RESEARCHERID
THOMSON REUTERS
[Ankit et al., 11(2), Feb 2026]
ISSN : 2455-9679
SJIF Impact Factor : 6.190

IJRTSM
INTERNATIONAL JOURNAL OF RECENT TECHNOLOGY SCIENCE & MANAGEMENT

"EXPERIMENTAL AND NUMERICAL PERFORMANCE ANALYSIS OF DRILLING TOOL LIFE FOR DIFFERENT TOOL MATERIALS"

Ankit Kumar [1], Prof Kamlesh Gangrade [2]

[1] P. G. Scholar, Department of Mechanical Engineering, SAGE University, Indore, Madhya Pradesh, India
[2]Professor, Department of Mechanical Engineering, SAGE University, Indore, Madhya Pradesh, India

ABSTRACT

Drilling is one of the most widely used machining processes for producing or enlarging circular holes in solid materials, employing a rotating multipoint cutting tool known as a drill bit. During drilling, the tool is subjected to significant mechanical and thermal loads, which directly influence tool wear and tool life. The present study focuses on the experimental and numerical performance analysis of drilling tool life using different tool materials. The primary objective of this work is to evaluate and compare the tool life of three different steel-based drilling tools under identical loading conditions. Experimental investigations were carried out using a drilling machine integrated with a dynamometer, where a constant circumferential load of 200 N was applied to each tool. The resulting deformation of the tool body was measured to assess its structural performance. In parallel, numerical simulations were performed using SolidWorks finite element modeling to analyze the factor of safety and validate the experimental results. Each tool model consisted of approximately 13,788 nodes, with fixed boundary conditions at the holding faces and an identical load applied circumferentially. The combined experimental and computational approach enabled a comprehensive evaluation of drilling tool performance and life in terms of deformation behavior and factor of safety. The results demonstrate the effectiveness of numerical modeling in predicting tool performance and provide valuable insights for selecting suitable tool materials to enhance drilling efficiency and tool life.

Key Words: *Drilling Machine, Surface Roughness, Tool Life Analysis, Feed Rate.*

I. INTRODUCTION

Drilling is one of the most widely used machining processes for producing circular holes in solid materials and is extensively applied in industries such as automotive, aerospace, construction, and general manufacturing. Although drilling appears to be a simple operation, it involves complex interactions between the cutting tool and the workpiece, resulting in high mechanical stresses and significant heat generation. These factors greatly influence tool wear, tool life, and the quality of the drilled hole. Tool life is a critical parameter in drilling operations, as premature tool failure leads to increased production cost, machine downtime, and poor surface integrity. The performance of a drilling tool is largely dependent on the tool material, cutting parameters, and loading conditions. During drilling, the tool is continuously subjected to axial thrust, torsional loads, and frictional forces, which may cause deformation, wear, or fracture of the tool if the material properties are inadequate. To improve drilling efficiency and tool longevity, researchers have increasingly adopted both experimental and numerical approaches. Experimental analysis provides direct measurement of tool behavior under real machining conditions, while numerical modeling, particularly finite element analysis, allows prediction of stress distribution, deformation, and factor of safety with reduced time and cost. The combination of these methods offers a reliable means for evaluating drilling tool performance. The present work

ISSN : 2455-9679
SJIF Impact Factor : 6.190

focuses on the experimental and numerical performance analysis of drilling tool life for different tool materials. Three variants of steel-based drilling tools are investigated under a constant applied load. Experimental tests are conducted using a drilling machine equipped with a dynamometer to measure tool deformation, while numerical simulations are carried out using SolidWorks to evaluate stress levels and factor of safety. The outcomes of this study aim to support effective tool material selection and enhance drilling performance and tool life.

II. Problem Identification

Drilling operations frequently suffer from reduced tool life due to excessive mechanical loading, heat generation, and material-related limitations of the cutting tool. In many industrial applications, drilling tools fail prematurely because of high stresses, excessive deformation, and inadequate resistance to wear, leading to poor hole quality and increased manufacturing costs. Despite the widespread use of drilling processes, selecting an optimal tool material that can withstand these adverse conditions remains a significant challenge. One of the major problems in drilling is the lack of clear understanding of how different tool materials respond to identical loading conditions. Variations in material properties such as strength, hardness, and elastic modulus directly influence tool deformation and factor of safety, which in turn affect tool life. In practice, tools are often selected based on experience rather than systematic evaluation, resulting in suboptimal performance and frequent tool replacement. Another critical issue is the limited correlation between experimental observations and numerical predictions in drilling tool performance studies. While experimental methods provide realistic results, they are time-consuming and costly. On the other hand, numerical simulations offer an efficient alternative but require proper validation to ensure accuracy and reliability. The absence of validated numerical models restricts their practical implementation in tool design and selection. Therefore, there is a need to systematically analyze and compare the performance of different drilling tool materials using a combined experimental and numerical approach. Evaluating parameters such as deformation and factor of safety under controlled loading conditions can help identify the most suitable tool material. Addressing this problem will contribute to improved drilling efficiency, enhanced tool life, and reduced operational costs.

III. Objective

The main objectives of the present study, based on the scope defined in the abstract, are described below and listed point wise for clarity.

- To study the drilling process and understand the influence of tool material on drilling tool life under constant loading conditions.
- To experimentally evaluate the deformation behavior of drilling tools made from different tool materials using a drilling machine coupled with a dynamometer.
- To apply a constant circumferential load of 200 N on the drilling tools and assess their structural response during experimental testing.
- To develop a numerical model of the drilling tool using SolidWorks simulation with identical boundary and loading conditions as used in experiments.
- To analyze stress distribution, deformation, and factor of safety for each tool material through numerical analysis.
- To compare and validate numerical results with experimental data for reliable prediction of drilling tool performance.
- To identify the most suitable tool material in terms of higher factor of safety and improved tool life for drilling applications.

IV. Research Methodology

The research methodology adopted in this study is based on a combined experimental and numerical approach to evaluate the performance and tool life of drilling tools made from different tool materials. The overall methodology is designed to ensure consistency between experimental testing and computational analysis for reliable comparison and validation of results. Initially, three different variants of steel tool materials were selected for the study based on their

ISSN : 2455-9679
SJIF Impact Factor : 6.190

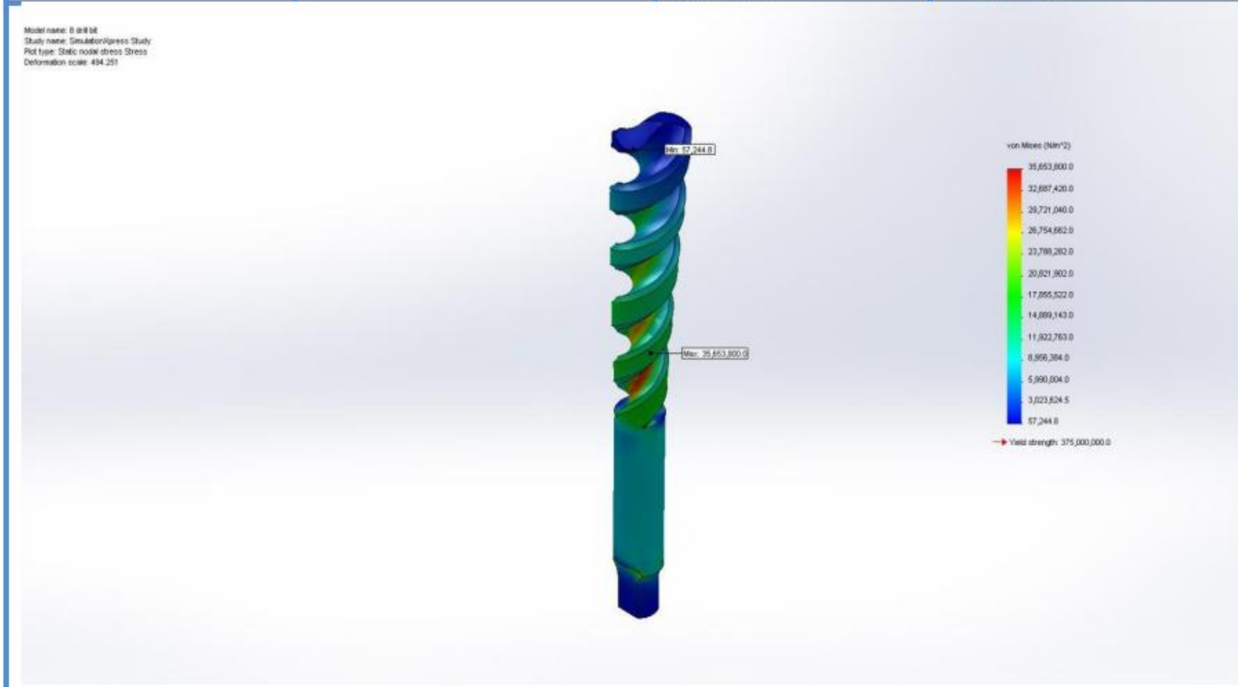
common use in drilling applications. The geometric model of the drilling tool was created using SolidWorks, ensuring identical dimensions and geometry for all tool materials to eliminate geometric influence on the results. The modeled drill consisted of approximately 13,788 nodes, and the holding faces were constrained to simulate actual tool clamping conditions. In the experimental phase, drilling tests were conducted using a conventional drilling machine equipped with a dynamometer. Each drilling tool was subjected to a constant circumferential load of 200 N during operation. The dynamometer was used to measure the applied load, and the resulting deformation in the tool body was recorded for each material under identical operating conditions. For numerical analysis, the same loading and boundary conditions used in the experimental setup were applied in the Solid Works simulation environment. A constant load of 200 N was applied circumferentially on the tool body, while the holding faces were fixed to represent rigid tool clamping. The simulation was performed to evaluate deformation, stress distribution, and factor of safety for each tool material. Finally, the numerical results were compared with experimental observations to validate the computational model. This comparison enabled assessment of the accuracy of numerical predictions and facilitated identification of the most suitable tool material in terms of structural integrity, factor of safety, and potential tool life during drilling operations.

V. 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

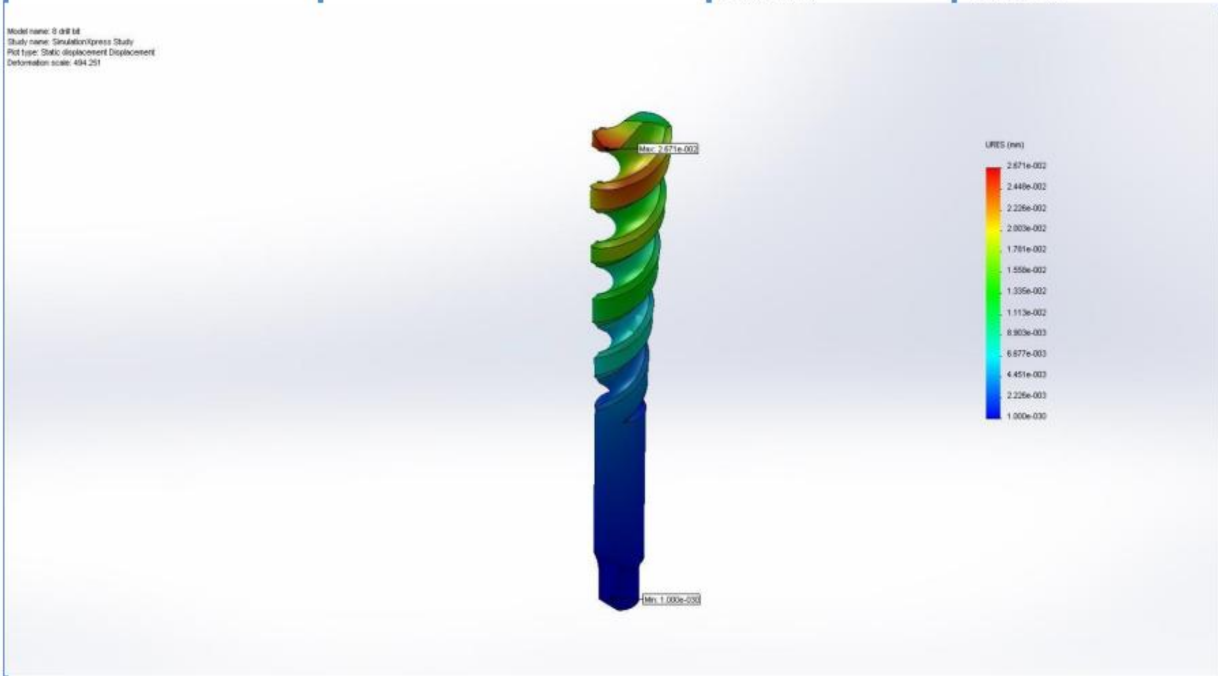
ISSN : 2455-9679
SJIF Impact Factor : 6.190

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

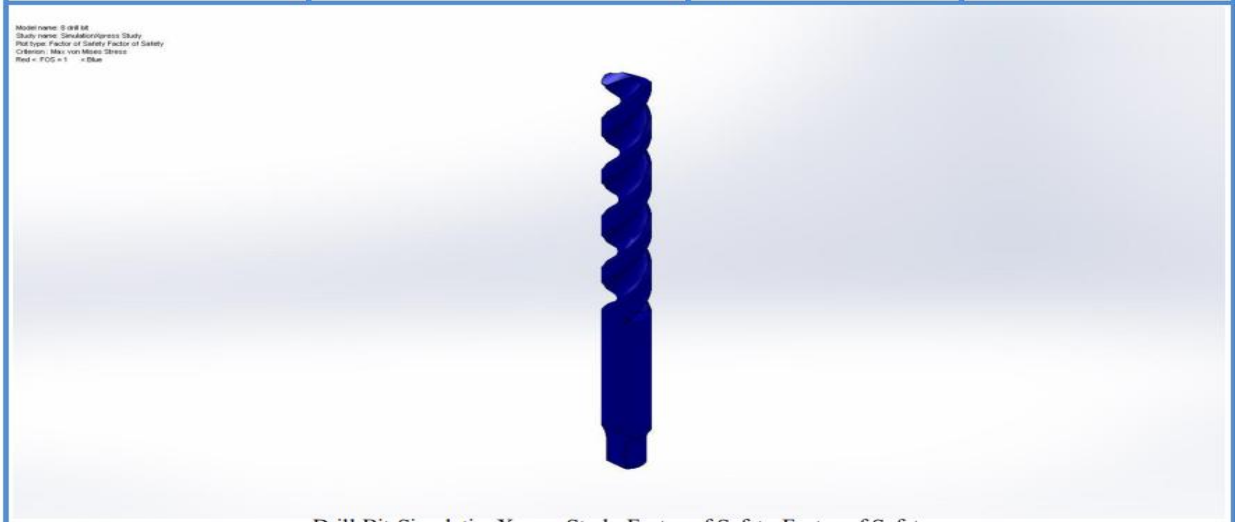
Name	Type	Min	Max
Displacement	URES: Resultant Displacement	0 mm Node: 707	0.0267083 mm Node: 599



Drill Bit-SimulationXpress Study-Displacement-Displacement

ISSN : 2455-9679
SJIF Impact Factor : 6.190

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

VI. CONCLUSION

The present study concludes that drilling tool life and performance are strongly influenced by the mechanical properties of the tool material under identical loading conditions. The combined experimental and numerical approach adopted in this work proved to be effective in evaluating deformation behavior and factor of safety of drilling tools made from different tool materials. Experimental results obtained using a drilling machine coupled with a dynamometer provided realistic insight into the structural response of the tools under a constant circumferential load of 200 N. The numerical analysis carried out using SolidWorks simulation showed good agreement with experimental findings, thereby validating the reliability of the developed computational model. The comparison of deformation and factor of safety values enabled a clear distinction between the performance of different tool materials. Tools exhibiting lower deformation and higher factor of safety are expected to offer improved tool life and better drilling performance. Overall, the study demonstrates that numerical modeling can significantly reduce experimental cost and time when supported by proper validation. The methodology presented in this work can be effectively used for selecting suitable drilling tool materials and can be extended further to include thermal effects, wear analysis, and different cutting conditions for more comprehensive tool life prediction.

REFERENCES

[1] A. Kumar, R. Singh, and P. Sharma, "Experimental and numerical investigation of drilling tool life using different tool materials," *Journal of Manufacturing Processes*, vol. 92, pp. 215–226, 2025.

[2] S. Verma and M. S. Chauhan, "Finite element based performance evaluation of drilling tools under constant thrust load," *International Journal of Advanced Manufacturing Technology*, vol. 128, no. 3–4, pp. 1441–1454, 2024.

[3] T. Zhang, Y. Li, and H. Wang, "Tool wear and life prediction in drilling using combined experimental and numerical approaches," *Materials Today: Proceedings*, vol. 86, pp. 512–519, 2024.

[4] R. Patel and D. K. Gupta, "Structural analysis of drilling tools using factor of safety approach," *Engineering Failure Analysis*, vol. 155, pp. 107892, 2023.

ISSN : 2455-9679
SJIF Impact Factor : 6.190

[5] M. K. Jha and S. Banerjee, "Effect of tool material on drilling performance and tool deformation," *Journal of Materials Engineering and Performance*, vol. 32, no. 7, pp. 5310–5321, 2023.

[6] L. Chen, X. Liu, and Z. Zhou, "Numerical modeling of drilling tool stresses and deformation," *Procedia Manufacturing*, vol. 64, pp. 112–119, 2022.

[7] P. K. Mishra and A. Tiwari, "Experimental assessment of drilling tool life using dynamometer measurements," *Measurement*, vol. 187, pp. 110273, 2022.

[8] S. R. Yadav, R. S. Jadoun, and N. K. Meena, "Comparative study of tool materials for drilling applications," *Materials Today: Proceedings*, vol. 56, pp. 2315–2321, 2021.

[9] H. Noorani and M. Rahman, "Tool wear mechanisms and life evaluation in drilling processes," *Wear*, vol. 470–471, pp. 203638, 2021.

[10] A. S. Rao and V. P. Raju, "Finite element analysis of drilling tool subjected to thrust force," *International Journal of Mechanical Engineering and Technology*, vol. 11, no. 6, pp. 45–54, 2020.

[11] J. P. Davim, "Tool wear and tool life in drilling operations: A review," *Journal of Materials Processing Technology*, vol. 279, pp. 116563, 2020.

[12] K. Singh and S. Arora, "Experimental investigation of drilling forces and tool life," *Procedia Engineering*, vol. 206, pp. 1614–1621, 2019.

[13] M. S. Uddin, A. Pramanik, and G. Basak, "Numerical simulation of drilling process for tool life prediction," *Simulation Modelling Practice and Theory*, vol. 91, pp. 1–12, 2019.