International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 • Website: www.ijfmr.com • Email: editor@ijfmr.com

Design, Analysis, and Optimization of Jib Boom Mechanism in Mobile Cranes

Yunus[1], Ali Serhat[2]

[1]Guder, Konya Technical University
[2]Ersoyoglu, Konya Technical University

Abstract:
In this paper, the construction design of the jib boom for a 100-ton capacity 8x8 mobile crane has been carried out. Numerical calculations and both static and dynamic analyses of the system using the finite element method have been performed. Based on the analysis results, necessary improvements have been applied to the model. The work presented in this publication includes optimizations of the dimensions and weight values of the jib booms in the analysis environment.

Keywords: Mobile crane, jib boom, optimisation

1. Introduction

With developments in the construction sector and the creation of large structures, the use of auxiliary tools such as tower cranes, mobile cranes, and various lifting machines has rapidly become widespread. In ports where intercontinental transportation has been carried out for centuries, the need for lifting equipment has always remained relevant. Especially in recent years, with the shift towards alternative energy sources, there has been an increasing demand for cranes with high extension reach and greater lifting capacities for the production, transportation, and installation of massive wind turbines.

To meet this demand, many manufacturing companies have been established in the crane manufacturing industry. With increasing competition, manufacturers are utilizing all available engineering and technological resources to make their products more efficient and to simultaneously reduce production costs.

The load to be lifted by a telescopic mobile crane can be moved from one location to another, considering the operating conditions of the nested telescopic booms. The movement of these nested telescopic booms is achieved through an extension cylinder and a pulley-rope system. This extension system is most efficient when used with up to three telescopic booms. In cranes with more than three telescopic booms, the rope-pulley system loses reliability under the load. To meet the needs of lifting over longer distances, having a higher number of telescopic booms requires a different method for the extension system. The telescopic mobile crane currently being produced features one telescopic main boom and five telescopic booms, with the extension system implemented using a lock mechanism telescopic cylinder. (2)

The schematic design of the 100-ton capacity telescopic mobile crane is shown in Figure 1. Based on this basic model structure, analytical calculations have been performed. The designed model underwent static and dynamic analyses using the finite element method. The MSC SimXpert software was used for the finite element analysis.

International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

1. 1.Jib boom
2. Chassis
3. Upright boom (or Mast)
4. Counterweight
5. Telescopic boom
6. Lifting cylinder

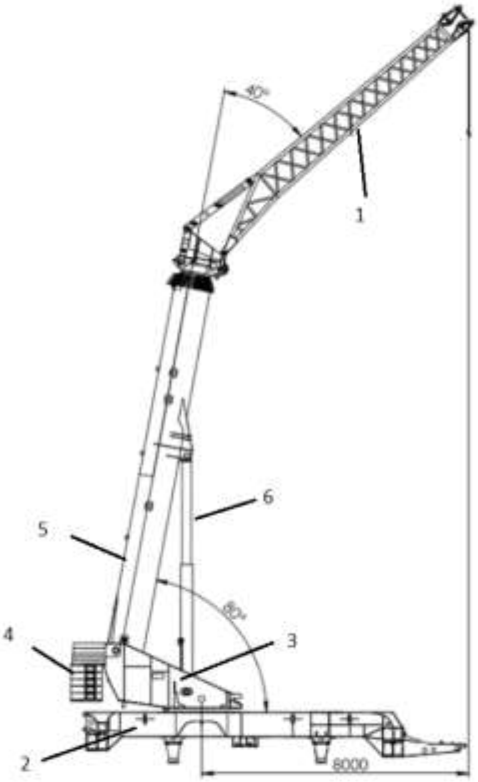

Figure 1. Telescopic Mobile Crane

The designed jib boom has a length of 10 meters and three positions: 0°, 20°, and 40°. The load capacity in the critically considered 40° position is 9.5 tons. The system consists of 1 pulley and 2 ropes. (6)

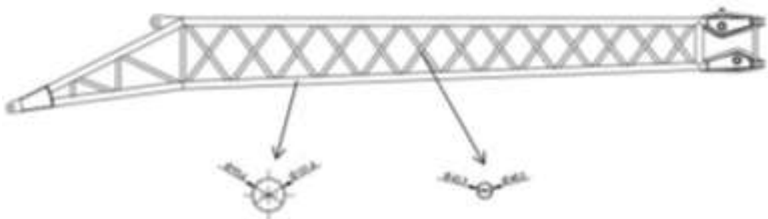

Figure 2. Pipe Cross-Sections of the Jib Boom

The jib boom can be used as 10 meters, or with the addition of a second jib boom, it can extend to 19 meters. Additionally, the second jib boom has three positions: 0°, 20°, and 40°. In the critically considered 40° position, the load at the end is taken as Fj2 = 39,000 N (3.9 tons).

International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

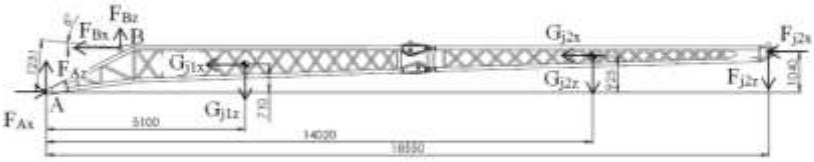

Figure 3. Free Body Diagram of the Complete Jib Booms

2. Static Analysis of the Jib Booms

The fundamental idea behind the finite element method is to replace a complex problem with an equivalent but simpler problem to find a solution. Since a different problem is substituted for the real problem, the results obtained are generally not exact but approximate. With the help of current mathematical methods and computer programs, it is possible to achieve satisfactory approximations for almost any problem using the finite element method. (3) By employing the finite element method, static solutions were obtained for the jib booms under different loading conditions, and stress values were determined.

Booms are subjected to bending, compression, and shear stresses under load. In crane calculations, the applied load is taken as 1.25 times the rated capacity. (4)

The critical positions for the 1st and 2nd jib booms are at the 40° position, so the analyses were performed for this configuration. The load capacity at this position is taken as 9.5 tons for the 1st jib boom and 3.9 tons for the 2nd jib boom.

The boundary conditions and force values for the static strength calculations of the 1st and 2nd jib booms were entered into the analysis program to obtain the results.

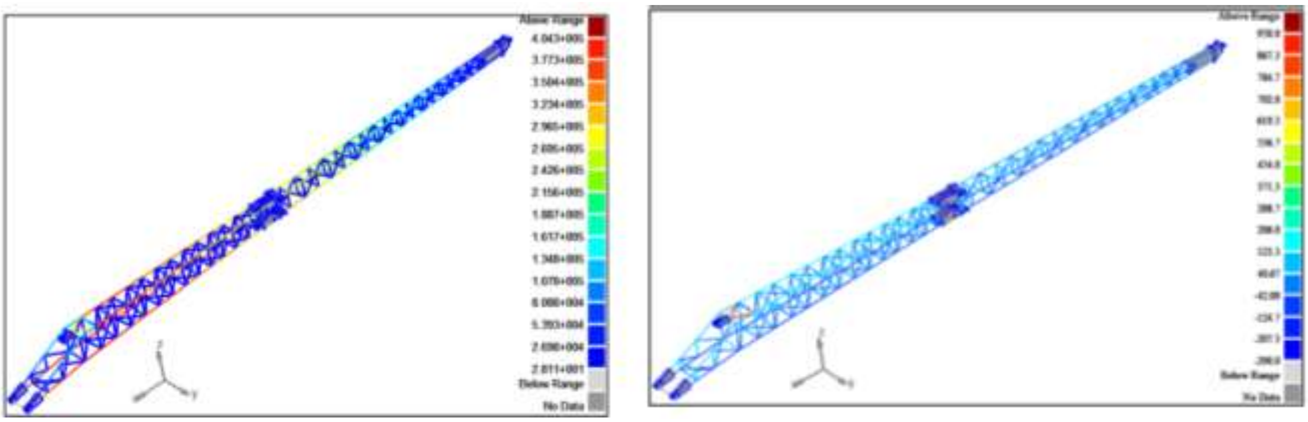

Figure 4. Force Distribution and Stress Analysis in the Complete Jib Boom Beam Element

The static analysis results show that the maximum force on the beam element in the 1st and 2nd jib booms is 404,300 N, and the stress is 950 MPa. The high stress is due to the presence of three beam elements, as observed in the analysis of the 1st jib boom. For the beam elements made of Optim HS 900 QH, the material's yield stress is σAk=900 MPa. The static safety factor is calculated to be 0.95. (1)

2.1. Jib Boom Optimization Results

As a result of the static analysis, the cross-sectional dimensions of the three beam elements causing stress concentration in the 1st jib boom were modified from an outer diameter of 48.3 mm to 101.6 mm, and an inner diameter of 43.3 mm to 93.6 mm. Static analysis was performed with these dimensions, and the results are shown in the figure.

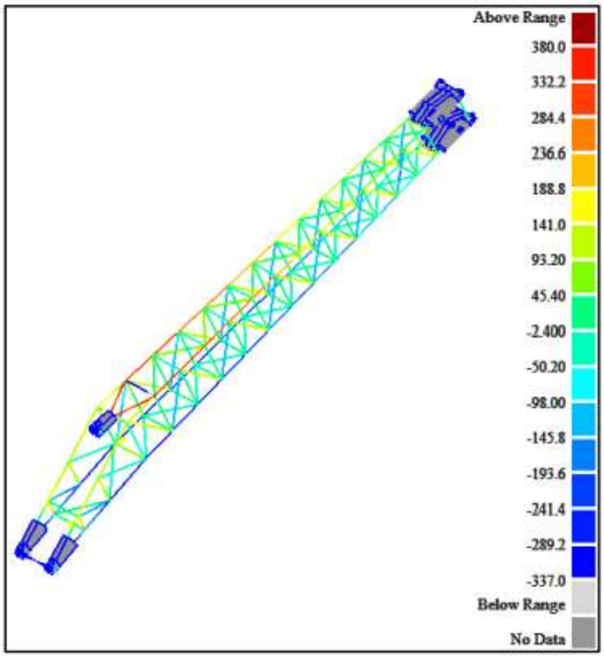

Figure 5. Stress Analysis of the 1st Jib Boom After Optimization

As a result of the static analysis, the maximum stress was found to be 380 MPa. The stress values of the three beam elements were reduced to match those of the other beam elements. The safety factor was calculated to be 2.37. Considering the safety factor obtained after optimization, a second optimization was deemed necessary. In the second optimization, the large-profile jib boom was adjusted from an outer diameter of 101.6 mm to 88.9 mm and an inner diameter from 93.6 mm to 80.9 mm. Static analysis was performed with these dimensions, and the results are shown in the figure.

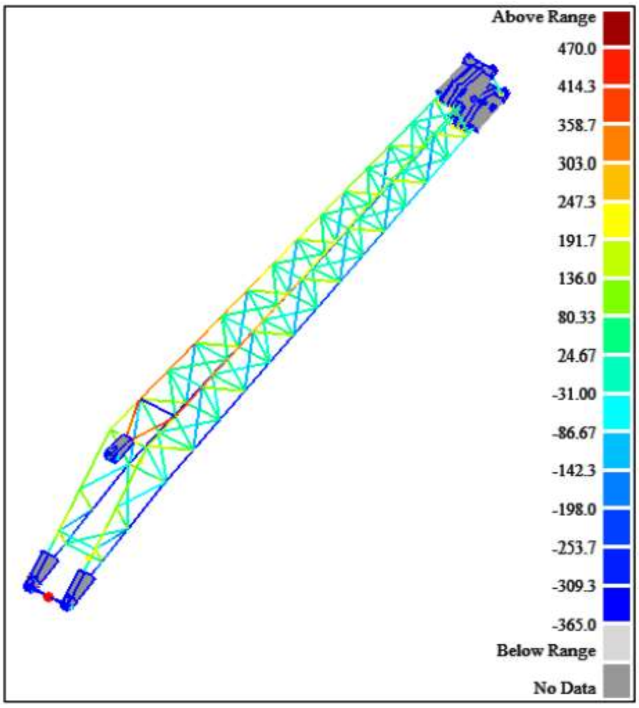

Figure 6. Stress Analysis Results of the 1st Jib Boom After Second Optimization

As a result of the static analysis, the maximum stress was found to be 470 MPa. The safety factor was calculated to be 1.91.

2.2. 1st and 2nd Jib Boom Complete Optimization Results

The large-profile jib boom was optimized with an outer diameter reduced from 101.6 mm to 88.9 mm and an inner diameter reduced from 93.6 mm to 80.9 mm. Static analysis was performed with these dimensions, and the results are shown in Figure 7.

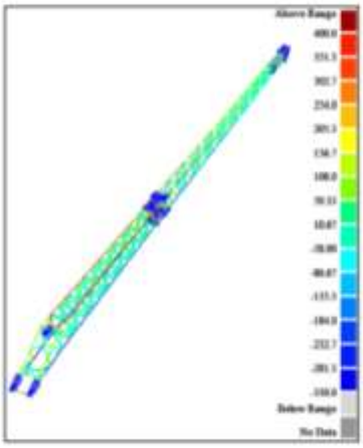

Figure 7. Stress Analysis Results of the 1st and 2nd Jib Boom After Optimization

As a result of the static analysis, the maximum stress was found to be 400 MPa, and the safety factor was calculated to be 2.25. The results of the static analysis and optimization of the jib boom are shown in Table 1. By examining these results, the optimum diameter and thickness were determined and are provided in Table 2.

Table 1. Static Analysis Results of the Jib Boom

Jib Boom Static Analysis Results			
Jib Boom No.	Stress Values from the Analysis (MPa)	Stress Values from the First Optimization (MPa)	Stress Values from the Second Optimization (MPa)
Firs Jib boom	1000	380	470
Complete Jib Boom	950	270	400

Table 2. Optimum Diameters and Thicknesses

Jib Boom Dimensions			
	Outer Diameter (mm)	Inner Diameter (mm)	Weight (kg)
Design Model	Q 101,6x4	Q 48,3x2,5	1975
Optimal Model	Q 88,9x4	Q 48,3x2,5	1890

3. Evaluation

In this study, 3D designs of the jib booms and other booms of the crane were created. Using this program, information on weight, cross-sectional area, moment of inertia, and positioning was obtained. Analytical calculations were performed using strength calculation formulas. Static analyses were conducted in the finite element software by inputting the model's constraints and force values obtained from the analytical calculations, resulting in stress values. For the optimization of the jib booms, calculations were carried out through thickness reduction and repeated analyses. In this way, the material diameters and weights of the jib booms were optimized.

4. References

1. Akkurt, M., 1990, Makine Elemanları Cilt II, Birsen Yayınevi, İstanbul
2. Erdil, A., 2007, Portal kreynlerin tasarım ve sonlu elemanlar yöntemiyle gerilme analizi, Yüksek Lisans Tezi, İstanbul Teknik Üniversitesi Fen Bilimleri Enstitüsü, İstanbul
3. Özkur, M., 2012, ‚Dört kademeli teleskobik vincin hareket mekanizmasının tasarımı ve analizi‛, Yüksek
4. TS EN 12999, Aralık 2005, Vinç ve Yükleyici Vinçler
5. Yunus GÜDER, “MOBİL VİNÇLERDE TELESKOBİK BOM VE JİB BOM MEKANİZMASININ TASARIMI, ANALİZİ VE OPTİMİZASYONU”, Yüksek lisans tezi, 2014