Vibration analysis and shape optimization of Sugar Cane mill head stock using Finite Element Method

Dr. Rachayya. R. Arakerimath, Professor, JSPM's Rajarshi Shahu College of Engineering, Pune, Maharashtra, India.

Nitin J Chavan, PG Scholar Design Engineering, JSPM Rajarshi Shahu College of Engineering, Pune, Maharashtra, India. arakeri2020@gmail.com

Abstract - Vibration analysis of a sugar cane mill headstock is an important maintenance practice to ensure the smooth and efficient operation of the mill. The headstock is a critical component that supports the entire milling process and is subjected to significant stresses and forces during operation. Vibration analysis helps in detecting any abnormalities or potential issues with the headstock before they escalate into major problems, leading to downtime and costly repairs. In this paper FEA of 3- different materials is done and compared for frequency generated, stresses and deformation. And also weight in each and found 11% reduction in the weight with lesser thickness after shape optimization.

Keywords: Sugar Mill, Headstock, FEA, Static Analysis, Modal Analysis

I. INTRODUCTION

The headstock of a sugar mill is a critical component that supports the entire milling process and houses the main driving mechanism for the mill rollers. Its design is essential to ensure the efficient and safe operation of the mill. Below are some of the key design aspects that should be considered for a sugar mill headstock:

Structural Integrity: The headstock must be designed to withstand the heavy loads and forces generated during the milling process. It should be constructed using robust materials, such as high-quality steel, and designed to have sufficient strength and rigidity.

Alignment and Tolerance: Accurate alignment of the headstock components is crucial to ensure smooth and efficient operation. Proper tolerances should be maintained to prevent misalignment, which can lead to increased wear, reduced efficiency, and potential damage to the mill.

Roller Bearings: The headstock houses the roller bearings that support the mill rollers. The selection of high-quality bearings is vital to reduce friction, minimize heat generation, and increase the overall lifespan of the mill.

Lubrication System: An effective lubrication system is necessary to keep the roller bearings and other moving parts well-lubricated during operation. This prevents excessive wear and helps maintain the mill's performance.

Shaft and Gear Design: The headstock contains shafts and gears that transmit power from the mill's main drive to the rollers. These components should be designed to handle the required torque and power while maintaining smooth operation and minimizing noise.

Safety Features: Safety is of utmost importance in the design of the headstock. Proper guards and safety mechanisms should be incorporated to prevent access to moving parts during operation and to protect personnel from potential hazards.

Vibration Damping: Sugar cane milling generates significant vibrations. Designing the headstock with appropriate damping features can help reduce excessive vibrations, which can lead to premature wear and decreased efficiency.

Cooling System: Sugar milling generates heat due to friction and mechanical energy. An efficient cooling system is essential to dissipate heat and prevent overheating of critical components.

Maintenance and Accessibility: The design should allow easy access to components for inspection, maintenance, and repairs. This facilitates routine maintenance tasks and reduces downtime.

Operational Flexibility: The headstock design should accommodate different operating conditions and be adaptable to variations in cane quality and throughput.

Load Distribution: The design should ensure an even distribution of the load among the mill rollers to avoid uneven wear and ensure efficient extraction of juice from the sugar cane.

Environmental Considerations: In some regions, sugar mills may be exposed to harsh environmental conditions. The

 DOI : 10.35291/2454-9150.2023.0170

ISSN : 2454-9150 Vol-09, Issue-05, Aug 2023

design should take into account factors like corrosion resistance in such environments.

The design of a sugar mill headstock requires a combination of engineering expertise, material selection, and a deep understanding of the operational requirements. Regular inspections and maintenance are essential to ensure the headstock's longevity and safe operation throughout the mill's life cycle.

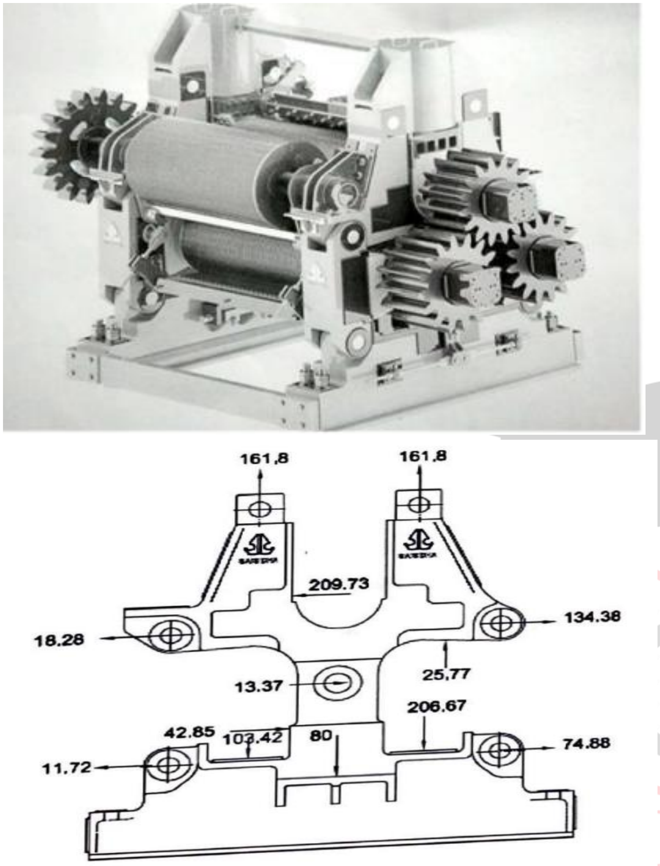

Fig-1 Sugar Mill Headstock Assembly and Loading Diagram

II. HEADSTOCK CAD MODEL AND DETAILS

Headstock shape is designed by taking reference of mill roller arrangement and its height from foundation bed. The casting and machining design of sugar mill headstock are different but we want to check strength of machining design which is going to mount on foundation bed so we have done CAD model in catia v5 software using 2D Industrial dimensions.

Finite element analysis of Headstock:

Finite Element Analysis (FEA) is a powerful numerical simulation technique used to analyze the structural behavior and performance of complex engineering systems, including mill headstocks. In the context of a sugar mill headstock, FEA can be employed to assess its structural integrity, predict stress distribution, evaluate deformations, and identify potential failure points. This analysis helps in optimizing the design and ensuring the headstock's reliability and safety during its operational life.

Here are the general steps involved in conducting FEA of a mill headstock:

Geometry Creation: The first step is to create a detailed 3D geometric model of the mill headstock using specialized computer-aided design (CAD) software. The model should accurately represent all the physical components and features of the headstock.

Mesh Generation: After creating the geometry, the next step is to discretize it into smaller, finite elements to perform the analysis. This process is called mesh generation. The accuracy and efficiency of the FEA heavily depend on the quality and density of the mesh.

Material Properties: Assign appropriate material properties to each element of the mesh. Sugar mill headstocks are often made of steel or other composite materials. The material properties, such as Young's modulus, Poisson's ratio, and density, are essential for accurate simulation.

Boundary Conditions: Define the boundary conditions to simulate the real-world loading and constraints applied to the headstock during operation. For example, support conditions, forces, torques, and thermal effects should be applied to the model based on the mill's actual operating conditions.

Analysis Type: Choose the appropriate analysis type based on the objectives of the study. Common types include static analysis, dynamic analysis, thermal analysis, and fatigue analysis. Static analysis is commonly used to assess the structural integrity under steady loads, while dynamic analysis can account for vibrations and transient loads.

Solving the Equations: The meshed model with boundary conditions and material properties is then subjected to the governing equations of solid mechanics using numerical methods. The finite element solver calculates the displacements, stresses, and strains in each element.

Results Interpretation: Once the FEA simulation is complete, the results are interpreted. Engineers can visualize stress contours, deformations, and other relevant parameters to identify critical areas and evaluate the performance of the headstock under various load scenarios.

Model Validation: It is essential to validate the FEA model by comparing its predictions with physical test results or analytical calculations. Model validation ensures that the FEA accurately represents the real-world behavior of the headstock.

Optimization and Design Improvements: Based on the analysis results, engineers can make design modifications to improve the headstock's performance, such as changing material properties, adjusting geometry, or reinforcing critical areas.

 DOI : 10.35291/2454-9150.2023.0170

FEA is a valuable tool in the design and analysis of complex engineering structures like sugar mill headstocks. It enables engineers to understand the behavior of the system under different conditions and make informed decisions to enhance performance and safety.

III. Shape Optimization

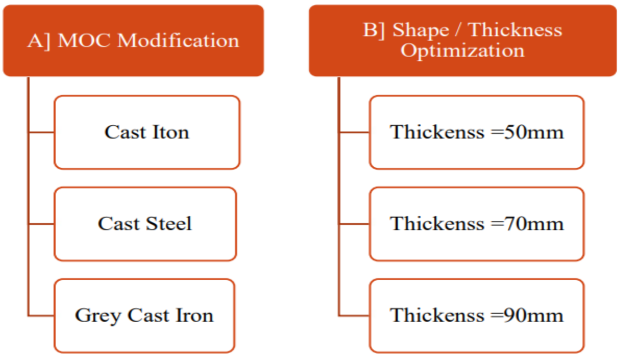

Fig-02: Types of material and Thickness used in Optimization

Size optimization is widely used to find optimal solutions for key product characteristics, such as cross-sectional thicknesses, material choice, and other part parameters. When we observe high-stress concentrations during their initial concept analysis, then turn to shape and free-shape optimization to reduce the potential for product failure. Shape optimization enhances an existing geometry by adjusting the height, length, or radii of the design – morphing the part to distribute stress more evenly.

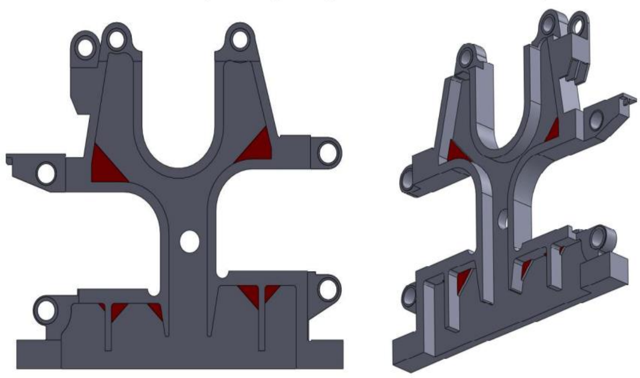

Fig-03: Shape Optimized models with stiffeners

IV. Modal Analysis and Results

Mode	Frequency [Hz] for CAST IRON		Frequency [Hz] for CAST STEEL (IS 1030)GR-28-56W	
	Cast Iron	Optimized Cast Iron	Cast Steel	Optimized Cast Steel
1	55.509	55.175	78.175	77.699
2	103.05	102.78	145.3	144.91
3	202.72	202.44	286.05	285.58
4	225.64	226.85	318.45	320.1
5	234.06	234.28	330.17	330.43
6	280.27	283.82	395.45	400.44

The Modal analysis is performed for the Assembly to check Natural Frequency. The Operational frequency for Mill is between 25 Hz to 30 Hz and we noticed there is huge gap between Natural frequency and Operational frequency. The Modal analysis is performed for the existing Assembly part as well as optimized shape. In all cases the Natural frequency is very high hence we do not foresee any resonance during operation.

The Modal analysis is performed for both MOCs and the minimum Frequency in Cast Iron part is resulted as 55 Hz and the same in Cast Steel part is 77 Hz. The comparison of the Modal analysis is tabulated in Table 1. The Stiffener arrangement shown in Modified Model is difficult to Cast and considering difficulty in manufacturability the Shape.

V. Conclusion

1.The Von Mises stress for original headstock is 153 MPa whereas for headstock with 70 mm thickness is 189.84 MPa. This shows that the optimized headstock has high stress which is less than the Maximum shear stress i.e. 200 MPa. Hence the optimized Headstock is safe.

2. The weight for original Headstock is 5704 Kg, whereas for the optimized headstock weight is 5174 Kg. This shows that there is 11% weight reduction which is safe with respect to stresses calculated.

3. Cast Steel Model is stronger than Cast Iron and with thickness Optimization from 90mm to 70mm reduced weight of part.

References

[1] "1. Yogini .V. Deore, Prof. Jitendra. R.Mahajan, Vinay Patil, "FEA Analysis And Optimization of Headstock Used For Diameter 50"X 100" Sugarcane Mill"", International journal of Mechanical engineering and Information technology,(ISSN-2348-196x) IJMEIT: Vol.03, Page No: 1550-1559, Issue 01, January-2017.

[2] "Santosh Y Salunkhe, "Design & Analysis of Ø40" x Ø 80" Conventional Sugar mill head stock"", International Journal of Scientific Engineering and Technology, ISSN :2277- 1581,Volume No.4 Issue No.7, pp: 397- 400,01 July 2015.

[3] "C. Adam, J. Loughran, "The Effffect of Blanket Thickness on Extraction Energy in Sugarcane Rolling Mills: a Finite Element Investigation"",Science direct, Biosystems Engineering (2005) 92 (2), 255–263 doi:10.1016/j.biosystemseng.2005.07.0

[4] Chetan T Rathod, Walmiki S Rathod, (2012) "Design and Analysis of Two Roller Sugar mill using FEA Techniques" International Journal of Scientific Engineering and Technology ,(ISSN : 2277-1581) , Volume No.1, Issue No.3, pg : 148-152.

 DOI : 10.35291/2454-9150.2023.0170

ISSN : 2454-9150 Vol-09, Issue-05, Aug 2023

[5] Rohit M. Chavan1, Prof. M. M. Mirza, R. Biradar, Design and Analysis of Hydraulic Jack for 2017. Sugar Mill Setting. International Journal of Engineering Research & Technology , Vol. 4 Issue 05

[6] Ray Aparajita P. R R Arakerimath. Design Analysis and Shape Optimization of Front Axle of Automotive Truck, International Journal of Engineering and Management Research (IJEMR). 2015, pp54-58.

[7] Aniket S Umap, Vijay S Pisal etal. Stress and Deflection Analysis of Orthogrid and Isogrid Structure, System Reliability, Quality Control, Safety, Maintenance and Management: Applications to Civil, Mechanical and Chemical Engineering, Springer Singapore, 2020, pp153-158

[8] S.M. Muzakkir, Harish Hirani, G.D. Thakre, M.R. Tyagi, "Tribological failure analysis of journal bearings used in sugar mills", Engineering Failure Analysis 18

[9] Mr.Akshay Patil , Prof. M.M.Mirza. ANALYSIS OF SUGAR MILL HEADSTOCK, International Journal Engineering Applied Sciences and Technology, 2020, Vol. 5, Issue 5, ISSN No. 2455-2143, Pages 217-222

 DOI : 10.35291/2454-9150.2023.0170