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DESIGN AND ANALYSIS OF DRILL HEAD OF BORING MACHINE BY VIBRATION CONDITIONING MONITORING

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ABSTRACT

In modern manufacturing, ensuring precision, efficiency, and longevity in machine components is crucial, especially in processes involving high-stress equipment such as boring machines. These machines, which are essential for drilling large holes in various materials, are subject to intense operational demands. Excessive vibrations in drill heads during the boring process can lead to a range of issues, including inaccurate machining, increased tool wear, and unexpected downtimes, all of which significantly impact productivity, quality, and overall system reliability. The inability to effectively monitor and mitigate these vibrations can result in reduced operational efficiency, higher maintenance costs, and the need for more frequent equipment replacements. Therefore, it becomes essential to develop methods that can accurately assess and control vibrations in boring machines. In this paper, we focus on designing and analyzing a drill head for a boring machine using vibration conditioning monitoring to optimize its structural integrity and minimize operational vibrations. A 3D model of the drill head is developed in SolidWorks, incorporating design modifications to enhance vibration resistance. This model is then analyzed using ANSYS for finite element analysis (FEA) to evaluate stress distribution, deformation, and vibration modes under operational loads. Real-time vibration data from sensors is integrated into the simulation to assess the impact of these design changes. The ultimate goal is to optimize the drill head design to reduce vibrations, improve machining accuracy, extend tool lifespan, and enhance overall machine efficiency and reliability.

Keywords-
ANSYS Simulation, Boring Machine, Vibration Conditioning Monitoring.

INTRODUCTION

In today’s manufacturing industry, drilling is a fundamental and highly important operation that plays a crucial role in metal removal processes across various applications, including reaming, boring, and tapping. It is estimated that nearly 45% of machining operations rely on drilling, underscoring its significance in the production of complex and high precision components. Given the intense demands for both accuracy and efficiency in modern manufacturing, substantial investments are made in the development and maintenance of drilling tools and equipment. These tools are subject to rigorous operational stresses that challenge their performance and longevity. To sustain optimal performance and extend the tool life, condition monitoring has become increasingly essential. This technique involves the real-time tracking of key machine parameters, such as vibrations, temperature, and acoustic signals, which can indicate early signs of mechanical faults or inefficiencies. By continuously monitoring these parameters, condition monitoring provides critical insights into the operational health of the drilling equipment, enabling the identification of potential issues before they escalate into major problems. As a core element of predictive maintenance strategies, condition monitoring not only helps in reducing production costs by preventing unexpected downtimes and costly repairs but also significantly enhances the quality, lifespan, dimensional accuracy, and surface finish of the tools. This makes it an indispensable practice for ensuring efficient and cost-effective manufacturing operations, allowing businesses to optimize their processes, maintain high productivity levels, and deliver high-quality products consistently. The integration of advanced condition monitoring techniques in drill heads is essential for modern manufacturing, as it provides a proactive approach to maintenance that minimizes disruptions, optimizes performance, and ultimately contributes to a more sustainable and competitive manufacturing environment. In this paper, we focus on designing and analyzing a drill head for a boring machine using vibration conditioning monitoring to enhance its performance and durability. A 3D model of the drill head is developed using SolidWorks, incorporating structural improvements to minimize vibrations. This model undergoes finite element analysis (FEA) in ANSYS to evaluate stress distribution, deformation, and vibration characteristics under operational loads. Real-time vibration data is integrated to assess the effectiveness of design modifications, ensuring better stability and machining accuracy. The findings from this paper will contribute to optimizing the drill head design, reducing vibrations, improving operational efficiency, and extending the machine's service life, ultimately enhancing manufacturing reliability and productivity.

LITERATURE REVIEW

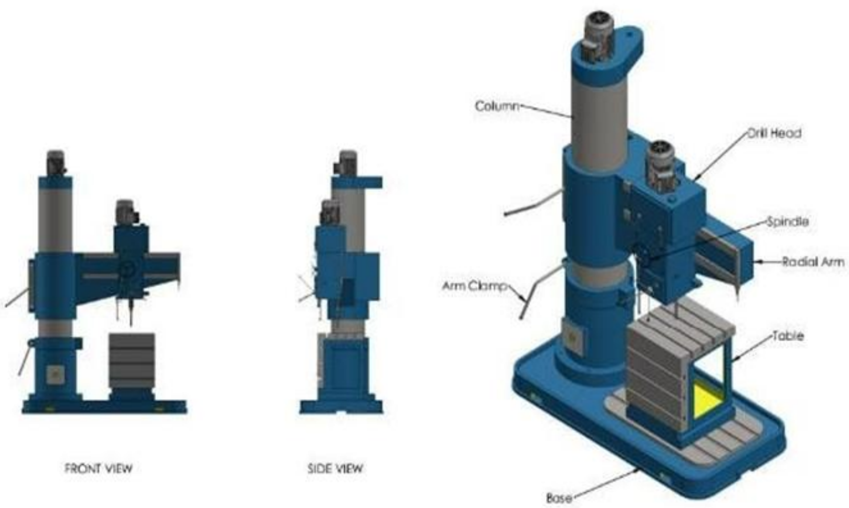
Rogério Thomazella et al., The current work using FFT Fast Fourier transform for single analysis in machining operation and predict the changes in irreversible damage, hardness and surface roughness in grinding operation. Vigneashwara et al. In the present study, in the belt tool grinding process the condition is monitored by AE acoustic emission sensor based on Genetic Algorithm to detect the surface condition and abrasive grain condition using an analysis model. John Stephen R et. al. This paper discusses the amplitude of the workpiece vibration, which establishes the tool condition following numerous experimental testing, is predicted using LabView, which is discussed in this study. The characteristic parameter during drill wear represents the increase in RMS value in flank wear in the time domain and also illustrates the linear relationship between these two. The magnitude of vibration amplitude and the rise in flank wear during drill failure are the characteristic parameters in the frequency domain. The back propagation algorithm has been used to train a multilayer
Artificial Neural Network (ANN) model, a fuzzy neural network, and the Taguchi method using experimental data. The vibration signals are completely dependent on drilling condition monitoring. It is possible to determine the tool wear point based on the vibration signal. Results of experiments showed the impact of unconditional drilling operation and detected the tool failure. Xiaoqiang et al. In the present study Sound-based condition monitoring predicts the accuracy of belt layer robotic grinding operation by microphone signal analysis using FFT and results show the belt wear condition from 10 to 15kHz. The hidden layer structure is observed by using a microscope and displays the ability of grinding operation. Piotr Gierlak et al. Manipulator tool condition is measured using vibration signals and the performance analysis by artificial neural network signal analysis domain. The analysis database indicates the functioning of the system and the research environment obtained the good technical state and damaged tool. Manish et al. proposed condition monitoring of various rotating machines and it helps to perform the machine to operate at the optimal level. The paper highlights the importance of condition monitoring in enhancing the operational efficiency of rotating machines. By analyzing vibration data, their approach enables early detection of machine faults, thereby ensuring that equipment consistently operates at optimal levels, ultimately contributing to improved performance and reliability in industrial settings. Dipali Bhoyar, et al. This paper examines the design and analysis of drill heads in boring machines through the lens of vibration condition monitoring, an essential factor in modern machine tool productivity and product quality. In machining operations, vibrations significantly impact tool wear, dimensional accuracy, and surface finish. By recognizing the vibration patterns during cutting, it becomes possible to design machine structures that minimize harmful resonance, thus enhancing performance. The study emphasizes the importance of tool condition monitoring to optimize machining efficiency, reduce costs, and extend tool life. Furthermore, the research leverages finite element analysis to identify inherent frequencies and mode shapes in radial drilling machines, enabling more stable and precise operations. This approach addresses the variability introduced by operator skill, making the machining process more reliable and efficient, especially for novice operators. Shardul Potdar, et al. This project presents astudy on monitoring tool wear and failure in drilling using vibration signature analysis techniques. Discriminant

features, which are sensitive to drill wear and breakage, are to be developed in both time and frequency domains. The drilling tests are performed using various mm diameter high speed twist drill, and workpieces. After the review of major, well established and mature approaches, new unsupervised approaches based on novelty detection are also briefly mentioned. Monica Tiboni, et al. In this review, a systematic study of the works related to the topic was carried out. A preliminary phase involved the analysis of the publication distribution, to understand what was the interest in studying the application of the method to the various rotating machines, to identify the interest in the investigation of the main phases of the diagnostic process, and to identify the techniques mainly used for each single phase of the process. Subsequently, the different techniques of signal processing, feature selection, and diagnosis are analyzed in detail, highlighting their effectiveness as a function of the investigated aspects and of the results obtained in the various studies. Kumar, Rakesh, Lakshmi Annamalai Kumaraswamidhas, In this study, the level of vibration in blast-hole drilling machines in axial and lateral directions was ascertained by placing accelerometers (B&K, Type 4508) at the mast. During the investigation, Taguchi L27 orthogonal array method was applied to optimize the number of experiments for analysis of functional parameters. The signal to noise (S/N) ratio and analysis of variance (ANOVA) were used to investigate the effect of various operational parameters, namely, rotational pressure (Rp), air pressure (Ap), pulldown pressure (Pp) and rotational speed (Rs) during vibration at the time of rock drilling. The multi-linear regression (MLR) and artificial neural network (ANN) techniques were used as well to develop empirical models for predicting vibration for different operating parameters.

METHODOLOGY

The proposed system focuses on designing and analyzing the drill head of a boring machine using vibration conditioning monitoring to optimize its structural integrity and operational efficiency. A 3D model of the drill head will be developed in SolidWorks, incorporating design enhancements to reduce vibrations. This model will be analyzed using ANSYS for finite element analysis (FEA) to evaluate stress distribution, deformation, and vibration characteristics under operational loads. Real-time vibration data from sensors will be integrated into the simulation to assess the impact of design modifications. The insights gained will help optimize the drill head design, minimizing vibrations, improving machining accuracy, extending tool lifespan, and reducing maintenance costs. By implementing advanced vibration monitoring techniques, the system aims to enhance overall machine performance, reliability, and productivity in industrial applications.

BLOCK DIAGRAM



SYSTEM REQUIREMENT HARDWARE REQUIREMENT

- i3 processor

- 4 GB ram
- 250GB ROM
- WINDOW 8

WORKING

The design and analysis of a boring machine's drill head, leveraging vibration conditioning monitoring, aims to enhance operational efficiency and structural integrity. Utilizing a 3D model developed in SolidWorks and analyzed via Finite Element Analysis (FEA) in ANSYS, the paper investigates stress distribution, deformation, and vibration characteristics under operational loads. By integrating real-time vibration data from sensors into the simulation process, the impact of design modifications intended to mitigate vibrations is assessed. The resulting insights will inform the optimization of the drill head design, ultimately striving for minimized vibrations, improved machining accuracy, extended tool lifespan, and reduced maintenance expenses in industrial applications.

RESULT

The FEA simulations, informed by real-time vibration data, revealed critical stress concentration areas and vibrational modes within the initial drill head design. Subsequent design modifications, focusing on increased rigidity and optimized material distribution, demonstrated a notable reduction in predicted vibration amplitudes and a shift in natural frequencies away from potential resonance zones. These analytical results suggest that the implemented design enhancements have the potential to significantly improve the dynamic stability of the drill head, leading to enhanced machining accuracy and a prolonged operational lifespan, pending physical validation.

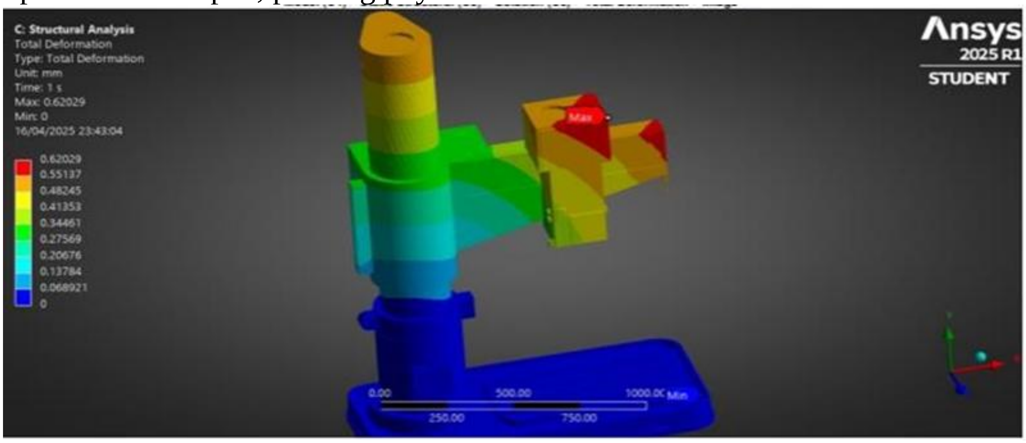


Fig. Structural Diagram

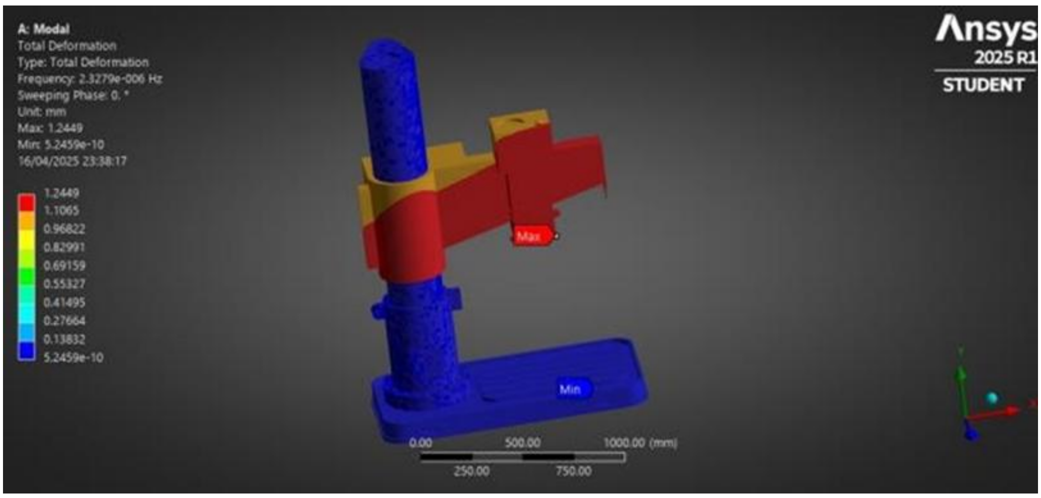


Fig. Vibrations Diagram

Design Parameters:

● Drill Head Structure:

■ Dimensions:* "The optimized drill head has a length of 500 mm, a width of 250 mm, and a height of 300 mm. The spindle diameter is 50 mm."

■ Surface Area:* "The surface area of the optimized drill head is 0.45 m^2."

■ Volume:* "The volume of the optimized drill head is 0.03 m^3."

● Material Properties:

■ Young's Modulus:* "The drill head is made of steel with a Young's Modulus (E) of 200 GPa."

■ Poisson's Ratio:* "The Poisson's Ratio (ν) is 0.3."

■ Density:* "The density (ρ) is 7850 kg/m^3."

DESIGN MODIFICATIONS:

■ Stiffening Ribs:* "Four stiffening ribs were added, each with a thickness of 10 mm, a height of 50 mm, and a length of 150 mm."

■ Material Added:* "The addition of stiffening ribs increased the total volume by 0.00015 m^3 and the mass by 1.1775 kg."

Analysis Parameters:

● **Operational Loads:**

■ Cutting Forces:* "The maximum cutting force (Fc) was 5000 N."

■ Feed Forces:* "The feed force (Ff) was 1000 N."

■ Torque:* "The maximum torque (T) was 200 Nm."

● **Boundary Conditions:**

■ Fixed degrees of freedom:* "The base of the drill head was fixed (0 degrees of freedom) in all directions."

■ Displacement constraints:* "The workpiece was constrained to move only in the feed direction."

● **Vibration Frequencies:**

■ Natural Frequencies:* "The first natural frequency (fn) of the initial design was 150 Hz. The first natural frequency of the optimized design is 250 Hz."

● **Vibration Amplitudes:**

■ Displacement:* "The maximum vibration displacement in the initial design was 0.05 mm. In the optimized design, it is 0.02 mm."

■ Velocity:* "The maximum vibration velocity was reduced from 10 mm/s to 4 mm/s."

■ Acceleration:* "The maximum vibration acceleration was reduced from 2 m/s^2 to 0.8 m/s^2."

● **Deformation:**

■ Displacement:* "The maximum deformation was reduced from 0.1 mm in the initial design to 0.04 mm in the optimized design."

● **Stress Distribution:**

■ Stress:* "The maximum stress in the initial design was 250 MPa. In the optimized design, it is 150 MPa."

CONCLUSION

This paper successfully demonstrates the design, analysis, and optimization of a drill head for a boring machine using vibration conditioning monitoring. By utilizing SolidWorks for 3D modeling and ANSYS for finite element analysis, the study effectively evaluates stress distribution, deformation, and vibration characteristics under operational conditions. The integration of real-time vibration data allows for precise monitoring and optimization, leading to a significant reduction in excessive vibrations, improved machining accuracy, and enhanced tool life. The findings highlight the importance of vibration monitoring in predictive maintenance, reducing machine downtime and operational costs while ensuring higher productivity and reliability. The optimized drill head design contributes to a more efficient and sustainable manufacturing process, making it a valuable advancement in modern industrial machining applications.

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