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Research Article

Finite Element Analysis and Wear Rate Analysis of Nano Coated High Speed Steel Tools for Industrial Application

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ABSTRACT

Numerous machining process output metrics may be used to evaluate a material's machinability, with tool life unquestionably being the most popular. The rate of tool wear, which is heavily reliant on the current wear mechanisms, determines the tool life in the main. The problem of tool wear needs to be rectified to improve machining quality such as surface roughness and production time. In this study, the thermal barrier coating (TBC) technique on machining tool (HSS) to improve its effectiveness. Utilizing Zirconia and Chromium-based compounds, the HSS tool have been coated. FEA (ANSYS software) was used to examine the material strength and wear of the suggested HSS tool. The tool life for machining is improved by suggesting these nano coated tools. Through this project's efforts, a cutting-edge tool might also be recommended.

1. INTRODUCTION

High-speed steel (HSS) is a tool material for cutting during machining operations and is often found in drill bits and power-saw blades. The qualities of high-speed steels are derived from either tungsten or molybdenum, frequently from a mixture of the two. Cutting tools still mostly produced of high-speed steels include drills, taps, cutters for milling, tool bits, gear cutters, saw blades, planer and jointer blades, and router bits. HSS tools cannot operate at very high speeds and feeds, as they will overheat and lose their hardness and edge quality. HSS tools also have a lower wear resistance than carbide tools, which means they will wear out faster and require more frequent replacement. For many years, high-speed steel (HSS) with physical vapour deposition-applied TiN coatings have been successfully employed in metal-cutting applications. Numerous studies have been published, and they all demonstrate that TiN coatings frequently result in lower wear rates and typically, lower friction coefficients.

Bovas et al [1] have developed a method to reduce tool wear through nano-coating the tool surface with TiAlN. Wear testing on the pin-on-disc device is carried out by dry sliding conditions. Yugandhar et al [2] was discusses the growth, mechanical, and tribological performance of titanium carbide and titanium nitride nanomaterial coatings on tungsten carbide cutting tools. According to Vikas et al. [3], it has been difficult to analyse a multi-point milling cutter using FEA because cutting tools wear out and shatter. This problem has been explored the tool wear. Kyung [4] since the coating deposition methods themselves are beneficial, under different cutting circumstances, the dual layer coating proved greater than the investigated three-layered coating. To improve the mechanical and tribological qualities of the material and to increase the lifespan of the cutting tool, a coating is employed as an alternative. Using multiple-layer coatings the study of hierarchical structures is still in its infancy and needs more time. The Layers can be mixed with various materials and thicknesses to maximize the effectiveness of the cutting instruments. This hierarchical structure can increase the strength and hardness of the coating, minimize wear, and stop crack propagation depending on the material and layer thickness [5]. Ninga et al [6] recommended to improve cutting tool life is required under the severe situations involved with dry cutting of hardened steels. When operating at temperatures exceeding 1000°C, this tool has to have a strong protective covering that is better suited to shield a strong and resilient substrate. The coaters must simultaneously utilize all of the benefits of all crucial coating components (Ti, Al, Cr, and Si) in order to perfect the coating process [7]. A ball on disk wear test and other characterization techniques were used to examine the evolution of the friction coefficient of the TiN coating [8]. Chegdani et al. [9] investigated the cutting behaviours of untreated tungsten carbide tools and those of both

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TiB_2-coated and diamond-coated tools were compared in order to examine the impacts of coated tools on the effectiveness of milling UDF/PP profiles. During the current study, dry cutting conditions were used to test both the up-milling and down-milling configurations.
The cathodic are evaporation procedure was used to bond the TiAIN/ALCrN bilayer coating of the tungsten carbide tool substrates, and the coating characteristics were investigated [10]. Impact of cutting depth, speed of cutting and feed on performance attributes in finish hard turning of AISI 52100 bearing steel using CBN tool [11]. High speed steel and tungsten carbide were studied as two separate cutter materials to analyze a load action [12]. In order to match a tool's axial profile to a drill with a certain cross-section profile, Agullo-Bathe et al. [14] indicate that this must be done. The investigation was carried out by switching the performance of hardening temperature in low- to medium-carbon steel operations [15]. The investigation was carried by in the high-speed cutting area has a significant impact on the tool-chip interaction. The amount of heat that is entered into the cutting tool from the secondary heat source rises as the cutting speed and contact area increase [16]. Natural materials are used to enhance the hardness and wear resistance of steel [17, 18]. An investigation of a multilayer coated carbide tool employing TiN to increase cutting speed and minimize temperature [19]. Increases in coating thickness on cemented carbide inserts PVD (Ti Al 46 N54) coated had a negative impact on the mechanical strength of the surface of the coating, but they improved cutting performance by activating the mechanism that grows the radius of the cutting edge [20].

2. OBJECTIVE AND METHODOLOGY

This study's main goal is to look into HSS tools coated with nanomaterial. Furthermore, to evaluate the rate of wear for machining tool and recommend modern machining tools because HSS tools cannot operate at very high speeds and feeds without overheating and losing hardness and edge quality. HSS tools also have lesser wear resistance than carbide tools, which means they will wear out faster and will need to be replaced more frequently.

For the past few years, industries have faced tool wear during the machining process. It affects the production and manufacturing units. We can overcome the problem with the help of journal papers, and then we have to plan and design to make a tool effectively. It was simulated and analyzed with the help of FEA. Then we conclude the expected outcome with the FEA.

3. MATERIAL

High-Speed Steel is a tool of steel alloys called for its ability to cut materials faster than normal high-carbon steels, which were formerly used in cutting tools. This is due to the alloying metals and heat treatment providing outstanding hardness, resistance to abrasion as well as high-temperature softening.
Zirconia is a white powdered substance that is commonly utilized in the production of dental frameworks for dental substructures like crowns and bridges. Zirconia has much greater flexibility than other technical ceramics, as well as exceptional wear resistance and strength, in contrast to ordinary ceramics, which are brittle and inflexible.
Chromium is a strong steel-grey metal that acquires a polished and used in alloys to boost strength and resistance to corrosion. The metal is brittle, white, hard, glossy, and remarkably resistant to ordinary corrosive agents; this resistance accounts for its widespread use as an electroplated protective covering.

Table 1. Material Properties

Properties	zirconia	Chromium
Density	5.68 g/cm^3	7.19 g/cm^3
Melting point	2715^{0}C	1907^{0}C
Tensile strength	330 MPa	0.31
Yield Strength	230 MPa	248 GPa
Poisson's ratio	0.34	69.1 W/mK

4. FINITE ELEMENT ANALYSIS

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4.1 Explicit Analysis

If the product must withstand impacts or short-duration, high-pressure loadings, ANSYS explicit dynamics solutions can help enhance its design. When computing very complicated and nonlinear situations requiring fast changes, such as material deformation or failure, use explicit dynamics. The analysis concluded by using time speed and cycle number to determine the difference in lifetime between the HSS tool with and without coating. Reducing the time and effort needed to obtain exact results is made easier by ANSYS' ability to mesh. ANSYS makes a contribution by creating better and more automated meshing tools since meshing typically takes up a significant amount of the time needed to obtain the simulation results in fig. 1 and 2.

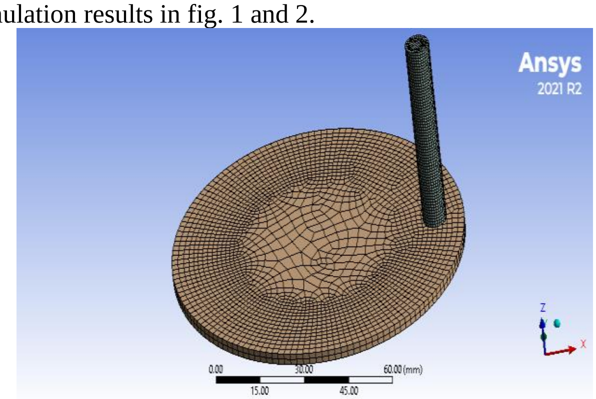

FIGURE 1. **Mesh Generation of Model 1 (without Coating)**

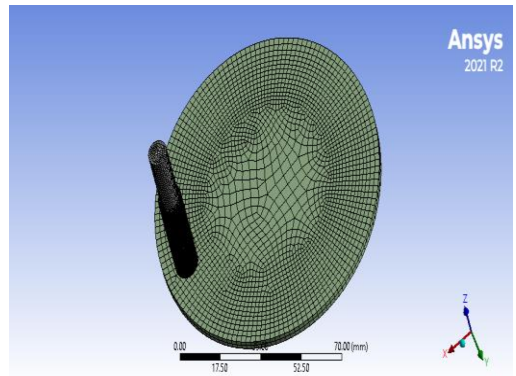

FIGURE 2. **Mesh Generation of Model 2 (with Coating)**

5. RESULT AND DISCUSSIONS

A simulation of an uncoated HSS tool is shown in figures 3-5. A maximum value of deformation, stress, and strain is collected by colleagues using the explicit technique.

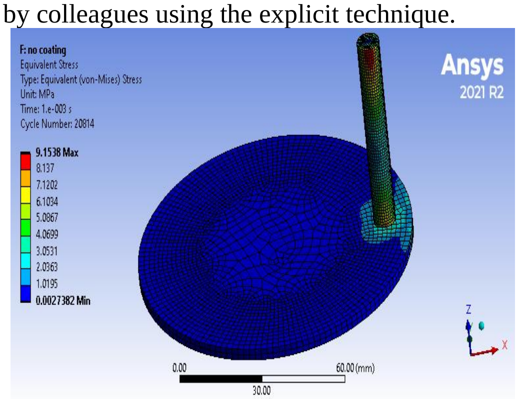

FIGURE 3. **Overall Deformation of HSS Tool without Coating**

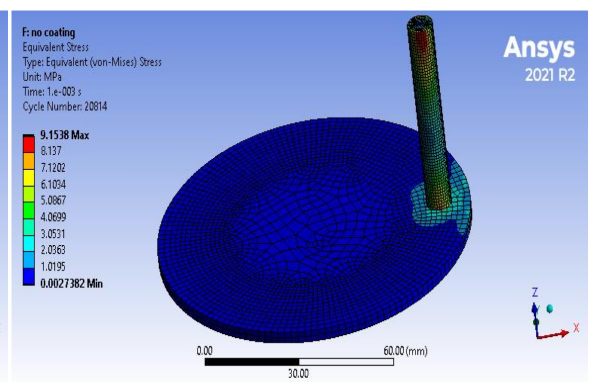

FIGURE 4. **Similar Stress of HSS Tool without Coating**

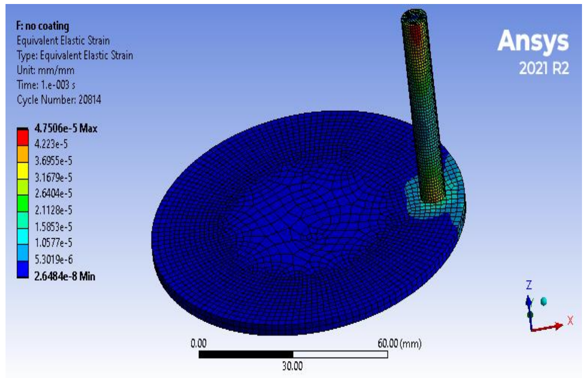

FIGURE 5. Elastic Strain of HSS Tool without Coating

When a work piece is sufficiently ductile, deformation procedures use irreversible deformation to permanently alter its shape while also achieving the appropriate microstructures and material properties. The HSS tool was then put to the test in a simulation during a deformation process with and without coating. The final results of the uncoated HSS tool are superior to those of the Nano coated HSS tool.

While strain is a deformation or change in the shape of the material brought on by the applied force, stress is the force applied to a material per unit area. The stress and strain simulation results of the HSS tool differ on coated and uncoated material, as opposed to the expected outcome of low stress and strain on coated material. Figures 6 to 8 depict the outcomes of a chromium coating, which has a cycle range 5899 times more than that of uncoated tools. The tool with a zirconia coating is shown in figures 9 to 11 above. The stress of the zirconia-coated tool is significantly higher than that of the uncoated tool, which extends the tool's life, according to an analysis.

When the testing results based on without coating of HSS tool, its overall deformation is 0.010169 mm, similar stress is 9.1538 MPa and strain was 4.7506e-5.HSS tool coated by chromium their overall deformation is 0.050381 mm, similar stress is 0.015153 MPa and strain was 0. 075416. Zirconia coated deformation 0.051448 mm, stress 0.0091571 MPa and strain 0.00018271 show in table 2. Overall, the result of simulation is different, but comparatively, the chromium and zirconia-coated tool performed well. Stress value was lower than coated HSS tool fig 12.

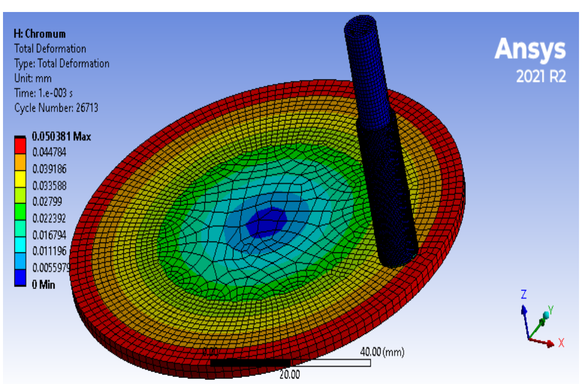

FIGURE 6. Overall Deformation of HSS Tool (Chromium)

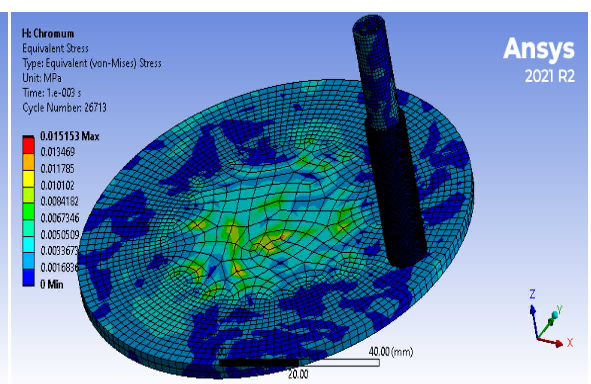

FIGURE 7. Similar Stress of HSS Tool (Chromium

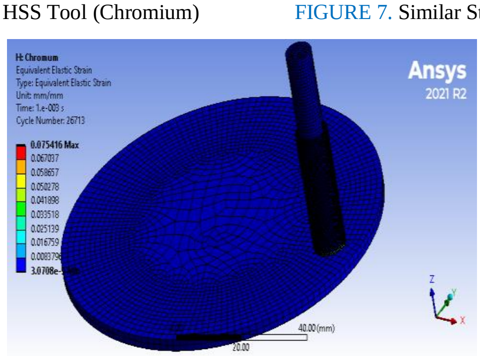

FIGURE 8. Elastic Strain of HSS Tool (Chromium)

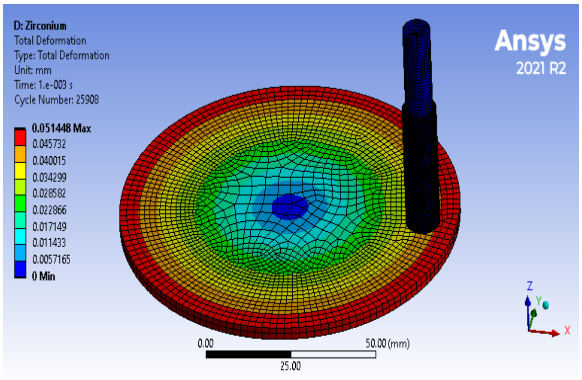

FIGURE 9. **Overall Deformation of HSS Tool (Zirconia)**

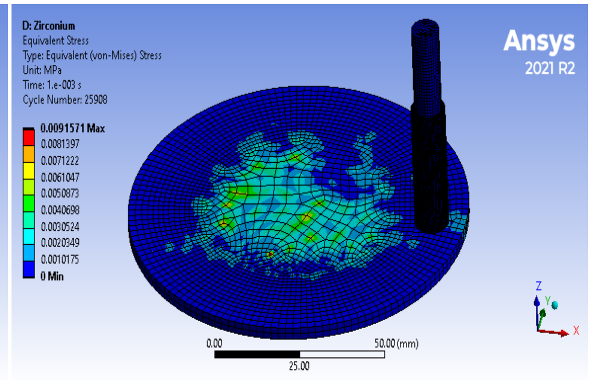

FIGURE 10. **Similar Stress of HSS Tool (Zirconia)**

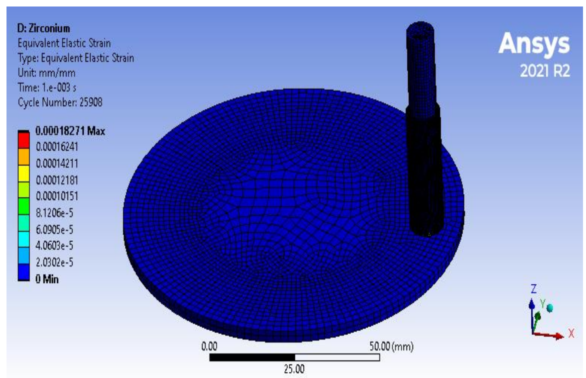

FIGURE 11. **Elastic Strain of HSS Tool (Zirconia)**

Table 2. Simulation Results

Material Condition	Overall Deformation (mm)	Similar Stress (mpa)	Elastic Strain
Without coating	0.010169	9.1538	4.7506e-5
Chromium	0.050381	0.015153	0.075416
zirconia	0.051448	0.0091571	0.00018271

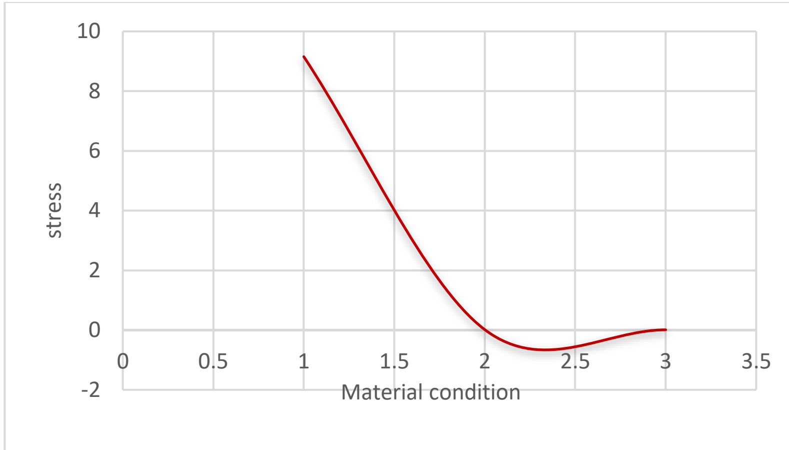

FIGURE 12. Stress Analyzing Graph

6. CONCLUSION

In this paper investigated by difference of without coating HSS tool to coat HSS tool based on deformation, equivalent stress and strain condition. The effect on the wear rate is simulated by ANSYS software. From this experimental result is concluded that zirconia coated tool was better than chromium coated tool on compares with equivalent stress and strain. This result of a HSS tool is better machining performance will result from the suggested system. The outcomes of this project's experimental work are as follows: zirconia coated HSS tool stress is 60.43% efficient than chromium.

NOMENCLATURE & ABBREVIATION:

W/mK	Watt per Meter Kelvin
mm	Millimeter
g/cm^3	Gram per cubic centimeter
MPa	Mega Pascal
GPa	Giga pascal
HSS	High Speed Steel
°C	Degree Celsius
3D	3 Dimension
TBC	Time based correction
FEA	Finite element analysis
TiN	Titanium nitride
Ti	Titanium
Al	Aluminum
Cr	Chromium
Si	Silicon
N	Nitride
B2	Titanium borides
AISI	American Iron and Steel Institute
CBN	Cubic boron nitride
PVD	Physical vapour deposition

Conflicts Of Interest

The authors declare no conflicts of interest.

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