International Journal of Engineering & Extended Technologies Research (IJEETR)

|ISSN: 2322-0163| www.ijeetr.com | A Bimonthly, Peer Reviewed, Scholarly Indexed Journal |

| Volume 8, Issue 2, March - April 2026 |

DOI:10.15662/IJEETR.2026.0802256

# Improving Surface Finish, Tool Life and Machining Efficiency While Reducing Wear and Material Waste

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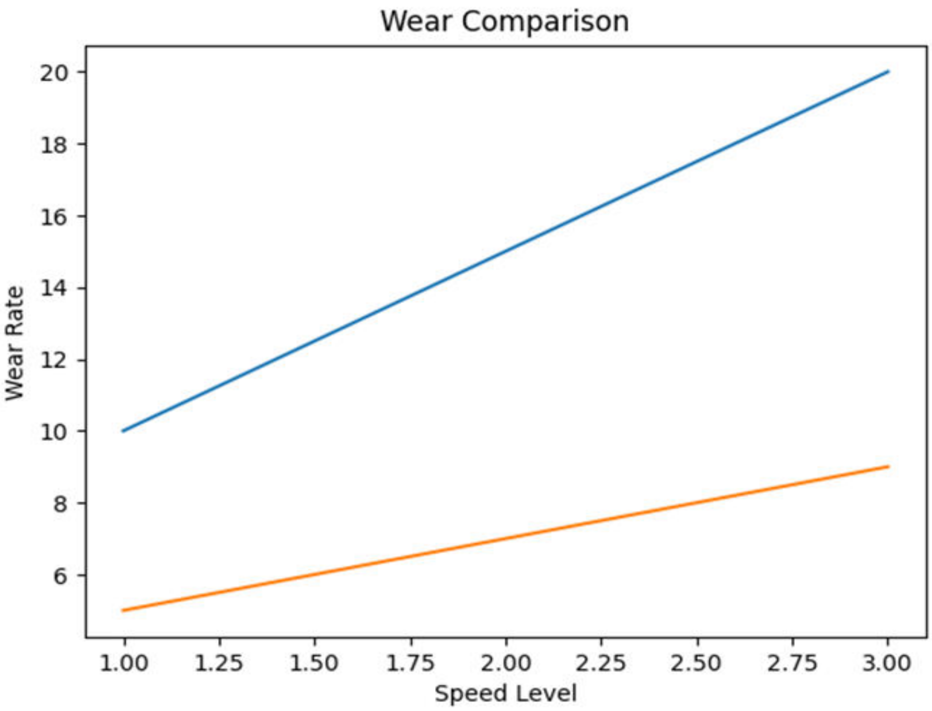
**Publication History:** Received: 25.02.2026; Revised: 20.03.2026; Accepted: 25.03. 2026; Published: 28.03.2026.

**ABSTRACT:** This paper presents a detailed study on improving machining performance using advanced coated cutting tools. The focus is on enhancing surface finish, tool life, and machining efficiency while reducing wear and material waste. Different coatings such as TiAlN, TiCN, and multilayer coatings were analyzed. The results indicate that multilayer coatings significantly improve wear resistance and reduce friction, leading to better machining applications




**KEYWORDS:** Surface finish, tool life, machining efficiency, wear reduction, material waste minimization, cutting parameters, lubrication techniques, tool wear, process optimization, manufacturing sustainability

## I. INTRODUCTION

Modern manufacturing industries demand high productivity, precision, and cost efficiency. Machining processes play a vital role in shaping materials into desired forms. However, challenges such as tool wear, poor surface finish, and excessive heat generation affect machining performance.

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Cutting tool materials have evolved significantly, from High-Speed Steel (HSS) to advanced ceramics and coated carbides. Among these, coated cutting tools have gained prominence due to their ability to withstand high temperatures, reduce friction, and improve durability.

Coatings act as a protective layer between the tool and workpiece, enhancing wear resistance and reducing material loss. This research investigates the effectiveness of multilayer coatings in improving machining performance.

## II. LITERATURE REVIEW

Previous studies highlight the importance of tool coatings in improving machining characteristics. Researchers have explored various coating materials such as TiN, TiAlN, and TiCN for enhancing hardness and wear resistance.

Studies on tribological behavior reveal that coated tools exhibit lower friction and improved thermal stability. Optimization techniques like Taguchi design and ANOVA have been widely used to analyze machining parameters such as cutting speed, feed rate, and depth of cut.

However, there exists a research gap in comparing multilayer coatings with single-layer coatings under varying machining conditions. This study aims to address this gap by evaluating the performance of multilayer coated tools.

## III. MATERIALS AND METHODS

### 3.1 Cutting Tool and Coating

Cutting tool inserts were coated using the Cathodic Arc Evaporation method under PVD technique. The coatings applied include:

- Single layer: TiAlN, TiCN
- Bilayer: TiAlN/WC-C
- Multilayer: TiCN/TiAlN/WC-C

### 3.2 Experimental Setup

Machining experiments were conducted on AISI 1015 steel using CNC turning operations. Key parameters considered:

- Cutting speed
- Feed rate
- Depth of cut
- Nose radius
- Cutting fluid flow rate

### 3.3 Testing Methods

- **Hardness Test:** Vickers microhardness tester
- **Surface Roughness:** Surface roughness tester
- **Wear Analysis:** Pin-on-disc tribometer
- **Coating Thickness:** XRF analysis

### 3.4 Optimization Technique

Taguchi Design of Experiments (DOE) was used with L27 and L18 orthogonal arrays. ANOVA was applied to determine the significance of parameters.

## IV. RESULTS AND DISCUSSION

The experimental results demonstrate significant improvements in machining performance with coated tools.

### 4.1 Wear Resistance

Multilayer-coated tools showed up to **217% improvement** in wear resistance compared to uncoated tools. At higher speeds, wear rate remained minimal.

### 4.2 Surface Roughness

Surface roughness was significantly reduced, achieving values as low as **0.219 µm**, indicating better surface finish.

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**4.3 Friction Characteristics**

The coefficient of friction for multilayer tools was lower (~0.47) compared to uncoated tools (~0.53), indicating smoother machining.

**4.4 Effect of Machining Parameters**

ANOVA results revealed:

- Cutting speed and feed rate significantly affect surface roughness
- Depth of cut influences tool wear
- Coating material plays a critical role in performance

**4.5 Chip Morphology**

Chip analysis showed improved chip formation and reduced deformation in coated tools, contributing to better machining efficiency.

## V. OPTIMIZATION

Taguchi optimization identified optimal conditions for minimizing wear and surface roughness. Key findings:

- Lower feed rate improves surface finish
- Moderate cutting speed enhances tool life
- Multilayer coating provides best overall performance

Signal-to-noise (S/N) ratio analysis confirmed that multilayer coated tools deliver consistent and reliable results under varying conditions.

## VI. CONCLUSION

**6.1 Conclusion**

This study concludes that:

- Multilayer coatings significantly enhance tool life and machining efficiency
- Surface finish improves due to reduced friction and wear
- Taguchi and ANOVA methods effectively optimize machining parameters
- TiCN/TiAlN/WC-C multilayer coating outperforms other coatings

**6.2 Future Scope**

Future research can focus on:

- Nano-coating technologies for further performance improvement
- Application of coatings in high-speed and dry machining
- Integration with AI-based optimization techniques

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