

Analysis of Load Variations and Operational Conditions on the Standardization of Spreader Bar Geometric Design

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Abstract: The spreader bar is a crucial component in heavy lifting systems used across various industries such as construction and manufacturing. Load variations experienced by the spreader bar can affect stress distribution and structural deformation, ultimately impacting operational safety and efficiency. Although various methods have been employed in the design of spreader bars, discrepancies in load capacity calculations still exist, potentially compromising design reliability. This study aims to analyze the impact of load variations on the geometric design of spreader bars in order to optimize structural durability and enhance safety standards. The method used in this study is numerical simulation based on the finite element method (FEM), which enables a quantitative analysis of stress distribution, deformation, and maximum load capacity. Several spreader bar models with variations in geometry, material thickness, and loading conditions are analyzed to evaluate their structural performance. The results show that load variations significantly influence stress distribution and deformation in the spreader bar. Increasing material thickness and optimizing geometric shapes can improve load capacity and reduce the risk of structural failure. Furthermore, the developed simulation model provides sufficiently accurate predictions compared to experimental-based approaches alone, making it a valuable reference in the design of spreader bars that are more adaptable to varying operational conditions. The conclusion of this study emphasizes that the integration of numerical simulations in spreader bar design can enhance efficiency and safety in industrial applications. This research is expected to serve as a foundation for developing more accurate design standards and aid in designing more reliable spreader bars tailored to industry needs.

Keywords: Design Standards, Geometric design, Operational Conditions, Spreader Bar.

I. INTRODUCTION

In structural engineering industries, spreader bars play a critical role in evenly distributing loads during the lifting and transportation of heavy materials. The load variations experienced by spreader bars are significantly influenced by their geometric design and configuration, which must comply with safety and structural efficiency standards. Recent studies have shown that optimal spreader bar designs can enhance resistance to load variations and reduce the risk of structural deformation that could lead to mechanical failure[1]. Although international standards such as ASME BTH-1 and EN 13155 have been widely applied in the design of spreader bars, discrepancies in load capacity calculation methods still exist, potentially compromising operational safety[2].

Previous research has primarily focused on experimental investigations into how load variation affects the structural integrity of spreader bars. For instance, a study by Gouda et al.

(2023) demonstrated that geometric imperfections can lead to uneven stress distribution, which accelerates structural failure compared to predictions based on existing design standards. Similarly, Karthik et al. (2022) highlighted that increased thickness and alternative material configurations can improve performance under dynamic loading conditions. However, they also emphasized the need for numerical simulation-based design optimization to achieve more accurate predictions[3]. Despite these findings, most of the current literature remains centered around experimental analysis, lacking the integration of numerical models that can offer a more comprehensive projection of the effects of load variation[4][5].

This study aims to address this research gap by developing a numerical simulation-based approach to evaluate the impact of load variation on the geometric design of spreader bars. By gaining a deeper understanding of load distribution and its effects on material deformation and failure, this research seeks to contribute to the enhancement of design standards for spreader

bars, making them more adaptive to varying operational conditions[6][7]. Theoretically, the outcomes of this study will support the development of predictive models and design optimization strategies based on load variation parameters.

II. RESEARCH METHODOLOGY

The methods used for data collection to analyze the impact of load variation and operational conditions on the geometric design standardization of spreader bars at PT Rekayasa Industri are as follows:

1) Observation

This data collection technique was conducted through direct observation of spreader bar lifting operations at various construction project sites managed by PT Rekayasa Industri. The aim was to identify variations in load conditions, lifting configurations, and the performance of different spreader bar geometries under real operational environments.

2) Literature Study

This method involved a comprehensive review of international design standards such as ASME BTH-1 and EN 13155, as well as engineering references and previous research on spreader bar structural performance, load distribution, and failure modes. The literature study also included company-specific design procedures and safety guidelines adopted by PT Rekayasa Industri.

3) Interviews and Discussions

Discussions were conducted through interviews with design engineers, structural analysts, and field supervisors from PT Rekayasa Industri. These interviews aimed to gain insights into practical challenges, decision-making criteria in geometric design, and the influence of load variation on design reliability and operational safety.

2.1 Primary Data

The primary data in this study were obtained from actual field activities, simulations, and technical documentation conducted during the engineering internship at PT Rekayasa Industri. The data collected served as the basis for modeling, analysis, and validation of spreader bar design performance under variable loads and operational conditions. The types of primary data include:

1) Spreader Bar Specifications

Specifications of spreader bars used in lifting operations were obtained from PT Rekayasa Industri's design database. These included geometry dimensions and material grades.

Table 1: Initial Conditions Spreader Bar SWL 150 Ton

Item	Amount
Actual Load at Spreader beam, P (kg)	150.000
Design factor (Factor of safety), Nd	2
Design Load with safety factor, Pd (kg)	300.000
Number of Point Lifting, n	2
Component force acting on beam, P (kg, N)	75.000
	735.750
Degree, a	60
Comperive Force, Px (N)	367.875
Length Of Spreader, L (mm)	12.000

Table 2: H-Beam Profile Dimension for SWL 150 Ton

Input Parameter	Amount
Flange - flange inner face height, H (mm)	312
Width, B (mm)	350
Flange thickness, h (mm)	19
Web Thickness, b (mm)	12
Longitudinal axis of lifting Lug, hp (mm)	280

Table 3: Parameter Conditions SWL 150 Ton

Parameter Conditon	
Input	Amount
Cross section area, A (mm)	17.044
Area moment of inertia, Ixx (mm ⁴)	425.433.089
Area moment of inertia, Iyy (mm ⁴)	135.815.761,33
Section modulus, Sxx (mm ³)	2.431.046,22
Section modulus, Syy (mm ³)	776.090,06
Center of gravity, Xcog (mm)	175
Center of gravity, Ycog (mm)	175
Radius of gyration, rx (mm)	158,0
Radius of gyration, ry (mm)	89,3
Polar of moment inertia, J (mm ⁴)	561.248.850,67

Table 4: Compressive Stress SWL 150 Ton

Compressive Stress	Amount
Allowable Compressive stress, Fc all (N/mm ²)	148,61
Actual Compressive stress, Fc (N/mm ²)	21,58
Satisfactory	Ok

Table 5: Bending Stress SWL 150 Ton

Bending Stress	Amount
Moment at beam, M (Nmm)	206.010.000,00
Stress due to moment, Sbx (N/mm ²)	84,74
Bending Stress allowable, Sbx all (N/mm ²)	150
Satisfactory	Ok

Table 6: Combine Stress SWL 150 Ton

Check Combine Stress	U	0,71
Satisfactory	Ok	

Table 7: Material Specification

Material A36	Amount
Modulus of Elascity, E (N/mm ²)	2,00E+05
Specified yield stress, Sy (N/mm ²)	250
Modulus of Elascity, E (N/mm ²)	2,05E+05

2) Spreader Bar Design Drawing

Design drawings refer to the technical visual representation of the spreader bar components and configurations.

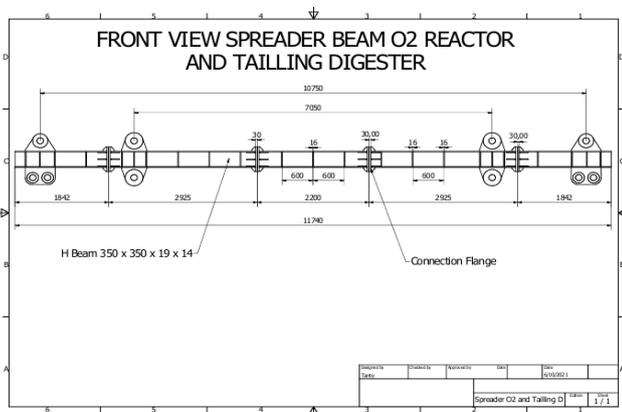


Figure 1: Spreader Bar Drawing SWL 150 Ton

2.2 Problem Identification and Analysis

To investigate the structural performance issues in spreader bars—such as excessive deformation, high stress concentration, or premature failure during lifting operations—a systematic evaluation approach was conducted. This began with a review of engineering design documents and continued through field validation and simulation-based analysis. The objective was to identify the root causes and propose corrective design improvements. A flowchart was developed to represent the logical progression of design evaluation, operational inspection, and simulation analysis. This flow-based diagnostic method provided a clearer path for iterative structural assessment and design validation.

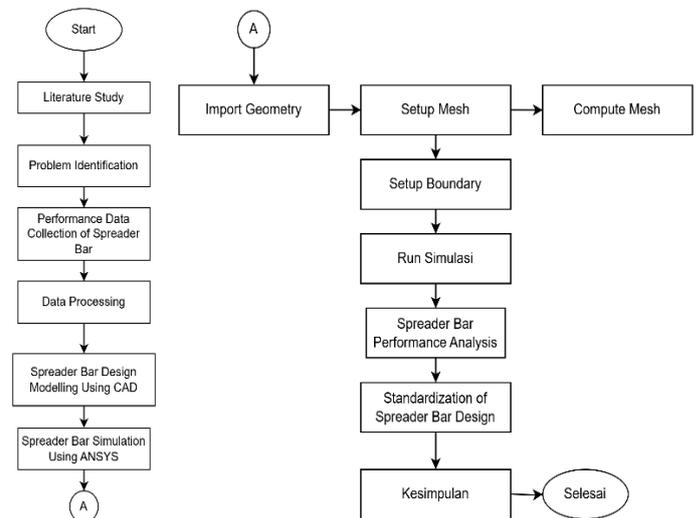


Figure 2: Flow Chart

A mathematical and simulation-based analysis was also conducted using the Finite Element Method (FEM). CAD models of spreader bars were developed with varied geometric parameters, and structural simulations were carried out using ANSYS Workbench to quantify stress distribution and deformation under static load conditions. These computations offered a theoretical benchmark against the real operating data collected from the compressor.

1) Moment at beam (M)

$$M = Px \times hp$$

2) Stress due to moment (Sbx)

$$Sbx = \frac{M}{Sxx}$$

3) Bending stress allowable (S_{bx} all)

$$S_{bx} = 0,6 \times S_y$$

4) Actual Compressive Stress (F_c)

$$F_c = \frac{Px}{A}$$

5) Allowable Compressive Stress (F_c all)

$$F_c \text{ all} = \frac{\pi^2 E}{1,15 \times Nd \times (kl/r)^2}$$

6) Combine Stress (U)

$$U = \frac{F_c}{F_c \text{ all}} + \frac{S_{bx}}{S_{bx} \text{ all}}$$

III. RESULTS AND DISCUSSIONS

3.1 Modelling and Simulation

The spreader bar geometry was modeled using CAD software (SolidWorks) to create a three-dimensional representation based on the geometric data and material specifications for each load variation (SWL). Each model was designed according to H-beam profiles commonly used in heavy lifting industries. The CAD model was then imported into ANSYS Workbench to perform numerical simulations using the finite element method (FEM). The simulation process included:

- 1) Meshing: Tetrahedral solid elements were applied with global and body sizing controls to ensure fine and accurate mesh distribution, especially in critical areas.
- 2) Boundary Conditions: Support constraints were applied at the lug holes as the lifting points, and loading was applied as a combination of vertical and horizontal forces resulting from sling tension at a 60° angle.
- 3) Solving: The static structural analysis method was used to determine von Mises stress, total deformation, and the structural response under combined compressive and bending loads.

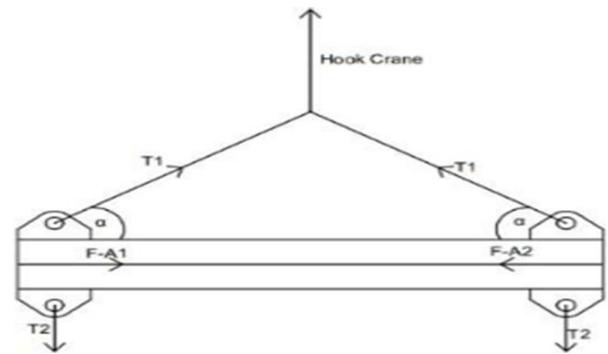


Figure 3: Free Body Diagram Spreader Bar

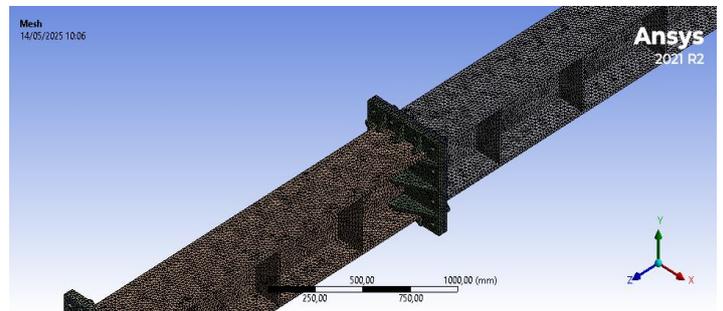


Figure 4: Mesh for Spreader Bar SWL 150 Ton

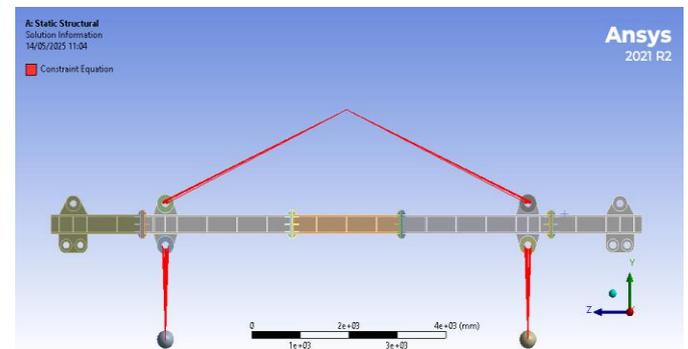


Figure 5: Boundary Conditions Spreader Bar SWL 150 Ton

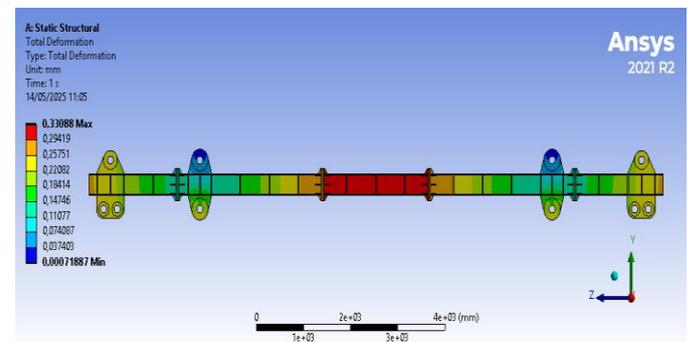


Figure 6: Total Deformation Spreader Bar SWL 150 Ton

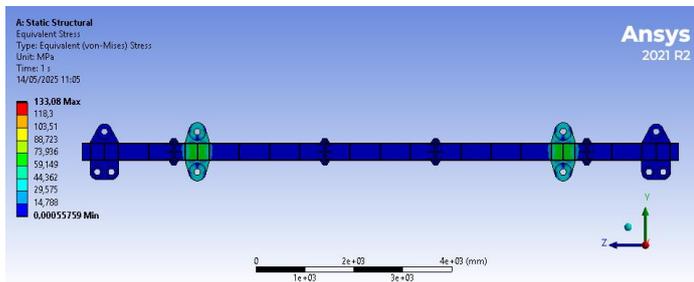


Figure 7: Equivalent Stress Spreader Bar SWL 150 Ton

3.2 Load Effect Analysis on Structural Response

Finite element simulation was specifically conducted for the 150-ton SWL spreader bar model. This scenario was selected as a representative case due to its position in the medium load category and its balanced geometric proportions between length, cross-sectional area, and structural capacity. The simulation revealed the following key structural responses:

- 1) Maximum von Mises stress was 84.74 N/mm², well below the yield strength of A36 steel (250 N/mm²).
- 2) Total deformation remained within acceptable limits, ensuring structural rigidity and stability.
- 3) The combined stress utilization factor (U) was 0.71, indicating the structure's safety under both bending and compressive loads.

These results confirmed that the spreader bar with the given dimensions and load conditions performs reliably and safely. More importantly, the structural behavior observed from the 150-ton simulation serves as a validated reference model for extrapolating and predicting performance in other SWL ranges.

Therefore, the analytical method and design configuration used in this simulation can be effectively applied to develop spreader bars for other load capacities. By adjusting key geometric parameters—such as section modulus, moment of inertia, and spreader length—similar levels of structural safety can be achieved without requiring full-scale simulation for each design.

3.3 Validation and Design Implication

Validation was conducted by comparing the simulation results with the analytical calculations presented earlier. All designs showed that:

- 1) The maximum stress values were well below the allowable limit of A36 steel.
- 2) The combined stress utilization factor (U) remained below 1 for all load variations.
- 3) The deformation patterns were consistent with theoretical expectations, increasing proportionally with length and load magnitude.

These results confirm that the applied design methodology is reliable and can be used as a reference for designing other spreader bars with different load capacities. The geometric parameters, dimensional ratios, and structural responses observed in the simulations provide valuable insight for developing a standardized and scalable design approach. Design implications include:

- 1) The potential to establish a standardized classification of spreader bars into light, medium, and heavy-duty categories.
- 2) The ability to create a preliminary design chart for future use based on SWL classes.
- 3) Simplified and accelerated design processes for new lifting applications using extrapolated results from validated models.

Thus, this validated simulation-based approach not only confirms the safety and feasibility of the current designs but also supports adaptive design development for a wide range of heavy lifting operations in industrial settings.

Table 8: Stress Analysis and Safety Status of Spreader Bars by SWL

SWL	Spreader Bar Length (mm)	H-Beam Dimensions	Bending Stress, S _{bx} (N/mm ²)	Compressive Stress, F _c (N/mm ²)	U	Status
10	12000	184×200×12×8	18.73	3.91	0.20	OK
50	6500	184×200×12×8	93.66	19.55	0.74	OK
150	12000	312×350×19×12	84.74	21.58	0.71	OK
250	5500	312×350×19×12	141.24	35.97	0.99	OK
500	12000	444×500×28×14.5	69.17	35.61	0.58	OK
1000	6500	444×500×28×14.5	138.34	71.21	0.90	OK

IV. CONCLUSION

This study has demonstrated that the integration of numerical simulation and structural analysis offers a reliable approach for evaluating and optimizing spreader bar designs under varying load conditions. Through comprehensive modeling and simulation using FEM-based tools, key insights

were gained regarding the distribution of stress, deformation patterns, and safety margins across different Safe Working Load (SWL) scenarios ranging from 10 to 1000 tons. The results showed that all configurations met the safety criteria, with stress levels and combined utilization factors (U) remaining below critical thresholds for A36 steel. These findings validate the effectiveness of the design methodology and its alignment with structural mechanics theory and international standards.

Furthermore, the data and outcomes obtained from this analysis can serve as a foundation for the standardization of spreader bar geometries. By utilizing the derived parameters and performance indicators, engineers can predict and design spreader bars for other load cases efficiently—minimizing trial-and-error processes and reducing dependency on physical testing during early-stage design.

In conclusion, this research provides a practical framework for safer, more adaptable, and cost-effective spreader bar designs in industrial lifting applications. The validated simulation approach not only ensures structural integrity but also opens opportunities for future development of modular or scalable lifting solutions.

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