Failure Analysis & Redesign of Boom under Static Analysis of Self-Propelled Surface Drilling Machine

Gajendra Patil  
Department of Mechanical Engineering  
S.S.G.B. College of Engineering & Technology, Bhusawal, Maharashtra, India

Prof. A.V. Patil  
Department of Mechanical Engineering  
S.S.G.B. College of Engineering & Technology, Bhusawal, Maharashtra, India

Abstract- A surface Drilling Rig having a Boom and feed mechanism to support rotation head which used for generate required torque for drilling hole in mines. The main purpose of Boom design is to sustain the weight of Drill Guide assembly of approximate 3 ton. The Boom has a box structure with additional lower support by various cylinders whose function is to apply motion to the Boom at various positions to capture drilling area. The drawback of this design is that the boom is designed with single plate thickness which results in the eccentric action of forces whereby the boom bents upwards in the vertical plane. The results of the strength calculations confirmed that stress concentrations occur in the fracture location and the standard allowable stress (based on the welded joint notch class, the level of mean stress and the stress change range) for changing position at extreme downside.

Keywords – Boom Design, Surface mining boom,
**Input Material sizes & weight:**

Boom tube size - 200x200x12 th
Weight of feed beam assembly - 3105 Kg=30460.05 N, Weight of boom assembly - 702 Kg=6886.2 N
Calculating section modulus (Z) for boom [figure2]
Sq. tube outer side, a = 200 mm, Thickness = 12 mm
Sq. tube inner side, b = 176 mm
Moment of inertia = \((a^4-b^4)/12\) = 53373952 mm\(^4\)
Z for section of boom= \((a^4-b^4)/6a\) = 533739.52 mm\(^3\)
A. Case 1: Boom is in Horizontal condition & drill guide at 22deg to vertical (Figure3)

Hence by Calculations, Moment of Inertia, $M_x = 93123364.437 \text{ Nmm}$

$Z$ for combine section of boom at $X = 533739.52 \text{ mm}^3$

Hence bending stress induced in the boom = $M_x / Z = 174.47 \text{ N/mm}^2$

**Hence maximum induced bending stress at case 1 is 174.47 N/mm²**

B. Case 2: Boom is in Horizontal condition & drill guide in horizontal (Figure4)

Hence by Calculations, Moment of Inertia, $M_x = -39892447.404 \text{ Nmm}$

Total Moment of inertia, $I = 53483952 \text{ mm}^4$

$Z$ for section of boom, $Z = 608908.5455 \text{ mm}^3$

Hence bending stress induced in the boom = $M_x / Z = 65.51 \text{ N/mm}^2$

**Hence maximum induced bending stress at case 2 is 65.51 N/mm²**
C. **Case 3: Calculating Stress coming on the boom when lift cylinder is actuated**

Piston dia of the cylinder = 13 cm= 130 mm
Pressure on the hydraulic line = 200 Bar= $20 \times 10^6$ N/m$^2$
Force acting when the cylinder is actuated = $P \times A = 260277.4485$ N
From Graphical Analysis for boom angle $55^\circ$, $\Phi = 30^\circ$ [Figure5]

![Figure 5 Ray Diagram of the Boom and Lift Cylinder](image)

Perpendicular distance from hinge point to line of action of force (a) = 379 mm
Moment of cylinder force acting on boom = $F \times a = 98645152.9815$ Nmm
Stress on the boom tube because of cylinder force ($S = M_{xx}/I = 162.64$ Nmm$^2$

**Hence Combined Stress induced in Boom (including all cases) = 337.1198 N/mm$^2$**

Now, Yield stress for rolled steel section FE410W = 245 Mpa
Allowable stress IS: 800 - 1984, Steel handbook = 24.5 Kg/mm$^2$ = 245 N/mm$^2$

Hence, The Total stress induced in the Boom is more than the permissible yield stress of the material without considering any factor of safety only for static load conditions. Hence it is recommended to use higher strength material or modify boom cross section for safe functioning.

**III. PROPOSED SOLUTION**

*Input Material sizes & weight:*

Boom tube size - 200x200x12 th
Weight of feed beam assembly - 3105 Kg=30460.05 N,
Weight of boom assembly - 750 Kg=6916.05 N (due to increase in weight of plates)
Calculating section modulus (Z) for boom [figure6]
Figure 6. Cross Section of Proposed Boom

Sq. tube outside, $a_1 = 200$ mm, Thickness = 12 mm, Sq. tube inner side, $b_1 = 176$ mm
Moment of inertia $I_1 = \frac{(a_1^4 - b_1^4)}{12} = 53373952$ mm$^4$
Plate 150x12, $b_2 = 12$ mm, $h_2 = 150$ mm
Hence, Moment of inertia $I_2 = 45000$ mm$^4$
Plate 150x16, $b_3 = 16$ mm, $h_2 = 150$ mm
Hence, Moment of inertia $I_3 = 60000$ mm$^4$
Total Moment of inertia $I = 53483952$ mm$^4$

Z for section of boom $= 608908.5455$ mm$^3$

Now, Calculating stress for above same cases with new Moment of Inertia & Section modulus, we get,

**Case 1: Boom is in Horizontal condition & drill guide at 22deg to vertical.**

Bending stress induced in the boom = $\frac{M_x}{Z} = 104.231$ N/mm$^2$

**Case 2: Boom is in Horizontal condition & drill guide in horizontal**

Bending stress induced in the boom = $\frac{M_x}{Z} = 65.51$ N/mm$^2$

**Case 3: Stress coming on the boom when lift cylinder is actuated**

Stress induced in boom = 162.64 N/mm$^2$

**Hence Combined Stress induced in Boom = 266.871 N/mm$^2$**

Now, Yield stress for rolled steel section FE510W = 377 Mpa
Allowable stress IS: 800 - 1984, Steel handbook = 37.7 Kg/mm$^2$=377 N/mm$^2$

Material is also changed from Fe410WA to Fe510WC which is having yield strength 37.7 Kg/mm$^2$. The Total stress induced in the Boom is less than the permissible yield stress of the material only for static load conditions. Hence Design is safe with factor of safety 1.41.
IV. CONCLUSION

Based on the results of Theoretical calculations, currently, it is concluded that the underlying causes of load substance due to increased weight of Drill mast is solved. Mainly, in the Boom critical zone it is the super positioning of influences that, more or less, has a detrimental effect on the local stress distribution: (a) influence of the support plates; and (b) influence of the proximity of the cross section affected by the load. Because of this the key idea of the Boom redesign is to dislocate the above mentioned stress concentrators in order to minimize as much as possible the detrimental effects of stress concentration super positioning. The Theoretical calculations results pointed out that the maximum stress value in the critical zone of the redesigned column head is 1.41 times lower than the permissible stress value. It is important to highlight that the reconstruction solution is designed in such a way as to be realized in field conditions.

REFERENCES