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An Analytical Study on Tool Life During Drilling Processes

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ABSTRACT

Drilling is a machining operation widely used to create or extend circular holes in solid materials using a rotating drill bit, typically equipped with multiple cutting points. The drill bit rotates at high speeds—ranging from a few hundred to several thousand RPM—while applying axial pressure, enabling material removal in the form of chips. Although generally intended for circular holes, certain specially designed bits can produce non-circular geometries, such as square holes. This study focuses on evaluating the performance and longevity of drilling tools made from different steel variants. A combination of computational modeling and experimental methods was employed to assess the Factor of Safety (FoS) for each tool material. In the experimental setup, tools were tested under a uniform 200 N load using a drilling machine equipped with a dynamometer. The resulting deformations were recorded and compared. Parallelly, Solid Works simulation was used for modeling each tool variant, with a consistent node count (13,788 nodes) and fixed boundary conditions at holding surfaces. The same 200 N load was applied circumferentially in simulations to analyze stress distribution and deformation. The comparative study between experimental data and simulation results helped determine tool performance and estimated life based on FoS values.

Keywords- Drilling Machine, Surface Roughness, Tool Life Analysis, Feed Rate

1. INTRODUCTION

Drilling is one of the most fundamental and widely used machining operations in manufacturing industries. It is primarily employed to create or enlarge circular holes in a wide range of materials using a rotating drill bit. The effectiveness of a drilling process significantly depends on the material and geometry of the tool, the applied force, and the machining parameters. As industries evolve towards higher precision and efficiency, the need to evaluate and enhance tool performance becomes increasingly important. Tool wear and failure are major challenges in drilling, directly affecting production quality and operational cost. Hence, analyzing the strength and lifespan of drill bits made from different materials is essential for selecting optimal tooling solutions. Traditional experimental approaches, when combined with modern computational tools, provide a robust framework for evaluating such performance parameters. This research aims to study the mechanical behavior of drill bits made from three different steel variants under a constant applied load. A comparative analysis has been performed using both experimental methods—employing a dynamometer-equipped drilling machine—and computational simulations using Solid Works software. The Factor of Safety (FoS) was considered the key metric for assessing tool reliability, enabling the estimation of tool life under uniform loading conditions. This integrated approach provides valuable insights into the deformation behavior and overall durability of each material, ultimately supporting informed decision-making in tool selection and design. The outcomes of this study can contribute significantly to improving tool design and enhancing the operational efficiency of drilling processes in industrial applications.

2. PROBLEM IDENTIFICATION

Drilling is an essential machining operation in manufacturing industries, but the efficiency and cost-effectiveness of this process are often compromised by the wear and degradation of the drilling tool. The tool life is influenced by several factors, including the material properties of the drill bit, cutting speed, feed rate, and the applied forces during drilling. In particular, understanding how different tool materials perform under constant operational conditions is critical to ensuring the longevity and reliability of the drilling process. Despite advancements in tool materials, drilling operations often experience inconsistent tool life due to the complex interplay between mechanical, thermal, and wear factors. The challenge lies in accurately predicting tool wear and failure under varying machining environments. While conventional experimental methods provide some insight, they are time-consuming and resource-intensive. Moreover, there is a lack of standardized approaches to assess and compare the performance of different tool materials in terms of their durability and wear resistance. This study addresses the need for a comprehensive analysis that integrates both experimental and computational methods to evaluate the tool life of different materials used in drilling operations. Specifically, it investigates the deformation behavior and Factor of Safety of drill bits made from three steel variants when subjected to a constant applied load. The key issue is the absence of a systematic framework that compares these materials under similar conditions, thus hindering the optimization of tool selection and enhancing the efficiency of the drilling process.

Identifying these gaps will help in better understanding tool degradation mechanisms, which can ultimately lead to the development of more durable and cost-effective drilling tools.

3. OBJECTIVES

The objectives of the Solid Works modeling and experimental analysis are:

1. To examine the impact of different drilling tool materials and variations in applied forces on the drilled workpiece.
2. To compare and validate the outcomes from Computational Analysis (Solid Works Modeling) with Experimental Analysis.
3. To assess the Factor of Safety for various tool materials, enabling the evaluation of drilling tool life.

By analyzing the deformation behavior resulting from changes in drilling tool materials, the study aims to optimize drilling forces and tool geometry. Ultimately, this will provide insights into the deformation of drilling tools and their overall life expectancy.

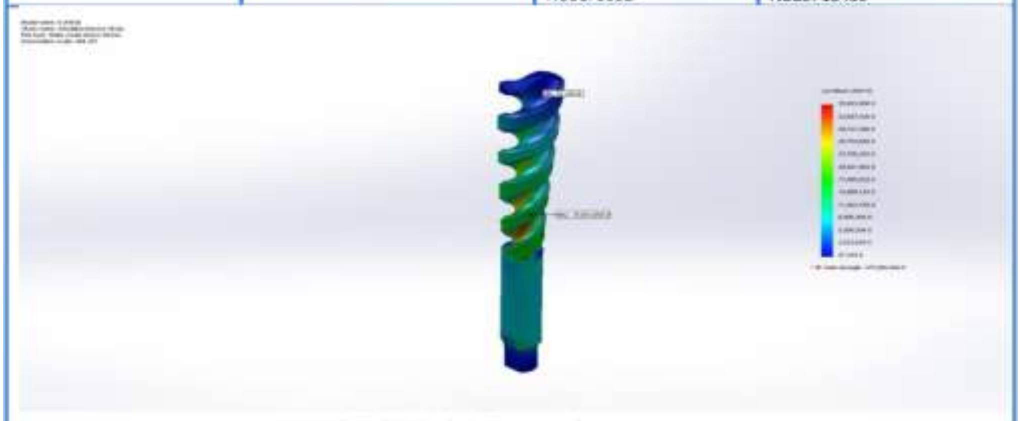
4. RESEARCH METHODOLOGY

The methodology for evaluating the drilling tool life and performance involves both computational and experimental approaches to study the behavior of different tool materials under applied forces. Initially, Solid Works software is used for creating 3D models of drilling tools made from three different steel variants. These models are then subjected to simulations in which a constant force of 200 N is applied uniformly around the tool surface. The models are constrained at two fixed points to simulate realistic holding conditions, and the Factor of Safety (FoS) is calculated based on the tool's response to the applied load. In parallel, experimental tests are conducted using a drilling machine fitted with a dynamometer to measure the actual force experienced by the tool. The same tool materials used in the simulations are employed in these experiments. A constant load of 200 N is applied circumferentially on each tool during drilling operations. The deformation and wear characteristics are recorded, and these measurements help assess the actual tool performance in terms of material strength and durability. The results from the experimental tests are then compared with the simulation data obtained from Solid Works. This comparison helps validate the computational model and provides deeper insights into the behavior of the drilling tool under various operating conditions. By analyzing the tool’s deformation and safety factor in both scenarios, we aim to determine the most effective tool materials and optimize the drilling process for enhanced tool life and performance.

5. RESULT AND DISCUSSION

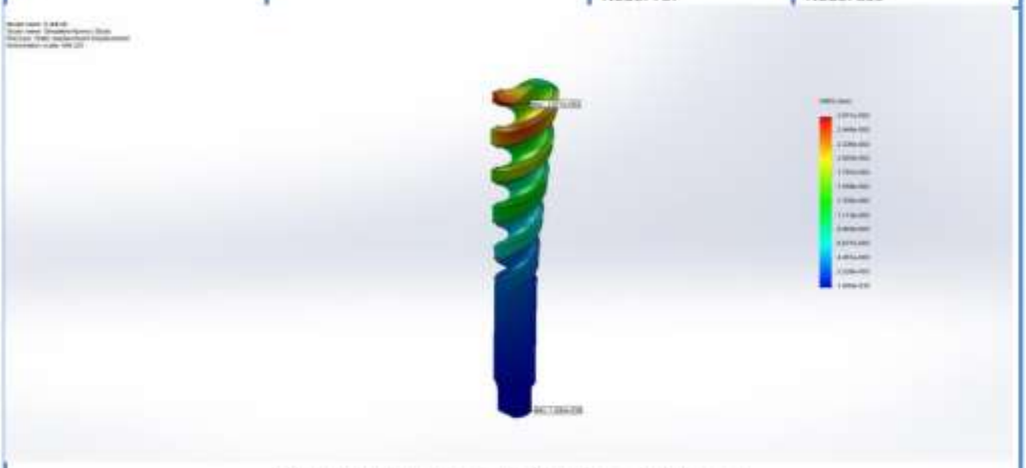
Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points	4 Points
Element Size	1.83193 mm
Tolerance	0.0915963 mm
Mesh Quality	High
Total Nodes	13788
Total Elements	8223
Maximum Aspect Ratio	24.354
% of elements with Aspect Ratio < 3	96.2
% of elements with Aspect Ratio > 10	0.0608
% of distorted elements(Jacobian)	0
Time to complete mesh(hh;mm;ss):	00:00:04
Computer name:	VIRUS-PC

Name	Type	Min	Max
Stress	VON: von Mises Stress	57244.8 N/m^2 Node: 9992	3.56538e+007 N/m^2 Node: 10459



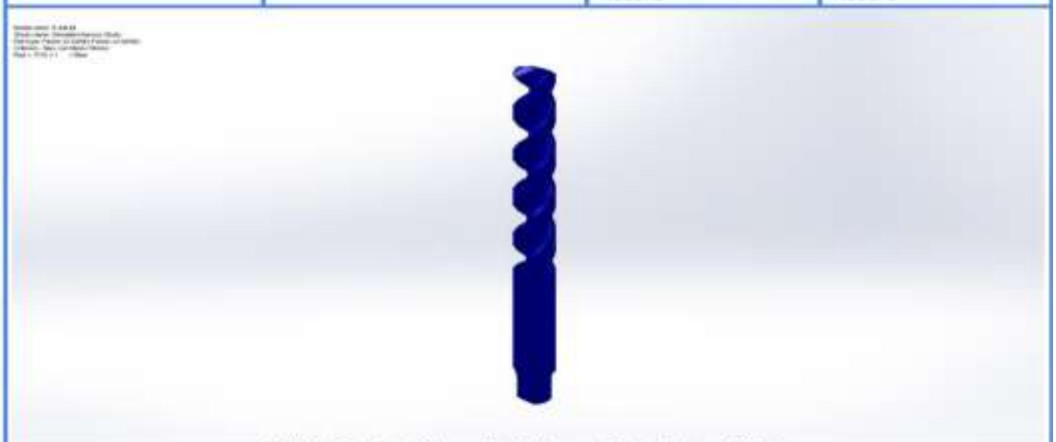
Drill Bit-SimulationXpress Study-Stress-Stress

Name	Type	Min	Max
Displacement	URES: Resultant Displacement	0 mm Node: 707	0.0267083 mm Node: 599



Drill Bit-SimulationXpress Study-Displacement-Displacement

Name	Type	Min	Max
Factor of Safety	Max von Mises Stress	0 Node: 1	0 Node: 1



Drill Bit-SimulationXpress Study-Factor of Safety-Factor of Safety

6. CONCLUSION

The primary goal of this project was to evaluate the life of drilling tools made from various materials by applying Solid Works modeling and experimental analysis. Using three different steel materials, we analyzed the Factor of Safety (FoS) and deformation under a constant applied force. The computational model in Solid Works and the experimental results demonstrated consistency, with tool deformation measured at 0.026 mm in both cases. The comparison confirms the accuracy of the Solid Works simulations for predicting key parameters like deformation, stress, and FoS. For the first material (44SMnPb28), the simulation showed a maximum Von Mises stress of 3.56538×10^7 N/m² at node 10459, with a minimum FoS of 13.75. The maximum displacement in this tool was 0.0267 mm, matching experimental results. In the second material (11SMn37), no significant FoS was required for maintaining tool life, as its minimum FoS was 0. The third material (11SMnPb30) also showed a minimum FoS of 0 and a similar deformation pattern. The results of this study indicate that the tool materials' performance and tool life can be predicted accurately using computational methods, confirming the reliability of Solid Works modeling in evaluating tool behavior. This approach helps optimize material selection and improve the efficiency of the drilling process.

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