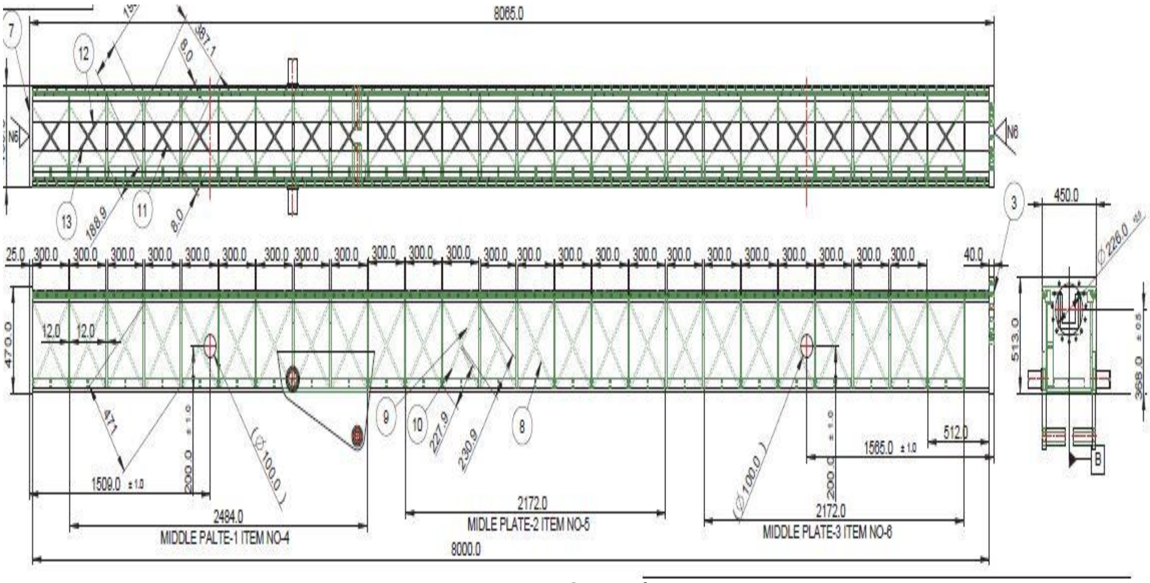


Fig. 1.3 pictorial view of new mast

Table 1 Parts description for new mast design

S.NO	DESCRIPTION	FINISH SIZE	MATERIAL	QTY
1	SIDE PLATE	8000*383*12 THK	MS	2
2	BOTTOM PLATE	8000*370*12 THK	MS	1
3	CYL MNTG PLATE	513*450*40 THK	MS	1
4	MIDDLE PLATE 1	413*359*12 THK	MS	9
5	MIDDLE PLATE 2	413*359*12 THK	MS	8
6	MIDDLE PLATE 3	413*359*12 THK	MS	8
7	MAST END PLATE	470*450*25 THK	MS	1
8	SIDE STIFFENERS - 1	471*50*12 THK	MS	50
9	SIDE STIFFENERS - 2	231*50*12 THK	MS	50
10	SIDE STIFFENERS - 3	227.50*50*12 THK	MS	50
11	BTM STIFFENERS -1	387*50*8 THK	MS	50
12	BTM STIFFENERS -2	189*50*8 THK	MS	50
13	BTM STIFFENERS -3	190*50*8 THK	MS	50
14	GUIDE BLOCK	45*47*8000 THK	EN-8	2

III. Analysis of Mast structure

There are many conditions to be considered which influence the failures of mast structure. The main cause for failure of mast is due to drill rod load. Maximum stress on the mast structure depends on the number of drill rods inserted to drill the earth crust, where as each drill rod will have a length of 15feet and mass of 103 kg.

As maximum stress on the mast structure depends on the number of drill rods inserted to drill the earth crust, the number of drill rods inserted increases stress intensity on mast increases gradually.

In present work, a typical finite element (FE) model of a MAST MEMBER was developed and analysis was carried out using solid works. Stress analysis is conducted on existing mast design and modified design under different loading conditions using solid works. Practically it is observed that the load on the mast varies and it is ranging from 12 to 20 tons. However for the purpose of analysis, three (3) different loads at three different positions are considered. The load conditions are:

Lifting drill condition - Gear box at its top most height with least load where as only weight of the gear box and drill rod is acting i.e. 15 tons

Drilling condition - Gear box at mid-span with transmission of power to drill rod i.e. 20 tons and Maximum load condition - Gear box at maximum load and at its lowest position i.e. 25 tons.

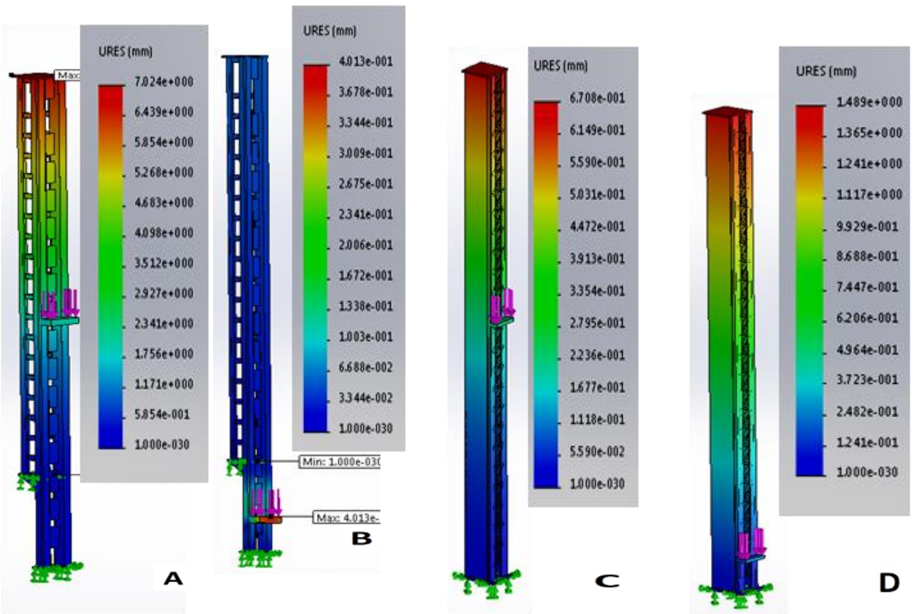
[A] Deformations and stresses under different loads

Deformation and stress analysis are done at different load conditions for old mast and new mast and are as follows.

Boundary conditions: Here the mast is assumed to be as column, where bottom end of the mast is fixed and top end of the mast is left free. Load is applied at different positions on the mast.

Old Mast: Under the load of 15 tons the maximum deflection of mast is 3.181 mm, when the load is applied at an offset distance of 320mm from top most fiber of mast member. At a load of 20 tons the maximum displacement of mast is 7.02 mm, when the load is applied at offset distance of 3900 mm from top most fiber of mast member. Finally, at the load of 25 tons the maximum displacement of mast is 0.4013mm; when the load is applied at offset distance of 525 mm from bottom most fiber of mast member.

Similarly, for modified mast design under the load of 20 tons the maximum displacement of mast is 6.708 mm and for 25 tons loads it is 1.489 mm.(fig 1.4)

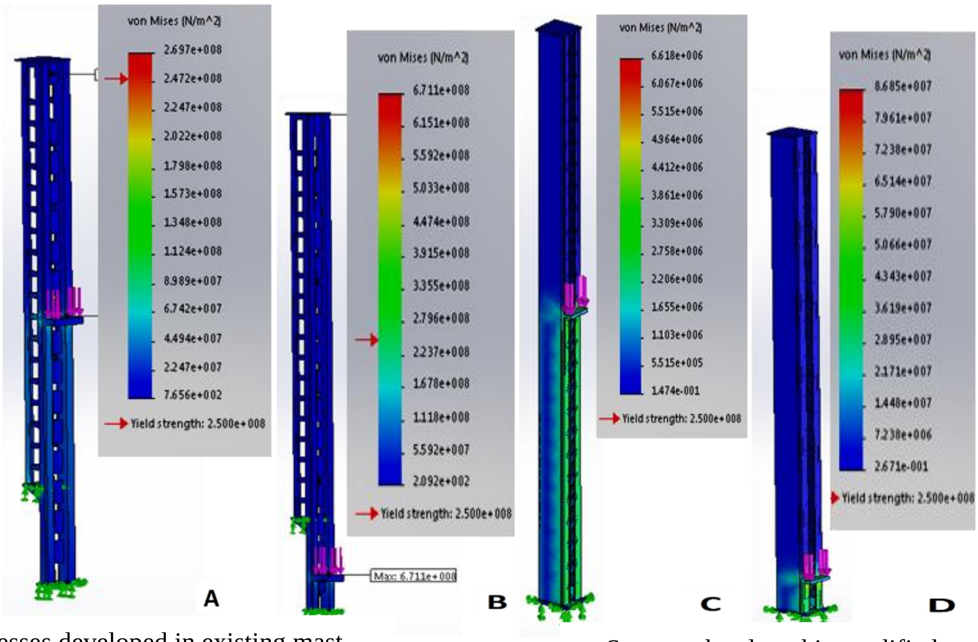


Displacement of existing mast [A] 20Tons [B] 25 Tons

Displacement of modified mast [C] 20Tons[D] 25 Tons

Fig 1.4 Displacements of existing and modified design under a load of 20 and 25 tons

In case of 20tons load, the stress on the upper mast is significantly greater than that of the lower mast, where as in case of 25tons load lower mast has greater stress intensity than upper mast. For 20 tons load stress, is equal to 235Mpa and 66.18Mpa in case of old and new designs respectively. For 25 tons load, the stress is 247.5 MPa in existing mast design and 86 Mpa in modified mast design.(Fig 1.5)



Stresses developed in existing mast
[A] 20Tons [B] 25 Tons

Stresses developed in modified mast
[C] 20Tons [D] 25 Tons

Fig 1.5 Stresses developed in existing and modified design under 20tons and 25 tons load

[B]Theoretical calculations

Stresses and deflections in old and new design mast are also calculated theoretically for 20 tons and 25 tons load with the help of the following equations.

Moment of inertia $I = [\frac{bd^3}{12} - \frac{2\ b1*d1^3}{12} - \frac{2b2*d2^3}{12} - \frac{b3*d3^3}{12} - \frac{2*b4*d4^3}{12} - \frac{2*b5*d5^3}{12}]$[3]

R=radius of gyration= $\sqrt{\frac{Ixx}{A}}$ = 136.07 mm

S.R = slender ratio = Leq / r = 117.57

Cc = $\sqrt{\frac{2*\pi^2*E}{Yieldstress}}$ = 128.15

Cc = Critical factor, F.s = Factor of safety = $[1- [\frac{(s.r)^2}{2*(Cc)^2}]*[\frac{Yeildstress}{Nominalstress}]]$ = 1.14

$$\sigma_{max} = \frac{P}{A} + \frac{P*e}{z} * \sec(\frac{Le}{2}\sqrt{\frac{P}{EI}})$$

$$V_{max} = e * [\sec\left(\frac{Le}{2}\sqrt{\frac{P}{EI}}\right) - 1]$$

For old mast design: Maximum stress at 20 tons load is 106.5 Mpa and for 25 tons load the maximum stress is 132.15 Mpa. The deflection at 20 tons load is 5.58 mm, and for 25 tons load is 0.42 mm.

For modified mast design: Maximum stress at 20 tons load is 58.760 Mpaand for 25 tons load the maximum stress is 73.45 Mpa. The deflection at 20 tons load is 4.10 mm, and for 25 tons load is2.20 mm.

The displacement and stress values resulted from theoretical calculations are compared with the values obtained from FEM software values and are shown in table 2. From the table 2 it is found that the theoretical and FEM software values are approximately equal with respect to displacement and stresses.

Table 2 Comparison of theoretical and FEM software values

	Theoretical values	Ansys values
OLD MAST		
Displacement		
20 tons	5.58 mm	7.02 mm
25 tons	0.42 mm	0.4013 mm
Stress		
20 tons	106.5MPA	235.5 MPA
25 tons	132.5MPA	247.5 MPA
New design		
Displacement		
20 tons	4.10mm	6.7 mm
25 tons	2.20mm	1.48 mm
Stress		
20 tons	58.76MPA	66.18 MPA
25 tons	73.45 MPA	86 MPA

All the above values from table 2 are under safe working conditions.

IV. Conclusion

By using the 3-D finite element method, the stress and displacement of the mast under different drilling conditions have been investigated. The results reveal that the stresses mainly concentrated in lower mast in working conditions. The maximum stress and displacement values are reduced in modified mast design.
Hence it is concluded that the modified design (after replacement of rectangular hollow rods by ‘x’ members and ‘C’ frames replaced by rectangular long rods) has enough strength to support the drilling rig compare to old design.

V. References

[1] Jian Qin, Yimin Ma, Yan Ding, Guangrui Tang, Yu Sun, and Jieming Bai. In this paper, according to the mast structure characteristics and force condition, the stress distribution of the mast is obtained based on the simplified finite element model of mast, and the static strength under lifting drill and drilling conditions is analyzed.

[2] In luo jua.b, li liang -ganga’yi weiali’xiaoliangb presents working performance analysis and optimization design of rotary drilling rig under a hard formation conditions. In this paper, these existing problems for power head, drill pipe etc. Of working device of rotary drilling rig were analyzed.

[3] Pritibala B. Pekhale1, Prof. P.V. Deshmukh. The main objective of the paper is to minimize the tower deformation by structural optimization to control its functional operation and improve its performance, and to upgrade the derrick structure for easy manufacturing and to define the test procedure for validation of new derrick structure.

[4] L. Brubak , j. Hellesland , e. Steen stated in their research paper present and validate an approximate, semi-analytical computational model for such plates subjected to in - plane loading for that estimation of the buckling strength is made using the von mises’ yield criterion for the membrane stress as the strength limit.

[5] J. Gregory Nutter, Reg Layden,Cody Grasmick,Don Eubank, “Innovative Drilling Rig Delivers Increased Drilling Performance in Permian Basin”, IADC World Drilling Conference,2009.

[6] Luo ju,Li Liang - gang, Yi wei,Li Xiaoliang, “Working Performance Analysis and Optimization Design of Rotary Drilling Rig under on Hard Formation Conditions”,Elsevier Procedia Engineering 73 (2014).

[7] Stipica Novoselac, Todor Ergić, Pavo Baličević, “Linear and non - linear buckling and post buckling analysis of a bar with the influence of imperfections”, Tehnički vjesnik 19, (2012), 695 – 701 Vol – 3 Issue – 6 2017 IJARIIE - ISSN(O) – 2395 – 4396 7182 www.ijariie.com 1655 .

[8] Song Jong Pham, Cao Hung Pham & Gregory Hancock, “Numerical Simulation of Cold - Formed Channel Sections with Intermediate Web Stiffeners Undergoing Pure Shear”, University of Sydney, School of civil engineering, Research Report No R930, July 2012.