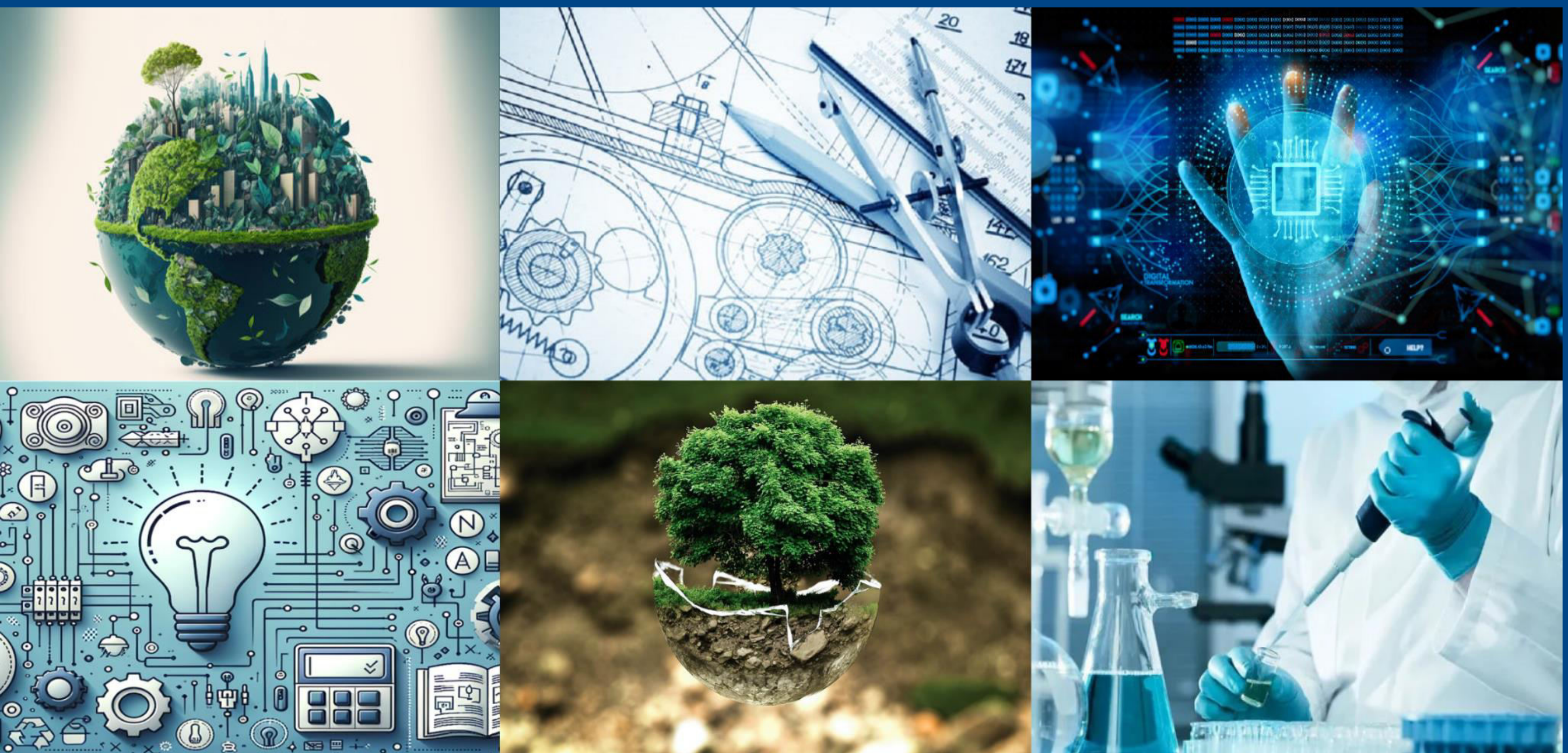
ISSN: 2582-7219

# International Journal of Multidisciplinary Research in Science, Engineering and Technology

*(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)*



Impact Factor: 9.864

Volume 9, Issue 7, July 2026

www.ijmrset.com ijmrset@gmail.com +91 6381 907 438 +91 63819 07438

© 2026 IJMRSET | Volume 9, Issue 7, July 2026| DOI:10.15680/IJMRSET.2026.0907015

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 9.864| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

# Investigation of Tool Wear Behaviour by experimental and FEA Methods

**Snehal Patil, Dr. Prashantkumar Bajaj**

PG Student, Dept. of Mech Engineering., Shri Sant Gadge Baba College of Engineering & Technology, Bhusawal, India

Associate Professor, Dept. of Mech Engineering, Shri Sant Gadge Baba College of Engineering & Technology, Bhusawal, India

**ABSTRACT:** Hard turning of hardened steels is extensively employed in the manufacturing of dies, molds, and precision engineering components because of the superior mechanical properties of these materials. However, the high hardness of hardened steels leads to severe cutting conditions, resulting in rapid tool wear, increased cutting forces, and reduced machining efficiency. Therefore, evaluating the wear characteristics of cutting tools and optimizing machining parameters are essential for improving productivity and extending tool service life. The present study investigates the wear behaviour of coated carbide inserts during the turning of hardened AISI D2 steel by integrating experimental machining with finite element analysis (FEA). The effects of cutting speed, feed rate, and depth of cut on flank wear, material removal rate (MRR), and tool life were systematically examined under dry machining conditions. Finite element simulations were performed to analyse the stress and thermal distribution developed at the cutting zone and to validate the experimental observations. A Taguchi design of experiments was employed to determine the optimal machining parameters that minimize tool wear while maintaining satisfactory machining performance. The experimental and numerical results indicate that machining parameters significantly influence the wear behaviour of the cutting insert. Higher cutting speeds improve material removal capability but also increase the thermal and mechanical loads acting on the cutting edge, thereby accelerating wear progression. Feed rate and depth of cut also contribute to variations in cutting performance and tool durability. The comparison between experimental measurements and FEA predictions demonstrates good agreement, confirming the effectiveness of numerical modelling for analysing machining behaviour. The outcomes of this research provide practical guidelines for selecting suitable machining parameters to enhance productivity, improve surface quality, and increase the service life of coated carbide inserts during the turning of hardened AISI D2 steel.

**KEYWORDS**: Tool wear, Hard turning, AISI D2 steel, Coated carbide inserts, Finite Element Analysis, Taguchi method

## I. INTRODUCTION

The machining of hardened steels has become increasingly important in modern manufacturing because of the growing demand for high-strength and wear-resistant components in the automotive, aerospace, tooling, and die industries. Although these materials provide excellent mechanical properties and long service life, their high hardness makes machining difficult by increasing cutting forces, temperature, and tool wear. Turning is one of the most widely used machining processes for producing cylindrical components with high dimensional accuracy and good surface finish. The machining performance is significantly influenced by cutting speed, feed rate, and depth of cut, which directly affects tool life, material removal rate (MRR), and surface quality. Therefore, selecting appropriate machining parameters is essential for improving productivity and reducing machining costs. Tool wear is one of the major factors affecting machining efficiency during the turning of hardened steels. Coated carbide inserts are widely used because of their high hardness, wear resistance, thermal stability, and cost-effectiveness. Their performance depends on machining conditions and the interaction between the cutting tool and the workpiece. Finite Element Analysis (FEA) has become an effective tool for analyzing machining processes by predicting stress, temperature, and wear behaviour under different cutting conditions. The integration of experimental investigation with FEA provides a reliable approach for evaluating tool performance and optimizing machining parameters. Therefore, the present study investigates the wear behaviour of coated carbide inserts during the turning of hardened AISI D2 steel using both experimental analysis and finite element modelling to improve tool life and machining performance.

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 9.864| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

## II. LITERATURE REVIEW

Machining difficulty machine materials is the emerging topic of today's industry. Turning is a material removal process which employs a single point cutting tool for machining materials possesses different hardness. The flexibility and ability to manufacture complex shapes is one of the major advantages of turning compared to other machining processes. Tool wear caused by hardness of workpiece material is the emerging areas of research in turning process. Several researchers have contributed to study the influence of process parameters on tool wear while machining different grades of steel materials. Authors studied the wear behaviour of CBN tools and coated carbide tools while machining different grades of hardened steel and hardened AISI 4340 steel respectively. An attempt has been made to study the influence of process parameters on tool wear using PCBN tool, patterned and non-patterned tool inserts and using CVD coated carbide tools.

**Research Gap and Objectives:**

The literature indicates that considerable research has been conducted on optimizing machining parameters using the Taguchi method to improve surface finish and reduce tool wear during the turning of hardened steels. Previous studies have mainly focused on the influence of cutting speed, feed rate, and depth of cut on machining performance using different cutting tool materials. However, limited research has investigated the combined experimental and finite element analysis (FEA) of coated carbide insert wear during the turning of hardened AISI D2 steel. Therefore, further investigation is required to correlate machining parameters with tool wear behaviour and improve tool life.

**Objectives:**

- To investigate the influence of cutting speed, feed rate, and depth of cut on tool wear during the turning of hardened AISI D2 steel.
- To evaluate the performance of CVD-coated carbide inserts under different machining conditions.
- To analyse tool wear behaviour using both experimental investigation and finite element analysis (FEA).
- To optimize machining parameters for improved tool life and machining performance using the Taguchi method.

## III. METHODOLOGY OF PROPOSED SURVEY

The experimental investigation was carried out to evaluate the wear behaviour of coated carbide inserts during the turning of hardened AISI D2 steel. The workpiece material possessed a hardness of approximately 66 HRC, making it suitable for hard turning applications. Owing to its excellent wear resistance, compressive strength, and dimensional stability, AISI D2 steel is extensively used in the manufacturing of dies, molds, punches, gears, bearings, and precision engineering components. However, its high hardness makes machining difficult and results in rapid tool wear under severe cutting conditions. The machining experiments were performed under dry cutting conditions using a CNC turning machine equipped with a CVD-coated carbide insert. Dry machining was selected to eliminate the influence of cutting fluids and to evaluate the actual wear characteristics of the cutting tool. The machining parameters selected for this investigation were cutting speed, feed rate, and depth of cut, as these variables significantly influence cutting forces, heat generation, material removal rate, and tool life. The Taguchi Design of Experiments (DOE) was adopted to design the experimental trials using an orthogonal array. This statistical approach minimizes the number of experiments while providing reliable information about the influence of machining parameters on the response variables. The performance of the cutting tool was evaluated by measuring flank wear (VB), material removal rate (MRR), and tool life after each machining trial. Flank wear was considered the primary criterion for evaluating tool performance because it directly affects machining accuracy, surface quality, and dimensional tolerance. Finite Element Analysis (FEA) was carried out to simulate the machining process and to study the distribution of stress, strain, and temperature at the tool–workpiece interface. The numerical model was developed by considering the material properties of both the workpiece and the cutting insert under actual machining conditions. The simulation results were compared with the experimental observations to validate the accuracy of the numerical model. The influence of different machining parameters on tool wear and machining performance was analysed using both experimental data and simulation results. The combined experimental and numerical approach provides a comprehensive understanding of the wear mechanisms occurring during hard turning. The findings of this methodology can be used to optimize machining conditions, improve tool life, reduce production costs, and enhance productivity in industrial machining applications. Furthermore, the proposed methodology offers a reliable framework for future investigations involving advanced cutting tool materials and difficult-to-machine alloys.

 DOI:10.15680/IJMRSET.2026.0907015

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 9.864| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

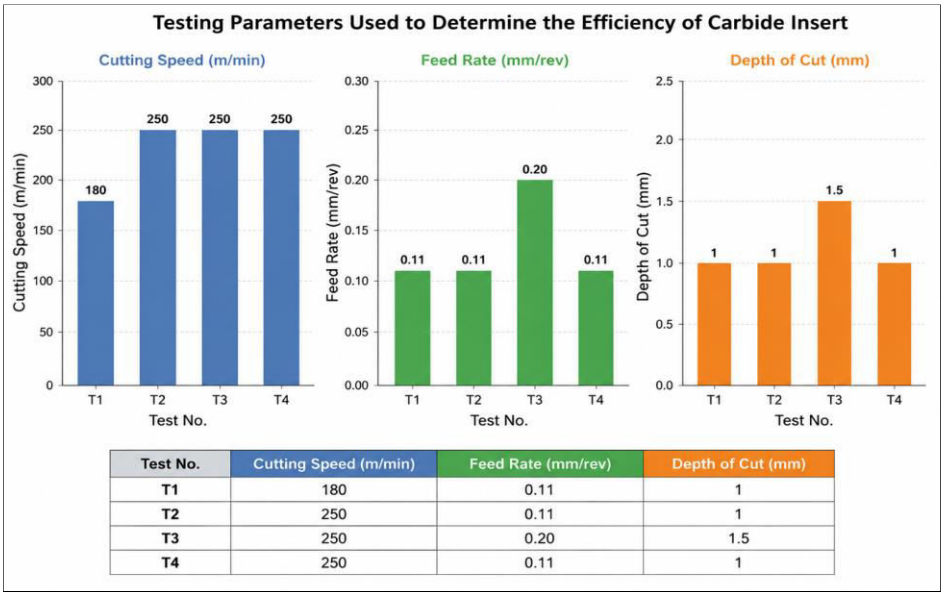
(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

**Finite Element Analysis**:

Finite Element Analysis (FEA) is a powerful numerical simulation technique widely used to investigate the mechanical and thermal behaviour of engineering components under different operating conditions. In machining applications, FEA helps predict stress distribution, strain, temperature, cutting forces, and tool wear without conducting a large number of experimental trials. The integration of experimental investigations with finite element simulations improves the understanding of machining behaviour and supports the optimization of cutting parameters. In the present study, FEA was employed to analyse the wear behaviour of the coated carbide insert during the turning of hardened AISI D2 steel. A three-dimensional numerical model of the cutting tool and workpiece was developed using suitable material properties and machining conditions. The cutting speed, feed rate, and depth of cut used in the simulation were selected according to the experimental design. Appropriate boundary conditions and contact interactions were defined to accurately represent the machining process. The finite element model was used to evaluate the distribution of stress, strain, and temperature at the tool–workpiece interface. These parameters play an important role in understanding the wear mechanism and predicting tool performance under different cutting conditions. The simulation results were compared with the experimental observations to validate the numerical model and assess its accuracy. A close agreement between the experimental and simulation results confirms the effectiveness of the FEA approach for analysing machining performance and predicting tool wear.

## IV. CONCLUSION AND FUTURE WORK

The cutting parameters such as cutting speed, feed rate, depth of cut has been tested at some specific parameters using the insert are given in the table 1. as follows. The cutting parameters are used in the calculations of theoretical, practical and finite element analysis.




| Test No. | Cutting Speed (m/min) | Feed Rate (mm/rev) | Depth of Cut (mm) |
|---|---|---|---|
| T1 | 180 | 0.11 | 1 |
| T2 | 250 | 0.11 | 1 |
| T3 | 250 | 0.20 | 1.5 |
| T4 | 250 | 0.11 | 1 |

**Table 1. Testing parameters used to determine the efficiency of carbide insert**

The influence of process parameters on MRR and tool wear are calculated in table such as the comparison of the finite element analysis calculations, theoretical calculations and the practical calculations. Temperature is taken stable at 35℃ in all the experiments.

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 9.864| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

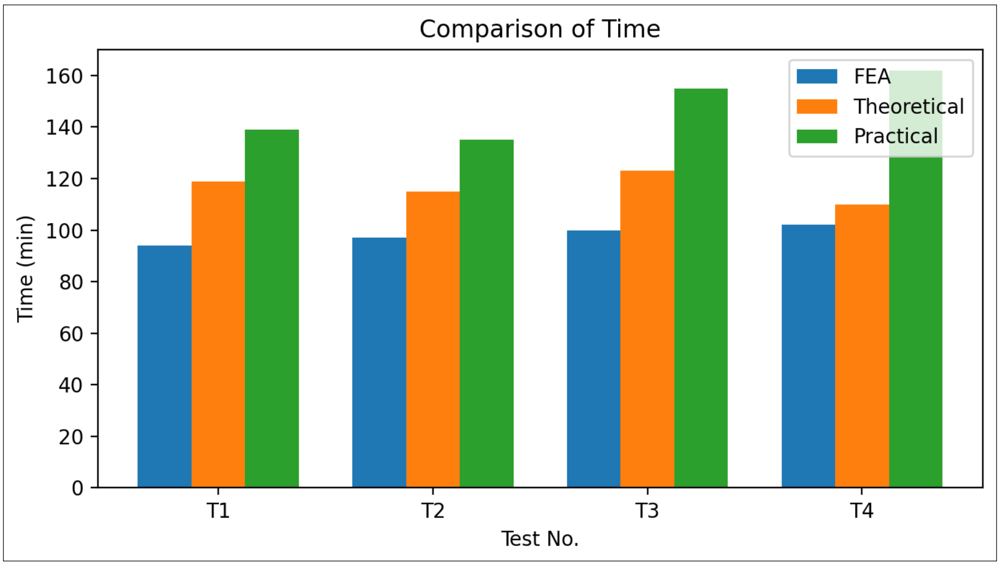



**Table 2. Result table**

## REFERENCES

[1] Baldonado, M., Chang, C.-C.K., Gravano, L., Paepcke, A.: The Stanford Digital Library Metadata Architecture. Int. J. Digit. Libr. 1 (1997) 108–121
[2] Yen, Y. C., Söhner, J., Lilly, B., & Altan, T. (2004). Estimation of tool wear in orthogonal cutting using the finite element analysis. Journal of Materials Processing Technology, 146(1), 82–91. DOI: 10.1016/S0924-0136(03)00847-1
[3] Attanasio, A., Ceretti, E., Umbrello, D., & Cappellini, C. (2016). An FEM-based approach for tool wear estimation in machining. Wear, 368–369, 10–24. DOI: 10.1016/j.wear.2016.08.007
[4] Usui, E., Shirakashi, T., & Kitagawa, T. (1984). Analytical prediction of cutting tool wear. Wear, 100, 129–151.
[5] Lin, J., & colleagues (2005). Modeling flank wear of carbide tool insert in metal cutting. Wear, 259, 1235–1240. DOI: 10.1016/j.wear.2005.02.044
[6] Molinari, A., & Nouari, M. (2002). Modeling of tool wear by diffusion and adhesion mechanisms. Cappellini, C., & Abeni, A. (2022).


INTERNATIONAL JOURNAL OF

MULTIDISCIPLINARY RESEARCH

IN SCIENCE, ENGINEERING AND TECHNOLOGY

| Mobile No: +91-6381907438 | Whatsapp: +91-6381907438 | ijmrset@gmail.com |

www.ijmrset.com