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STRESS ANALYSIS OPTIMIZATION OF AXLE, WOOD TRANSFER SYSTEM

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Abstract: This project presents the design, stress analysis, and optimization of an axle used in a wood transfer system equipped with roller and chain conveyors. The primary aim is to improve the structural integrity and performance of the axle, which supports the load transferred by feeder wheels in a high-load, high-precision environment. Using both analytical calculations and simulation through SolidWorks, stress and deflection under applied forces were evalu ated for various iterations. Initial designs using S235JRG2 material showed failure due to stresses exceeding the yield strength. Through optimization of geometry and material substi tution with C45 steel, the final design demonstrated safe stress levels and minimal deflection, ensuring operational reliability and long-term durability. The analysis confirms that proper selection of material and geometry can significantly enhance the load-bearing capacity and lifespan of machine components in industrial applications.

Index Terms - Axle design, Finite Element Analysis, SolidWorks Simulation, Stress Optimization, Conveyor System, S235JRG2, C45 Steel, Wood Transfer System, Structural Integrity, Mechanical Engineering.

I. INTRODUCTION

The Stress Analysis and Optimization of Axle in a Wood Transfer System aims to im prove the mechanical integrity and performance of an axle used in a high-precision, auto mated wooden block handling system. This system involves various subsystems including roller conveyors, chain conveyors, and pneumatic feeders, all of which rely on the axle for proper load transfer and motion synchronization. The axle in question bears a vertical force of nearly 200 kg applied through the feeder wheels and transfers this load via roller supports. The primary objective of this project is to ensure that the axle withstands such concentrated loads without yielding, while maintaining a minimal deflection profile. Using SolidWorks-based CAD modeling, analytical calcula tions, and Finite Element Analysis (FEA), this study explores various axle geometries and materials—including S235JRG2 and C45 steel—for structural optimization. This work contributes to improving the performance, reliability, and service life of mechanical components in automated wood processing lines. By simulating and analyzing stress concentrations and deformation behavior, the project ensures that the axle remains within safe design limits under operational conditions..

II. LITERATURE REVIEW

Wilczyński (2022) conducted an analysis of shaft selection in terms of stiffness and mass, comparing solid and hollow shaft geometries. The study emphasized the importance of optimizing design to reduce weight while maintaining sufficient stiffness and strength. These principles are directly applicable to the optimization of the axle in the present work.

Kamboh (2021) carried out a detailed design and analysis of a drive shaft using lightweight alloys and composite materials. Finite Element Analysis (FEA) was employed to evaluate stress levels and deformation under various loading conditions. This research highlights the role of simulation tools in improving axle geometry and material selection for enhanced mechanical performance.

Armah (2019) proposed a fatigue-based shaft design methodology following ASME standards. The study focused on identifying critical stress regions and iterative sizing procedures to enhance shaft durability. The insights from this work assist in understanding fatigue behavior and in applying similar methods for axle analysis in the current study.

Hou (2020) examined common failure modes and causes of shafts in mechanical equipment. The research identified fatigue, corrosion, wear, and deformation as major failure mechanisms. This review provides valuable guidance for selecting high-strength materials and optimizing geometry to mitigate fatigue-induced failures in the present axle design.

Pingulkar (2021) investigated shear and bending stress in shaft mechanisms used in winding machines. The study combined analytical and simulation approaches to understand bending and torsional load behavior. The findings from this work are mirrored in the current study to better analyze combined stress effects on the axle.

III. OBJECTIVES

To Prepare a CAD modelling of Axle by using SolidWorks. Analysis of Axle.
To propose an optimized model withstands the forces generated by the feeder wheel
To enhance the efficiency of shaft with minimal weight, cost & strength, Feeder machine Functionality.
Roller Conveyor, Chain Conveyor, Feeder Wheel, Pneumatic circuit Functions

IV. DESIGN AND ANALYSIS OF AXLE OF WOODEN BLOCK SYSTEM

During the machining process, the precise movement of raw materials is crucial to maintaining accuracy, efficiency, and overall productivity. Proper material handling ensures that the wooden block reaches the cutting machine in a controlled and predictable manner, reducing operational errors and enhancing output quality. When a wooden block is positioned beneath the feeder wheel, a feeder cylinder lowers the wheel, exerting a downward force of approximately 200 kg onto the block. This applied force ensures consistent contact between the feeder wheel and the wooden block, enabling a uniform and controlled linear motion toward the cutting machine. The rotational movement of the feeder wheel propels the block forward at a steady feed rate, which is critical for precision cutting and the stability of the machining operation.

The entire load from the feeder wheel is transferred to its underside, where it is supported by two roller wheels, each with a diameter of 150 mm. These rollers are mounted on a single axle, which bears the full 200 kg force. Given the concentration of this load on a relatively small structural component, the axle experiences substantial stress, making it essential for engineers to consider both static and dynamic loading conditions. Over time, repetitive loading can lead to potential issues such as material fatigue, bending stress, excessive deflection, and even structural failure due to strain accumulation. Factors such as vibration, sudden impact forces, and variations in material density further contribute to the mechanical stresses experienced by the axle.

To ensure the structural integrity and long-term reliability of the axle, several key engineering considerations must be taken into account. Material selection plays a pivotal role—high-strength alloys such as hardened steel, titanium composites, or specialized polymers may be required to withstand cyclic stress without deformation or breakage. Additionally, surface treatments such as heat tempering, carburizing, or protective coatings can improve durability by enhancing wear resistance and reducing susceptibility to corrosion. The axle should also undergo rigorous stress analysis using computational modeling techniques, such as finite element analysis (FEA), to evaluate load distribution and pinpoint potential failure zones before manufacturing begins.Beyond material optimization, structural reinforcements such as increased axle diameter, enhanced support brackets, or dual-bearing systems can further mitigate mechanical strain. Reinforced bearings and optimized lubrication systems play a vital role in minimizing frictional forces, reducing wear, and extending the service life of the axle. Lubricants with high viscosity and thermal stability can prevent premature degradation under high-load conditions, while precision-engineered bearing housings can help improve rotational efficiency.

In addition to thoughtful engineering and design enhancements, periodic maintenance is essential to ensure the longevity of the axle and the overall performance of the feeding system. Routine inspections should be conducted to detect early signs of fatigue, corrosion, mechanical wear, or potential misalignment. Implementing predictive maintenance strategies, such as vibration analysis and load monitoring sensors, can allow operators to proactively address mechanical concerns before they lead to critical failures. Proper load distribution techniques, such as adjusting the feeder mechanism’s pressure application or redistributing forces through additional roller supports, can further enhance reliability and prevent excessive strain on individual components.

By integrating advanced design principles, robust material selection, and proactive maintenance protocols, the feeder system can operate at peak efficiency, ensuring consistent and precise material movement while minimizing the risk of axle failure. A wellengineered axle not only enhances the durability and operational stability of the entire feeding mechanism but also contributes to the long-term success and productivity of machining processes. Through continuous improvements in engineering, material science, and mechanical analysis, manufacturing systems can achieve higher levels of reliability, precision, and overall operational excellence.

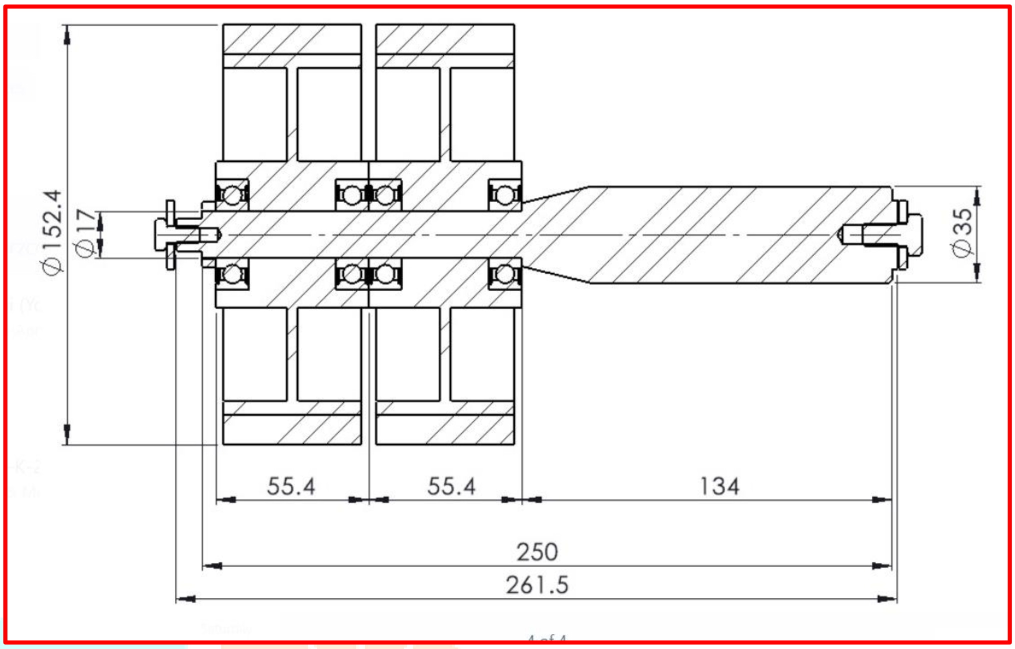

Figure 4.1 Axle Design

Given Data:

- Material: S235JrG2 (Yield Strength ≈ 235 MPa)
- Load (UDL at one end): 200 kg → (F = 200 \times 9.81 = 1962) N
- Length of UDL applied: 75 mm
- Shaft Diameter: 17 mm → Radius (r) = 8.5 mm
- Supports: Guided at both ends with 2.5 mm sheet

Step 1: Calculate the Bending Moment

Assuming a cantilever beam model (since the load is applied at one end):

M = F \ L

M = 1962 \0.075

M = 147.15 N

Step 2: Calculate the Moment of Inertia

For a circular shaft, the moment of inertia (I) is:

I = pi X D^4/{64}

I = {pi x (17)^4}/{64}

I = {pi x(83521)}/{64}

I = {262388.6}/{64} = 4106.1 mm^4

Step 3: Calculate Bending Stress

Using the bending stress formula:

σb = {M X C}/{I}

Where:

- (M = 147.15) Nm (= 147150) Nmm
- (c = 8.5) mm
- (I = 4106.1) mm(^4)

σb = 147150 X 8.5/4106.1

σb = 304.7 MPa

Step 4: Compare Bending Stress with Material Strength

- Yield Strength of S235JrG2 = 235 MPa
- Calculated Stress = 304.7 MPa

Conclusion:

Since 304.7 MPa > 235 MPa, the shaft exceeds the yield strength and may fail under bending stress.

Step 5: Calculate Shaft Deflection

For a cantilever beam, deflection is given by:

δ = {F XL^3}/{3EI}

Where:

- (E) (Elastic Modulus of S235JrG2) ≈ 200 GPa
- (I = 4106.1) mm(^4)

δ = {1962 \(75)3) /3X200000X4106.1}]

δ = {828558750}/{2463666000}

δ = 0.336 mm

Final Conclusion

- Bending stress exceeds yield strength, so failure is likely.

V. RESULTS AND DISCUSSION

5.1 Results of Descriptive Statics of Study Variables

Table 5.1: Descriptive Statics

Variable	Minimum	Maximum	Mean	Std. Deviation	Jarque-Bera test	Sig
KSE-100 Index	-0.11	0.14	0.020	0.047	5.558	0.062
Inflation	-0.01	0.02	0.007	0.008	1.345	0.510
Exchange rate	-0.07	0.04	0.003	0.013	1.517	0.467
Oil Prices	-0.24	0.11	0.041	0.060	2.474	0.290
Interest rate	-0.13	0.05	0.047	0.029	1.745	0.418

Table 4.1 displayed mean, standard deviation, maximum minimum and jarque-bera test and its p value of the macroeconomic variables of the study. The descriptive statistics indicated that the mean values of variables (index, INF, EX, OilP and INT) were 0.020, 0.007, 0.003, 0.041 and 0.047 respectively. The maximum values of the variables between the study periods were 0.14, 0.02, 0.04, 0.41, 0.11 and 0.05 for the KSE- 100 Index, inflation, exchange rate, oil prices and interest rate.

The standard deviations for each variable indicated that data were widely spread around their respective means.

Column 6 in table 4.1 shows jarque bera test which is used to checkthe normality of data. The hypotheses of the normal distribution are given;

H_0 : The data is normally distributed.

H_1 :The data is not normally distributed.

Table 4.1 shows that at 5 % level of confidence, the null hypothesis of normality cannot be rejected. KSE-100 index and macroeconomic variables inflation, exchange rate, oil prices and interest rate are normally distributed.

The descriptive statistics from Table 4.1 showed that the values were normally distributed about their mean and variance. This indicated that aggregate stock prices on the KSE and the macroeconomic factors, inflation rate, oil prices, exchange rate, and interest rate are all not too much sensitive to periodic changes and speculation. To interpret, this study found that an individual investor could not earn higher rate of profit from the KSE. Additionally, individual investors and corporations could not earn higher profits and interest rates from the economy and foreign companies could not earn considerably higher returns in terms of exchange rate. The investor could only earn a normal profit from KSE.

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