Design and Stress Behaviour Analysis of Cab Tilting Arrangement of Crane Cab assembly

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Abstract- Crane industries are very innovative and advance in engineering development. This work gives new tilting pivot assembly for CAB to be installed in crawler type mobile crane. Cab is having multiple loads for operating it from one fixed location to the end of Boom and jibs. So tilting and turning joint must be capable to hold the all loads coming on it, so pivot pin joint is designed here with unique rod insertion technique. To accommodate and balance forces on two pivots called tilting pivots.

Keywords: Crane cab, CAE, Joints.

1. INTRODUCTION
Work is in the fabricated arrangement of tilting cab with 30 degree positions maximum. The design of the cabin to a major extent should be driven by the need for optimum field visibility where there is an unrestricted and reliable view of the ground situation and working surroundings. Ergonomic guidelines require that a machine operator should have a free view of the operating zone without have to adjust posture. The guideline states that the operator should not have to turn their more than 30˚ to either side and that head should not tilt more than 5˚ up and 25˚ down maintain comfort. Occasional head movements of 50˚ to the sides and 40˚ up and 50˚ down are acceptable. Seats, windows and cabin features should be designed with these guidelines in perspective. The operator should inherit a clear view as possible free from large blind areas caused from window frames and obstructions due to the cabin structure such as cabin pillars. Tilting is done by hydraulics arrangement for making smooth and powerful movement. Tilting loads are to be considered like self weight of the cab fabricated body, operator’s weight, internal consoles and dashboards, glass panel work etc. Tilting is exist in crane cab for direct visibility of lifting object when it catches at different angle of jib or boom so for operator it’s very important to control slewing and tilting of boom by in hand control unit its possible only when the object is visible.

2. LITERATURE REVIEW
D. Chen and S. Cheng have made the analysis of the stress distribution in adhesive bonded tubular lap joints subjected to torsion. The analysis was based on the elasticity theory in conjunction with variational principle of complimentary energy, with two adhered may be having different materials and different thickness. The closed form solution so obtained was used to determine the stress intensities in adhesive layer and stress concentration factor.

Kozo Ikegami make the investigation of the strength of adhesive shaft joint under combined axial tensile and torsion load analytically and experimentally to study effect of overlap length and cross sectional ratio. The joint considered was consisting of two steel shafts and a coupling bonded with adhesive. The stress strain distributions were computed by the elastic Finite Element Method with the assumption of symmetric three dimensional conditions. For strength evaluation Von-Moses conditions were applied to the outer and inner adherents and to the adhesive layer.

2.1 Hydraulic Cab Tilt Systems

Fig.1 Hydraulic cab tilt system

Power-Packer’s complete range of cab tilt systems and hood assist units make it possible for us to design a cab tilting system that is perfectly matched to your
application. Combining our hydraulic cylinders with vertical visibility and less neck strain during certain any of our hydraulic pumps whether electric, air or work applications, such as setting cross arms on manually powered – we can offer you a better fitting system which results in a better performing system. Additionally, the tilt cab is located forward of the centerline of rotation, providing better horizontal visibility when rotating the crane clockwise. It’s a first boom truck crane manufacture to offer a tilt cab option.

2.1 Features
- Internal spring mechanism in hood assists units.
- Self-contained design.
- Cab Tilt systems consist of a very simple design - cylinder, pump and latch make a fully functioning system.

2.2 Benefits
- Many customization options available – choose from electric, air, or manually powered pump and we can design the system for you.
- Many standard options available to create the best fit possible.
- Enhance safety by allowing for easy access to any repairs on job site.
- Hood assist systems substantially reduce effort required to open and close hoods.
- Internal spring mechanism in hood assist units holds the hood in open position even in wind or uneven terrain.

3. PROBLEM IDENTIFICATION
Existing method to tilt it is by hydraulic cylinder it lifts the cab through hinges and main issues here is to maintenance multiple joints and big hydraulic arrangement, we need to replace it by single pivot rod connection. Metal to metal contact joint may form extra tightening and maintenance issue in joint parameters here we are planning to make bushing tube between holder and long pin.

4. OBJECTIVES
- To design new tilting arrangement with strength analysis for crane cab.
- To validated the new joint with strength analysis with examining real life boundary conditions.

4.1 The work includes
- Redesign of lifting bracket pivot assembly
- Design of pivot rod between superstructure body and the cab
- Design of weldment
- Stress analysis of pivot joint
- Stress analysis of structure
- Validation of the system using ansys workbench

4.2 Outcomes
The new cab allows the operator to adjust the angle of the cab from 0 degrees to 20 degrees above horizontal, with hydraulic power, the company said. The new tilt cab will allow operators to have better visibility and less neck strain during certain work applications.

4.3 Proposed Method of work
1. Design of pivot joint, development will be done once design get finalised.
2. Structural calculations and deflection analysis.
3. CAE on Ansys
4. FEA approach to make feasible working conditions.

5. DESIGN PARAMETER

5.1 Design Factors
Design factors are essentially “safety factors” that allow us to design safe, reliable sheet metal components. Each operator may have his own set of design factors, based on his experience, and the condition of the raw material used.
- Worst Possible Conditions
- Effect of Axial Tension on Collapse Strength
- Design for Burst, Collapse and Tension

Fig.2 coupling joint behavior in frames component

5.2 Sheet metal fabricated components
Bending of plate components, or plate bending, refers to the deflection of a plate perpendicular to the plane of the plate under the action of external forces and moments. The amount of deflection can be determined by solving the differential equations of an appropriate plate theory. The stresses in the plate can be calculated from these deflections. Once the stresses are known, failure theories can be used to determine whether a plate will fail under a given load.
Uniform load, edge simply supported.
Concentrated load at centre, edge simply supported.

\[ y_m = \frac{0.0284 \, pb^4}{Et^3[1,056/b(a)^5 + 1]} \]  

At centre

Concentrated load at centre, edge clamped.

If \( e \) is small then use \( e' \) as calculated below:

\[ e' = \left( \sqrt{1.8e^2 + 1} \right) - 0.675t \]  

if \( e < 0.5t \) else use \( e' = e \)

\[ \sigma_m = \frac{1.5P}{\pi t^2} (1 + \nu) \ln \left( \frac{2b}{\pi t} \right) + k_2 \]  

At centre

\[ \sigma_m = k_2 \frac{P}{t^2} \]  

Middle of edge a

\[ y_m = k_1 \frac{pb^2}{Et^3} \]  

At centre

5.3 Optimization stages

Material selection on raw material availability, strength behavior analysis and accordingly material and sizes to be finalized. Size, weight reduction will be done once higher side of strength we can get in mechanical components. Multiple joint options and metal flame cut designs to be made for option and optimized solution will be finalized.

5.4 CAD IMPLEMENTATION

5.4.1 Design implementation

1. Design of pivot joint, development will be done once design get finalised.
2. Structural calculations and deflection analysis.
3. CAE on ansys
4. FEA approach to make feasible working conditions.

5.4.2 Design strategy of joint

![Fig.3 CAB tilting joint Design](image)
Fig. 4 Tilting Rod

Fig. 5 Rod covering bushing pipe assembly

5.5 Formulation of cab holder
Considering the bracket as a cantilever beam of rectangular cross section as shown in fig.
As the total load acting is approximate 1070 N.
Hence, Load per unit length is 10.7 N/mm

The load is acting on entire length.

From equation (i),
\[
\frac{M}{I} = \frac{\sigma}{y}
\]

Moment of Inertia (I)
\[
I = \frac{bd^2}{12}
\]
\[
I = \frac{30 \times 20^2}{12}
\]
\[
I = 20000 \text{ mm}^4
\]
\[
y = 20/2
\]
\[
y = 10 \text{ mm}
\]
From equation (i),
\[
\frac{M}{I} = \frac{\sigma}{y}
\]
\[
\frac{53500}{20000} = \frac{\sigma}{10}
\]
σ = 26.75 N/mm²

Hence maximum bending stress developed is 26.75 MPa.

Maximum Deflection

\[ \sigma = \frac{P l^2}{8EI} \]

Where,

\[ E = \text{Modulus of Elasticity} = 2 \times 10^5 \text{ N/mm}^2 \]

\[ \sigma = \frac{8 \times 2 \times 10^3 \times 20000}{10.7 \times 10^5} \]

\[ \sigma = 0.0033 \text{ mm} \]

Hence Maximum Deflection is 0.0033 mm.

6. CAE Validation

Meshing details

214 kg load is coming vertically, 114 kg fabricated and other modules weight and 100 kg of operator’s weight.

So load = 2140 N

On one side holder bracket consider half load as two holder brackets we have used as shown

Deformation 0.02 mm
Stress we got 21.42 mpa

6.1 Material selection
Material to be used is AISI316 as cab can work in fluid medium so other parameters of supporting machineries are also get contact with wet medium hence here anticorrosive material to be applied everywhere. Also ergonomically it should be usable so SS medium is only the option. AISI316 grade of stainless steel

Material selected

<table>
<thead>
<tr>
<th>Grade</th>
<th>Tensile strength (MPa)</th>
<th>Ultimate strength (MPa)</th>
<th>Modulus of elasticity (GPa)</th>
<th>Elongation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stainless</td>
<td>304 (1.4301)</td>
<td>520</td>
<td>200</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>316 (1.4401)</td>
<td>520</td>
<td>200</td>
<td>40</td>
</tr>
<tr>
<td>Carbon steel</td>
<td>S275</td>
<td>410</td>
<td>205</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>S355</td>
<td>490</td>
<td>205</td>
<td>22</td>
</tr>
</tbody>
</table>

Material selected SS 316
No limitations on thickness in relation to brittle fracture apply to stainless steel; the limitations for carbon steel are not applicable due to the superior toughness of stainless steel. The austenitic stainless steel grades do not show a ductile-brittle impact strength transition as temperatures are lowered. Stainless steels can absorb considerable impact without fracturing due to their excellent ductility

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