Design and Stress Analysis 0f Various Cross Section of Hook

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Abstract: Crane hook is a curved beam. Hooks are employed in heavy industries to carry tones of loads safely. These hooks have a big role to play as far as the safety of crane loaded is concerned. With more and more industrialization the rate at which these hooks are forged are increasing. This project is carried out to study the stress variation in crane hooks for different cross sections such as circular and square and for different radii of curvature as well, experimentally and theoretically. Experimentally, the loads are obtained for different crane hooks for 5mm elongation on UTM (Universal Testing Machine). And then the stresses induced in the crane hooks against the loads obtained from experimentation are also calculated theoretically using curved beam theory. Then the different crane hooks are modeled in Pro-E 2.0 and then analysis is done for modeled hooks using ANSYS 12.1 to find the stresses induced in the hooks. Then the stresses evaluated from curved beam theory and ANSYS12.1 are compared and conclusions are made

Keywords: crane hook, Pro-e, ANSYS12.1, curved beam theory, Universal Testing Machine.

I. INTRODUCTION

A hook block is an assembly to which the hook of a hoist or crane is attached, it typically consists of a steel enclosure housing a number of sheaves or pulleys that carry the ropes or chains that facilitate the lifting of a load. Although this sounds unnecessarily complex, it would be impossible for a crane or hoist to operate efficiently and safely if the crane hook was simply attached directly to a rope and then raised or lowered by the cranes boom and winch system. A hook block allows for a considerable amount of flexibility and safety in lifting operations as opposed to a direct connection. One of the most important functions of any hook block is facilitating of a free turning or rotating hook arrangement. When loads are lifted, it is often necessary to turn the load to position it in a new location or to avoid striking obstructions. A crane hook attached directly to the hoist ropes would cause the ropes to twist if the load was turned from its original orientation. This would have a number of undesirable effects such as over-stressing the ropes and boom pulleys, creating an unbalanced load, and causing the load to swing back in an uncontrolled fashion when released. A hook block allows loads to be freely rotated without changing the orientation of the hoist ropes. To minimize the failure of crane hook, the stress induced in it must be studied. A crane is subjected to continuous loading and unloading. This may causes fatigue failure[6,7,8] of the crane hook but the load cycle frequency is very low. If a crack is developed in the crane hook, mainly at stress concentration areas, it can cause fracture of the hook and lead to serious accidents. In ductile fracture, the crack propagates continuously and is more easily detectable and hence preferred over brittle fracture. In brittle fracture, there is sudden propagation of the crack and the hook fails suddenly [9,10]. This type of fracture is very dangerous as it is difficult to detect. Strain aging embrittlement due to continuous loading and unloading changes the microstructure. Bending stresses combined with tensile stresses, weakening of hook due to wear, plastic deformation due to overloading, and

excessive
Thermal stresses are some of the other reasons for failure. Hence continuous use of crane hooks may increase the magnitude of these stresses and ultimately result in failure of the hook.

II. CURVED BEAM THEORY

The flexural formula is accurate for symmetrically loaded straight beams subjected to pure bending. It is also generally used to obtain approximate results for the design of straight beams subjected to shear loads, when the plane of loads, when the plane of loads contains the shear centre and is parallel to a principal axis of the beam; the resulting errors in the computed stresses are small enough to be negligible as long as the beam length is at least five times the maximum cross-sectional dimension. In addition, the flexure formula is reasonably accurate I the analysis of curved beams for which the radius of curvature is more than five times the beam depth. However, for curved beams the error in the computed stress predicted by the flexure formula increases as the ratio of the radius of curvature of the beam to the depth of the beam decreases in magnitude. Hence, as this ratio decreases, one needs a more accurate solution for curved beams. Timoshenko and Goodier (1970) have presented a solution based on the theory of elasticity for the linear elastic behavior of curved beams of rectangular cross sections for the loading. They used polar coordinates and obtained relations for the radial stress (σ_{rr}), the circumferential stress $(\sigma_{\theta\theta})$, and the shear stress $(\sigma_{r\theta})$.However, most curved beams do not have rectangular cross sections. Therefore, in the following we present an approximate curved beam solution that is generally applicable to all symmetrical cross sections.

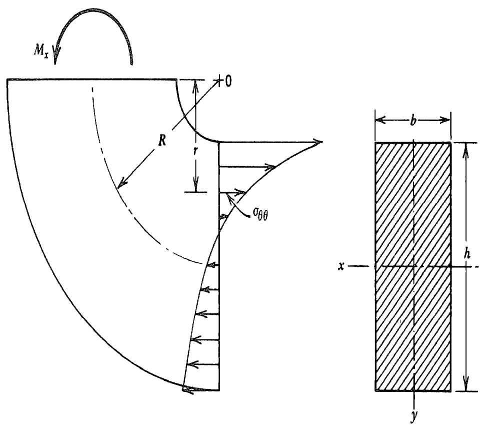

Fig1: Circumferential stress distribution in a rectangular section curved Beam

2.1. CIRCUMFERENTIAL STRESSES IN A CURVED BEAM

The circumferential stress[11] distribution for the curved beam(fig:1) is obtained by substituting to obtain the curved beam formula.

$$\sigma_{\theta\theta} = \frac{N}{A} + \frac{M_x(A - rA_m)}{Ar(RA_m - A)}$$

2.2 RADIAL STRESSES IN CURVED BEAMS

The radial stresses [11] stress distribution for the curved beam is obtained by substituting to obtain the curved beam formula.

$$\sigma_{rr} = \frac{AA'_m - A'A_m}{trA(RA_m - A)} M_x$$

III. METHODOLOGY

Three mild steel Circular rods of 12mm diameter and 20cm, 22cm and 25cm lengths are heated up to red hot condition (re-crystallization temp) and these rods are bent into shape of hook with 3cm, 4cm and 5cm radii of curvature respectively(fig:2). Similarly, Three mild steel square rods of 12mm side and 20cm, 22cm and 25cm lengths are heated up to red hot condition (re-crystallization temp) and these rods are also bent into shape of hook with 3cm, 4cm and 5cm radii of curvature respectively shown below(fig:3)

Fig 2: Hooks of circular c/s of 5cm, 4cm and 3cm radii of curvature.

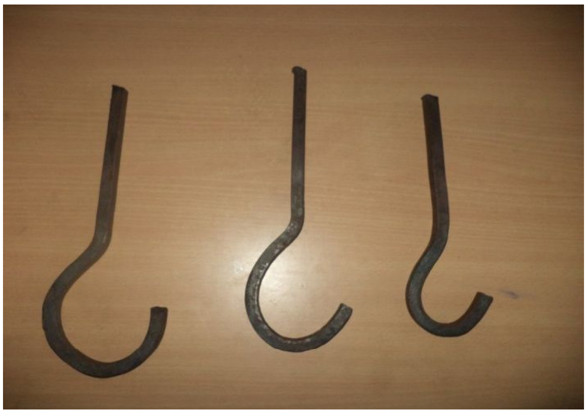

Fig 3: Hooks of square c/s of 5cm, 4cm and 3cm radii of curvature.

3.1.PREPARATION OF EYE BOLT

An Eye-Bolt of 16mm diameter with 15mm eye diameter is prepared for loading the crane hooks on UTM. It is made by hot forging method as that of hooks. Initially the rod is heated up to re-crystallization temperature i.e, red hot condition then the rod is shaped like Eye-Bolt by using anvil and forging tools and the diameter of the rod is 16mm (fig:4) and this rod is used for support the hook in the UTM machine.

Fig 4: Eye-Bolt

3.2 EXPERIMENTAL STRESSES USING CURVED BEAM THEORY

By applying the load gradually on hooks on UTM up to 5mm displacement, the following graphs (fig: 5 to 10) are obtained from the computer which is interfaced with the UTM

Crane hooks of circular cross section:

Load *vs* Elongation

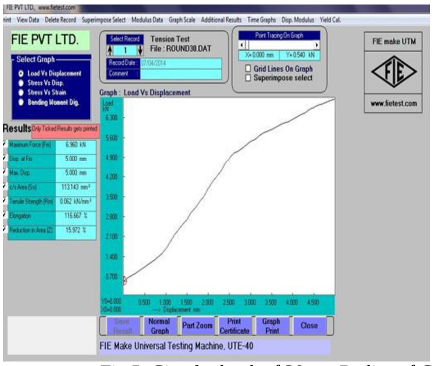

Fig 5: Circular hook of 30mm Radius of Curvature

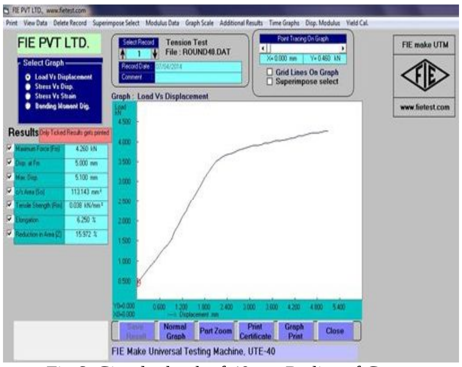

Fig 6: Circular hook of 40mm Radius of Curvature

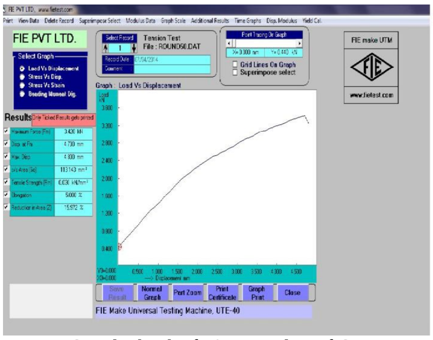

Fig 7: Circular hook of 50mm Radius of Curvature

Crane hooks of square cross section

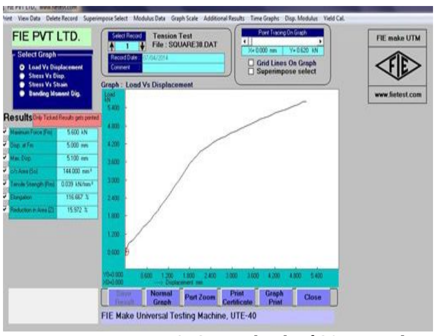

Fig 8: Square hook of 30mm Radius of Curvature

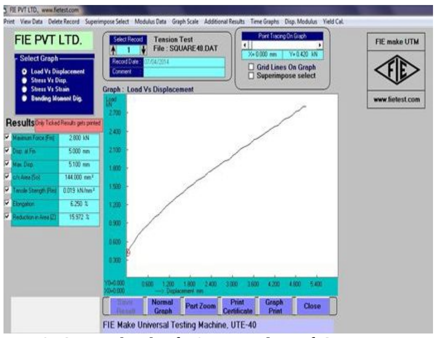

Fig 9: Square hook of 40mm Radius of Curvature

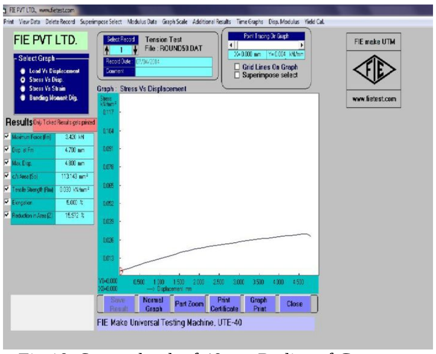

Fig 10: Square hook of 40mm Radius of Curvature

The loads to which crane hooks withstand for 5mm elongation[4]

Sl.no	Cross-section of hook	Radius of curvature	Load (kN)
1	Circular of 12 dia	30	6.96
		40	4.26
		50	3.42
2	Square of 12 side	30	5.6
		40	2.8
		50	2.16

Table 1: Comparisons of Round and Square Rods in UTM Machine

3.4 STRESS CALCULATIONS USING CURVED BEAM THEORY

The crane hooks are tested on UTM for 5mm deformation. But actually the crane hooks are designed for 0.5mm deflection[1,2,3,5] against the load applied. Otherwise the load carrying capacity of a crane hook is the load at which it undergoes 0.5 to 1mm.The load carrying capacity of crane hooks for 0.5mm deformation is given below

S no	Cross-section of hook	Radius of curvature (mm)	Load (kN)
1	Circular of 12 dia	30	1.15
		40	0.95
		50	0.9
2	Square of 12 side	30	1.1
		40	0.9
		50	0.8

Table 2: Theoretical values Of Circular and Square Rods

Crane Hook of Circular Cross Section:

Area of the round rod (A) = $\pi \times b^2$

$A_{m=}$= $2\pi\,(R - \sqrt{(R^2 - b^2)})$ for circle

M_x=P.R

$$\text{Normal stress } (\sigma_{\theta\theta}) = \frac{P}{A} + \frac{M_X(A - rA_m)}{Ar(RA_m - A)}$$

Crane Hook of Square Cross Section:

Area of square rod (A) = b(c-a)

$A_m = b \ln \frac{c}{a}$

Radius (R) = $\frac{a+c}{2}$, M_x=P.R

$$\text{Normal stress } (\sigma_{\theta\theta}) = \frac{P}{A} + \frac{M_X(A - rA_m)}{Ar(RA_m - A)}$$

3.5 THEORETICAL STRESSES USING FINITE ELEMENT ANALYSIS (ANSYS 12.1)

MODELING IN PRO-E:

The Hooks of Circular and Square cross sections of radius of curvature 30,40,50 mm are designed in the software of Pro-E 2.0 (fig:11 to 15)

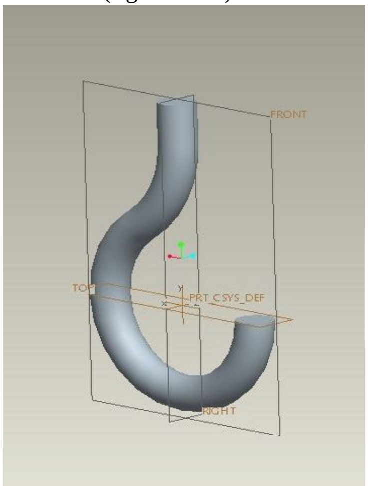

FIG 11: PRO-E Model of Crane hook of circular cross section30mm Radius of Curvature

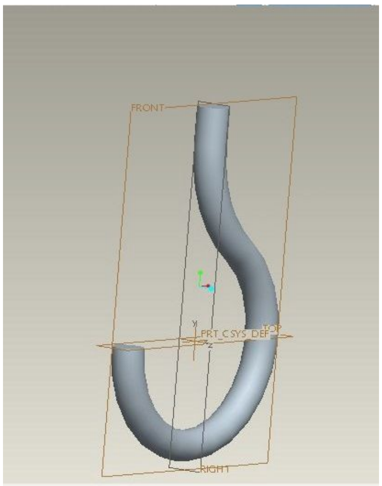

Fig 12: PRO-E Model of Crane hook of circular cross section 40mm Radius of Curvature

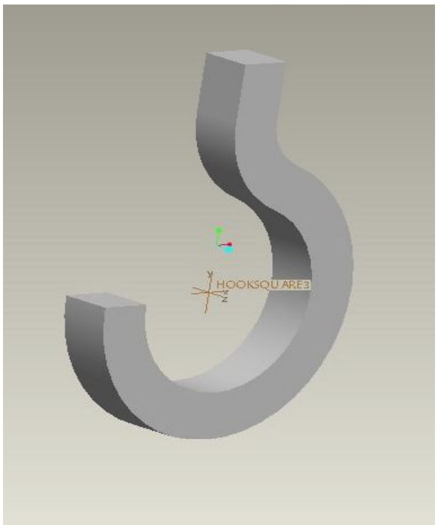

Fig 13: PRO-E Model of Crane hook of Square 30 mm cross section

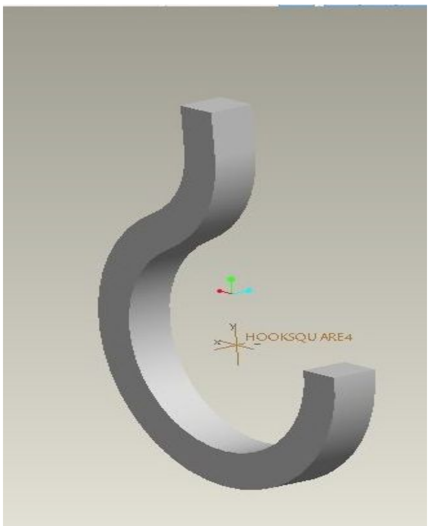

Fig 14: PRO-E Model of Crane hook of Square 40 mm cross section

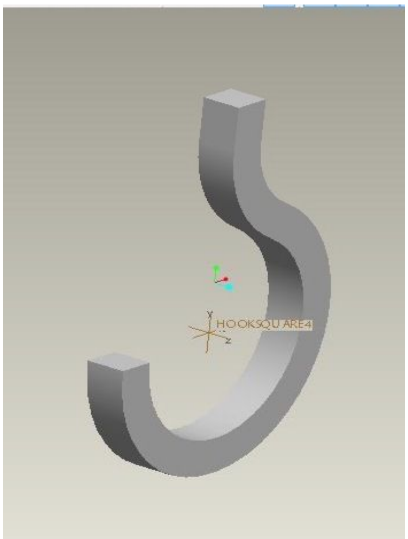

Fig 15: PRO-E Model of Crane hook of Square 50 mm cross section

ANALYSIS IN ANSYS 12.1:

The crane hooks are loaded as per the loads mentioned in the table 1 for square cross section and table 2 for circular cross section hooks

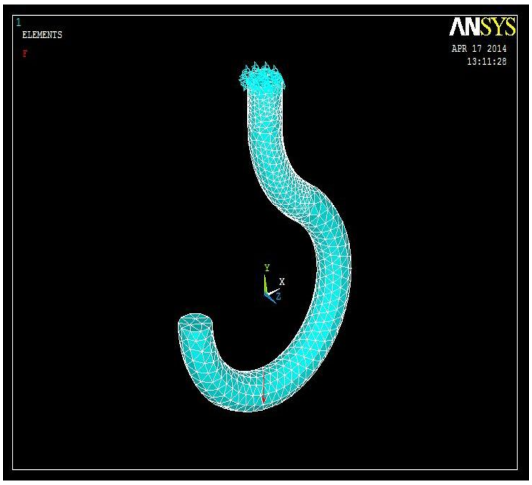

Fig 16: Crane hook after Meshing and Loading

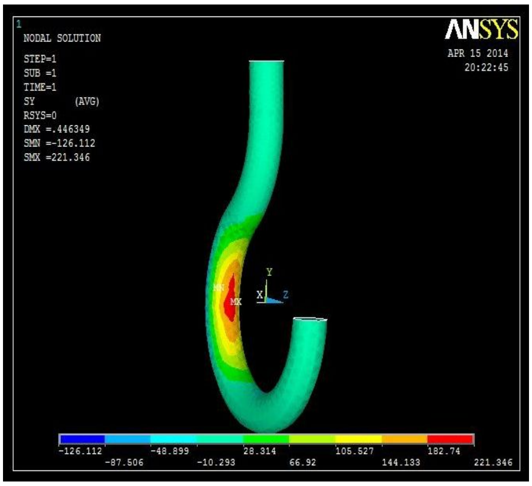

Fig 17: Stress distribution in 30mm radius of curvature

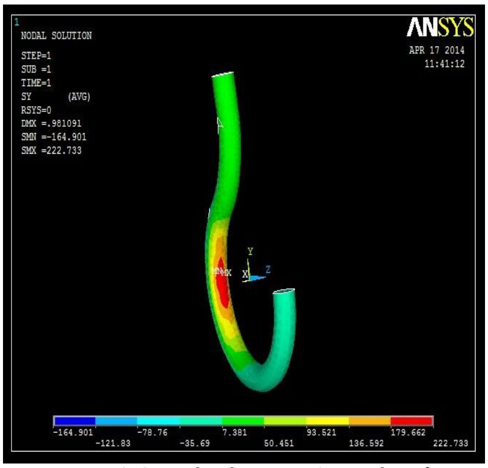

Fig 18: Stress distribution in 40mm radius of curvature

Fig 19: Stress distribution in 50mm radius of curvature

For crane hook of Square cross section

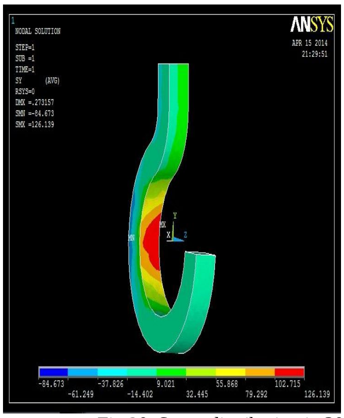

Fig 20: Stress distribution in 30mm radius of curvature

Fig 21: Stress distribution in 40mm radius of curvature

Fig 22: Stress distribution in 50mm radius of curvature

IV. RESULTS

The comparison of the theoretical stress and the experimental stress values for different radius of curvature of 30mm 40mm and 50mm rods. The stress values are tabulated below in table -3 for circular and in table-4 for square cross sections.

For circular cross section:

Table 3: Comparison of Theoretical and Practical circular rod

S.No	Radius of Curvature (mm)	Experimental stresses (N/m²)	Theoretical stresses (N/m²)
1	30	290	221.346
2	40	300.63	222.733
3	50	360	246.625

For Square cross section:

Table 4: Comparisons of Theoretical and Practical stresses for stresses for square rod

S.No	Radius of Curvature (mm)	Experimental stress (N/m²)	Theoretical stresses (N/m²)
1	30	165.16	126.139
2	40	167.08	123.734
3	50	179.10	127.596

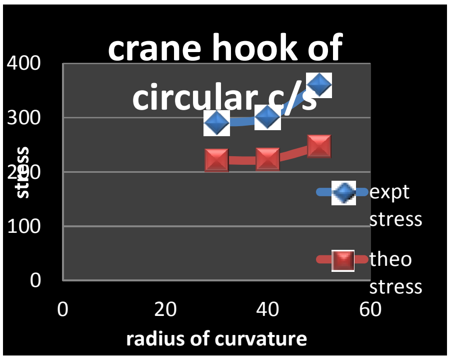

Fig 23: Stress distribution comparison for circular c/s hook between experiments and theoretical results

Fig 24: Stress distribution comparison for Square c/s hook between experiments and theoretical results

V. CONCUSIONS

It is observed from above tables and graphs that the Experimental stress values are greater than Theoretical stress values for all the hooks. The reason may be in ANSYS the crane hook is assumed as linear, isotropic and prismatic, but actually, the hooks prepared may not be linear, Isotropic and prismatic therefore the stress values induced in Experiments all are greater

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