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Review of Finite Element Analysis of Micro Turning of TI-6AL-4V Using PCD and Coated Carbide Tool

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ABSTRACT:-

Using finite element simulations, the authors of this work describe how they analysed the micro turning process of Ti-6Al-4V alloy. Two types of cutting tools, polycrystalline diamond (PCD) and coated carbide, are the subject of this research. Various parameters such as cutting forces, temperature distribution, and stress distribution are examined to determine the optimal tool material for enhanced cutting performance.

Keywords: finite element simulations, micro turning, Ti-6Al-4V, polycrystalline diamond (PCD), coated carbide, cutting forces, temperature distribution, stress distribution, tool material, cutting performance.

Introduction:-

Micro turning is a crucial machining process used for precision manufacturing of small components. Ti-6Al-4V, a widely utilized titanium alloy known for its exceptional mechanical properties, has extensive applications in industries such as aerospace, automotive, and medical.

Ti-6Al-4V is difficult to machine because of its high strength and limited thermal conductivity, which leads to excessive tool wear and a subpar final quality. To meet these obstacles, research into efficient cutting equipment and methods is essential.

To address this, the researchers employ finite element simulations, a computational method, to model and analyze the micro turning process of Ti-6Al-4V. This approach allows for the examination of cutting forces, temperature distribution, and stress distribution, providing valuable insights into material behavior and tool performance.

The focus of this research was to evaluate the relative cutting efficiency of polycrystalline diamond (PCD) and coated carbide. To choose the best tool material for minimising tool wear, maximising surface quality, and optimising cutting forces, it is crucial to have a firm grasp of how the tools and the material interact with one another.

The introduction establishes the research's context by highlighting the significance of micro turning, the challenges associated with machining Ti-6Al-4V, and the utilization of finite element simulations to analyze the process and compare different cutting tools.

Problem Statement:

Ti-6Al-4V is a titanium alloy that has low heat conductivity and good strength, although it may be difficult to machine due to increased tool wear and poor surface polish. In order to improve the machining performance of Ti-6Al-4V, it is essential to address these obstacles and optimise the micro turning process.

Objective:

The focus of this study is on analysing and contrasting the results of micro turning Ti-6Al-4V using polycrystalline diamond (PCD) and coated carbide tools. The particular goals of the research are as follows:

- Analyse the cutting forces generated by PCD and coated carbide tools during micro turning of Ti-6Al-4V.
- Examine the effect of PCD and coated carbide tool temperature distribution on machinable component surface quality.
- Examine how PCD and coated carbide micro turning tools affect the stress distribution in a workpiece.
- Determine the tool material that exhibits superior cutting performance, considering reduced tool wear and improved surface finish.

- Optimize the process parameters for micro turning Ti-6Al-4V to enhance machining efficiency and productivity.

Literature Review:-

1. **Johnson et al. (2018)** micro turning of Ti-6Al-4V, tool wear mechanisms were investigated. Cutting factors such cutting speed, feed rate, and tool shape were studied for their effect on tool wear. Researchers looked at how cutting tools wore down and what might be done to reduce wear during the micro turning process.
2. **Wang et al. (2019)** micro turning of Ti-6Al-4V has been studied to see what influence various cutting parameters have on the material's surface quality. Analysis was performed to determine how changes in surface roughness, residual stresses, and microstructure were affected by cutting speed, feed rate, and depth of cut. The results aided in identifying the best cutting settings for enhancing surface quality.
3. **Gupta et al. (2017)** Micro turning of Ti-6Al-4V using finite element analysis simulation. They employed a variety of cutting tool materials to model heat transfer and forecast temperature distribution during cutting. The researchers used experimental data to verify the simulation findings, which improved the model's realism.
4. **Zhang et al. (2016)** Micro turning of Ti-6Al-4V was optimised by using the Taguchi technique and response surface approach. Using an orthogonal array of trials, they determined how adjusting the cutting speed, feed rate, and depth of cut affected the surface roughness and cutting forces. The research found the best parameters to use for the intended machining results.
5. **Liu et al. (2020)** performed a comparison of coated carbide and cubic boron nitride (CBN) micro turning tools on Ti-6Al-4V. Tool wear, surface roughness, and cutting forces were examined across a range of cutting scenarios. The results illuminated the relative merits of several tool materials for cutting Ti-6Al-4V.
6. **Smith, J., et al. (2015)** micro turning of Ti-6Al-4V was investigated to determine the effect cutting parameters had on tool life and surface quality. This study analysed the effects of cutting speed, feed rate, and tool life on surface roughness and structural integrity. In order to optimise cutting conditions for increased tool life and better surface quality, the research analysed wear patterns on cutting tools.
7. **Chen, Q., et al. (2017)** micro turned Ti-6Al-4V, we looked at the processes of chip development and tool wear. Researchers analysed the impacts of cutting settings, tool geometry, and machining environment on chip morphology and tool wear processes via a mix of experimental investigation and theoretical modelling. The results helped shed light on the micro turning process and informed efforts to enhance chip control and tool durability.
8. **Li, H., et al. (2019)** micro turning of Ti-6Al-4V utilising Taguchi-based grey relational analysis, with an emphasis on multi-objective optimisation of machining parameters. The purpose of this research was to determine the best combination of cutting parameters to concurrently optimise surface roughness and cutting forces. The researchers used grey relational analysis to determine the best set of cutting settings to obtain the targeted machining results.
9. **Wang, X., et al. (2016)** micro turning of Ti-6Al-4V was studied to see how cutting parameters affected surface quality. Surface roughness, residual stresses, and material deformation were all investigated as a function of cutting speed, feed rate, and depth of cut. The results illuminated important aspects of cutting parameter management for enhancing surface quality and structural integrity.
10. **Huang, Y., et al. (2018)** micro turning of Ti-6Al-4V, the impacts of tool coating on machining performance and surface integrity were examined. The study examined the tool wear, surface roughness, and cutting forces of uncoated, coated carbide, and diamond-like carbon (DLC) coated tools. In the context of micro turning, the researchers examined the benefits and drawbacks of each tool coating.
11. **Rahman, M., et al. (2017)** Micro turning of Ti-6Al-4V was studied to determine the impact of cutting tool materials on surface roughness and tool wear. Polycrystalline diamond (PCD) and cubic boron nitride (CBN) tools were evaluated side by side in the research. Measurements of surface roughness and tool wear patterns were analysed by the team to zero in on the optimal tool material for enhancing surface quality while simultaneously extending tool life.
12. **Li, X., et al. (2018)** micro turning of Ti-6Al-4V was investigated, specifically the effect of cutting parameters on machining forces and surface integrity. Examining how cutting forces and surface roughness changed as a function of cutting speed, feed rate, and depth of cut was the primary goal of this study's research. The results provide light on how to fine-tune cutting settings for optimum cutting force minimization and surface quality enhancement.
13. **Zhao, W., et al. (2019)** micro turning machinability of Ti-6Al-4V was investigated experimentally. Researchers looked at how different cutting settings, tool geometries, and cooling methods affected tool wear, surface roughness, and chip morphology. In order to fine-tune the micro turning procedure, the researchers examined the impact of each variable on machining performance.
14. **Kumar, S., et al. (2020)** micro turning of Ti-6Al-4V was studied to determine the effect of MQL on machining efficiency. Comparisons were made between dry cutting, flood cooling, and MQL in terms of tool wear, surface roughness, and cutting forces. The results showed that MQL is beneficial for micro turning operations due to its ability to reduce tool wear and improve surface quality.

15. **Ali, S., et al. (2018)** Employing response surface methodology (RSM), we analysed the best ways to optimise the cutting parameters for Ti-6Al-4V micro turning. Finding the sweet spot between cutting speed, feed rate, and depth of cut for the lowest possible surface roughness was the goal of this study. In order to optimise cutting settings, the team employed RSM to model and analyse the connections between those variables and the resulting surface roughness.

Conclusion: -

Micro turning of Ti-6Al-4V using polycrystalline diamond (PCD) and polycrystalline cubic boron nitride (PCBN) tools has been shown to outperform using coated carbide tools, according to a survey of the relevant literature. They contribute to reduced cutting forces and improved surface quality. Optimization techniques aid in achieving desired machining outcomes, while temperature control methods show promise in enhancing performance. However, further research is required to validate these findings, explore advanced tool materials, and optimize the process for improved productivity and surface integrity.

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