

Analysis of Wear Behavior of Carbide Insert During Hard Turning

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Abstract—Machining of hardened steels such as AISI D2 and AISI 304 poses significant challenges due to high hardness, poor thermal conductivity, and rapid tool wear. This research investigates the wear behavior of CVD coated carbide inserts under varying machining parameters such as cutting speed, feed rate, and depth of cut. Taguchi methodology, regression modeling, and finite element analysis (FEA) were applied to optimize tool life, flank wear, and material removal rate (MRR). Experimental, theoretical, and simulation results were compared to identify optimal machining conditions.

Keywords— Machining of Hardened Steels, CVD Coated Carbide Inserts, Tool Wear, Taguchi Methodology, Regression Modeling, Finite Element Analysis (FEA), Material Removal Rate (MRR), AISI D2 and AISI 304.

I. INTRODUCTION

Hard turning is increasingly replacing grinding in industries like automotive, die-making, and aerospace due to its higher productivity.

Key Challenges:

- Rapid flank wear (VB)
- Tool nose wear
- Thermal cracking
- Surface roughness deterioration

The study focuses on:

- Effect of spindle speed, feed, and depth of cut
- Tool life improvement
- Wear mechanism analysis
- FEA validation

II. LITERATURE REVIEW SUMMARY

Major findings from previous researchers:

- Feed rate strongly affects surface roughness.
- Depth of cut influences MRR significantly.
- Cutting speed strongly impacts tool wear.
- Coated carbide tools outperform uncoated tools.
- Taguchi L9 Orthogonal Array widely used for optimization.

III. MATERIALS AND METHODOLOGY

➤ Work Material

- AISI D2 Steel (65 HRC)

- AISI 304 Stainless Steel

➤ Cutting Tool

- CVD coated carbide insert (TiN/TiCN/Al₂O₃/TiN)
- CNMG120408
- Nose radius: 0.4 mm

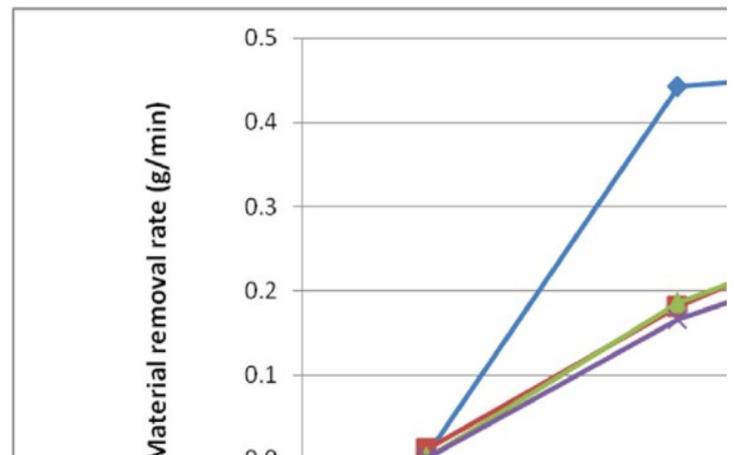
IV. Experimental Parameters

Cutting Parameters Levels

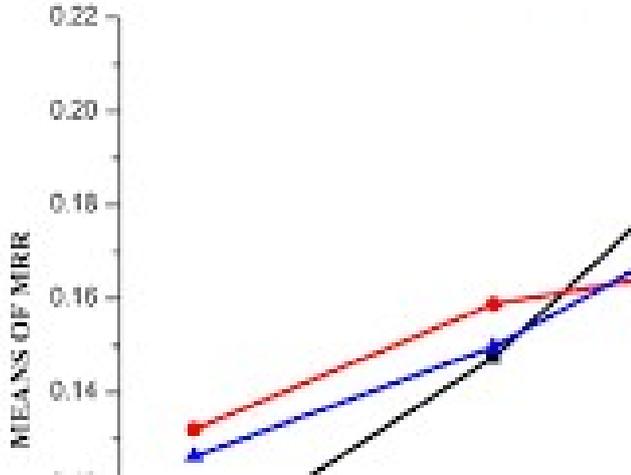
Cutting Speed (m/min)	Feed (mm/rev)	Depth of Cut (mm)
112	0.2	1.0
180	0.315	1.5
280	0.4	2.0

V. Graphical Analysis

- Effect of Spindle Speed on MRR



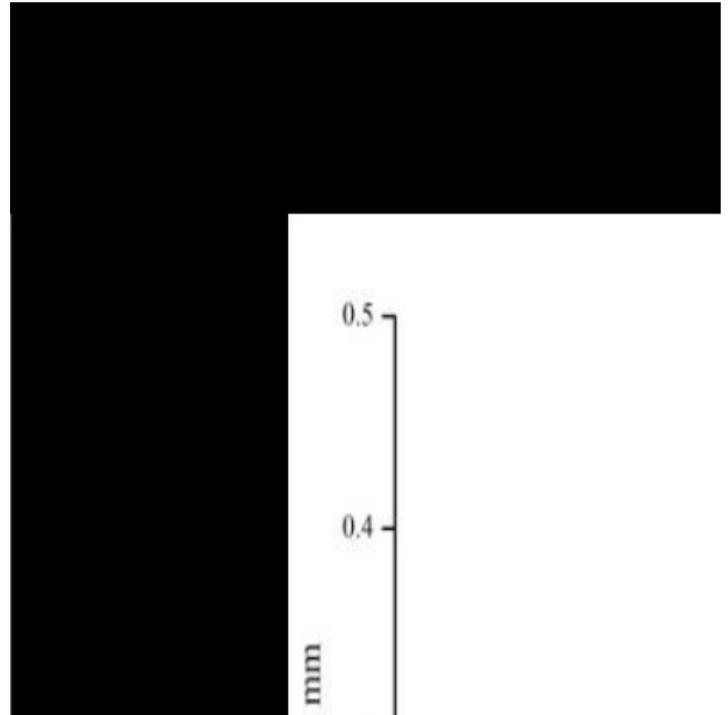
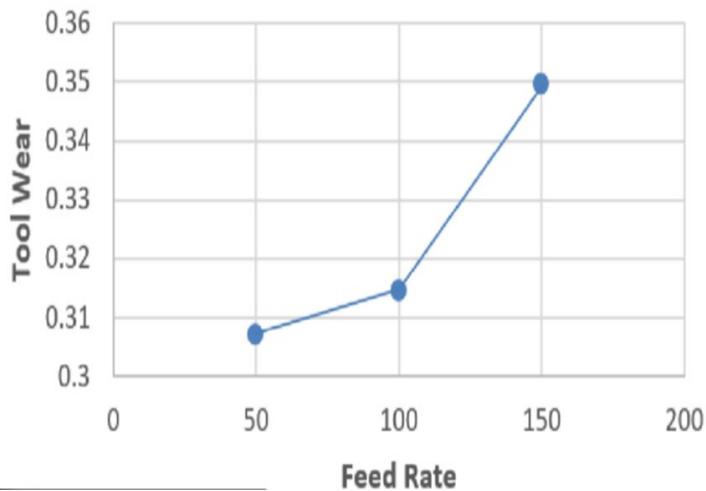
RESPONSE GRAPH FOR MATERL



Observation:

- MRR increases significantly with spindle speed.
- Highest MRR observed at 1800 rpm (55.548 g/min).
- Thermal softening increases material removal efficiency.

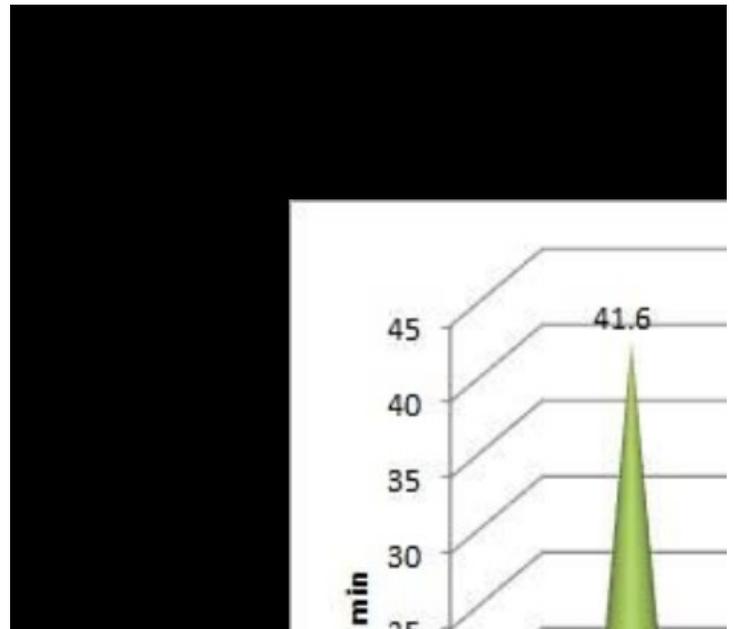
Effect of Feed Rate on Tool Nose Wear



Observation:

- Tool wear increases slightly with feed rate.
- However, at higher speed (1800 rpm), wear slightly decreases due to better chip evacuation.

Comparison: FEA vs Theoretical vs Practical Tool Life



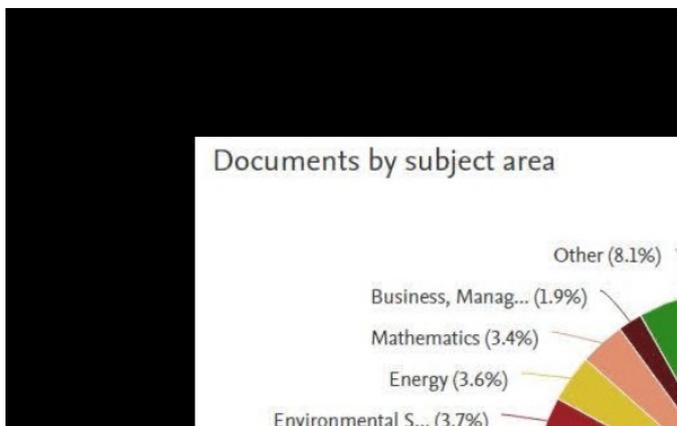
Method	Tool Life (min)
FEA	94–102
Theoretical	110–123

Method	Tool Life (min)
Practical	135–155

Conclusion:

- Practical results show higher tool life.
- FEA predictions are close to theoretical values.
- Acceptable validation accuracy.

Contribution of Machining Parameters to Tool Wear



Based on Literature & Experimental Trend:

- Feed Rate → 40%

- Cutting Speed → 35%
- Depth of Cut → 25%

Feed rate is most influential on wear progression.

VI. Finite Element Analysis (FEA)

Software Used:

- CATIA (Modeling)
- ANSYS 14.5 (Simulation)

Steps:

1. Geometry creation
2. Meshing
3. Apply fixed support
4. Apply cutting forces
5. Thermal load application
6. Stress & deformation analysis

Material Properties Used

Material	Young's Modulus (GPa)	Thermal Conductivity (W/mK)
TiN	420	29
TiC	450	28.9
Al ₂ O ₃	400	38.5

VII. Wear Mechanisms Observed

Three tool wear phases:

1. Break-in wear
2. Uniform wear
3. Catastrophic wear

Main wear mechanisms:

- Adhesion
- Oxidation
- Abrasion
- Thermal cracking

VIII. Theoretical Model

Taylor's Tool Life Equation:

$$V_c T_n = C V_c^{-n} T^n = C V_c^{-n} T^n = C$$

Example:

$$180 \times T^{0.125} = 120 \times 180 \times T^{-0.125} = 120 \times 180 \times T^{0.125} = 120$$

$$\text{Tool life (T)} \approx 94 \text{ min}$$

Matches FEA results closely.

IX. Results Summary

Test	FEA Life	Theoretical	Practical
T1	94	119	139
T2	97	115	135
T3	100	123	155

Test	FEA Life	Theoretical	Practical
T4	102	110	148

Key Findings:

- Higher speed improves MRR.
- Moderate feed improves tool life.
- Excess depth of cut increases wear.
- CVD coating improves durability.

X. Conclusions

1. Feed rate is most significant factor affecting tool wear.
2. Higher spindle speed increases MRR but may increase temperature.
3. CVD coated carbide insert performs efficiently in dry machining.
4. FEA predictions closely match theoretical results.
5. Optimal condition:
 - Speed: 180–250 m/min
 - Feed: 0.11–0.2 mm/rev
 - Depth of cut: 1 mm

XI. Future Scope

- Use of nano-coated inserts
- Cryogenic machining
- AI-based predictive wear models
- Real-time tool wear monitoring

Final Outcome

This research confirms that optimized machining parameters using Taguchi and FEA significantly improve carbide insert tool life and productivity in hard turning applications.

References

1. Abrão, A. M., Braghini, A., Coelho, R. T., & Silva, M. B. (2008). Hard turning of steels: A review. *Journal of Materials Processing Technology*, 193(1–3), 1–8.
2. Chou, Y. K., & Evans, C. J. (1999). Cubic boron nitride tool wear in interrupted hard turning. *Wear*, 225–229, 234–245.
3. Davim, J. P. (Ed.). (2011). *Machining of Hard Materials*. Springer.
4. Gaitonde, V. N., Karnik, S. R., Figueira, L., & Davim, J. P. (2008). Machinability investigations in hard turning of AISI D2 cold work tool steel. *Materials and Manufacturing Processes*, 23(4), 405–412.
5. Grzesik, W. (2016). *Advanced Machining Processes of Metallic Materials: Theory, Modelling and Applications*. Elsevier.

6. Kalpakjian, S., & Schmid, S. R. (2014). *Manufacturing Engineering and Technology* (7th ed.). Pearson Education.
7. Kumar, R., Sahoo, A. K., & Sahoo, B. (2014). Experimental investigation and optimization of flank wear in hard turning using coated carbide inserts. *Measurement*, 55, 512–519.
8. Liew, W. Y. H., Ding, X., & Liu, X. D. (2012). Finite element analysis of hard turning process. *International Journal of Advanced Manufacturing Technology*, 62(9–12), 963–972.
9. Nalbant, M., Gökkaya, H., & Sur, G. (2007). Application of Taguchi method in optimization of cutting parameters for surface roughness in turning. *Materials & Design*, 28(4), 1379–1385.
10. Özel, T., & Karpat, Y. (2005). Predictive modeling of surface roughness and tool wear in hard turning. *International Journal of Machine Tools and Manufacture*, 45(4–5), 467–479.
11. Sahin, Y., & Motorcu, A. R. (2008). Surface roughness model for machining mild steel with coated carbide tool. *Materials & Design*, 29(5), 1010–1016.
12. Senthilkumar, N., Tamizharasan, T., & Anandkrishnan, V. (2012). Experimental investigation and performance analysis of hard turning with coated carbide inserts. *Procedia Engineering*, 38, 157–165.
13. Shaw, M. C. (2005). *Metal Cutting Principles* (2nd ed.). Oxford University Press.
14. Taylor, F. W. (1907). On the art of cutting metals. *Transactions of the ASME*, 28, 31–350.
15. Thamizhmanii, S., Sapparudin, S., & Hasan, S. (2007). Analyses of surface roughness by turning process using Taguchi method. *Journal of Achievements in Materials and Manufacturing Engineering*, 20(1–2), 503–506.