CUTTING TOOL PERFORMANCE BASED ON WEAR TYPES, MAIN CAUSES, AND TEMPERATURE EFFECT ON TOOL'S LIFE.

Abdiev B.K.
Navoi State University of Mining and technologies
Khamidov B.Kh.
Navoi State University of Mining and technologies

Annotatsya: Kesish asboblari zamonaviy mashinalar uchun asosiy bo‘lib, unumdorlik, sirt sifati va operatsion xarajatlarga bevosita ta'sir qiladi. Kesuvchi asboblarni yeyilishi sababli (asosan yordamchi va asosiy kesuvchi yuzalari degradatsiyasi) ishlov berish samaradorligi pasayadi va energiya sarfi oshadi. Ushbu yeyilish ishqalanish, issiqlik va mexanik kuchlanish, ayniqsa asbob-ishlov beriladigan qism interfeysida sodir bo‘ladi. Sekin-asta yeyilishi kutilayotgan bo‘lsa-da, noto‘g’ri haroratni tartibga solish va suboptimal asbob tanlash tufayli erta ishdan chiqishi mumkin. Ushbu tadqiqot kesuvchi asbob yeyilish mexanizmlarini va haroratni nazorat qilish, material tanlash va asbob geometriyasining asbobning ishlash muddatini uzaytirish va tejamkor, yuqori samarali ishlov berishga erishishdagi rolini ichiga oladi.

Kalit so‘zlar: Kesish asboblari, haroratni tartibga solish, asboblarning eskirishi va ishdan chiqishi.

Аннотация: Режущие инструменты играют основополагающую роль в работе современных станков, напрямую влияя на производительность, качество поверхности и эксплуатационные расходы. По мере износа инструментов, особенно износа задней и передней поверхностей, снижается эффективность обработки и увеличивается энергопотребление. Этот износ обусловлен трением, нагревом и механическими нагрузками, особенно в зоне контакта инструмента с заготовкой. Хотя постепенный износ ожидаем, можно избежать преждевременного выхода из строя инструмента из-за ненадлежащего регулирования температуры и неоптимального выбора инструмента. В данном исследовании подчеркивается важность понимания механизмов износа и роль контроля температуры, выбора материала и геометрии инструмента в продлении срока службы инструмента и достижении экономичной и высокопроизводительной обработки.

Ключевые слова: Режущие инструменты, регулирование температуры, износ и отказ инструментов.

Abstract: Cutting tools are fundamental to modern machines, directly impacting productivity, surface quality, and operational cost. As tools undergo wear—especially flank and rake face degradation—machining efficiency declines and energy consumption rises. This wear is driven by friction, heat, and mechanical stress, particularly at the tool–workpiece interface. While gradual wear is expected,

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premature failure due to poor temperature regulation and suboptimal tool selection can be avoided. This study highlights the importance of understanding wear mechanisms and emphasizes the role of temperature control, material choice, and tool geometry in extending tool life and achieving cost-effective, high-performance machining.

Key words: Cutting tools, temperature regulation, tools wear and failure.

Introduction

Advancements in manufacturing technology have intensified the demand for cost-effective machines and high-quality components. Cutting tools, being central to this process, face continuous wear and potential failure. To reduce production costs and maintain efficiency, it is essential to optimize tool usage by extending tool life through best practices.

During machining, the cutting force acting perpendicular to the tool's velocity keeps the tool pressed firmly against the workpiece. This contact generates friction between the tool's clearance face and the machined surface, gradually flattening the cutting edge and forming a wear land along the clearance face.

As the wear land grows, friction and heat intensify, accelerating tool degradation. Once the wear reaches a critical threshold, cutting efficiency drops, leaving burnished marks on the workpiece and requiring more energy to remove the same volume of material.

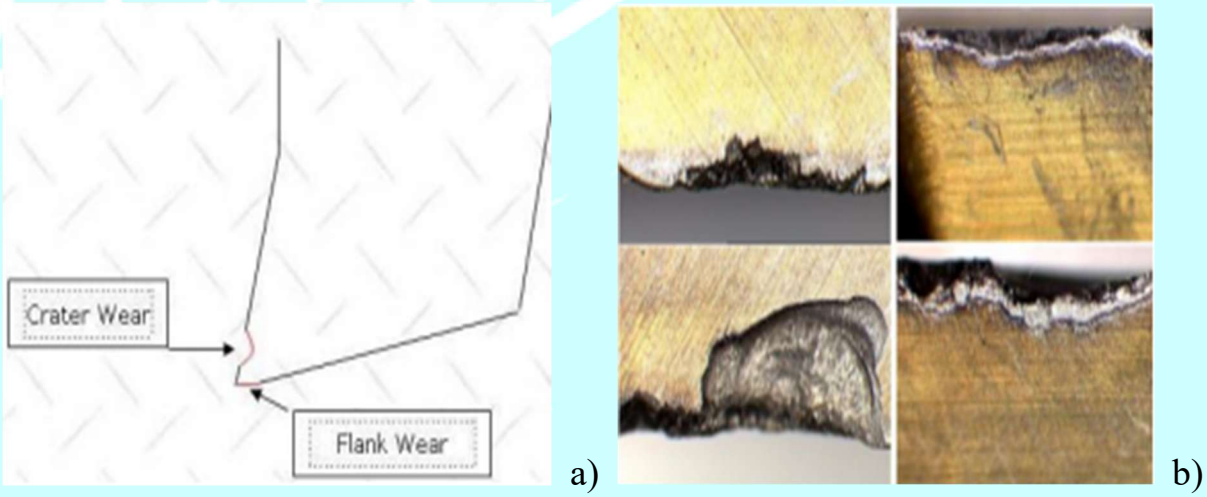


Fig.1 Rake Face Chipping type of wears of cutting tools

Flank wear tends to worsen under elevated temperatures—often caused by increased cutting speeds—and higher tool pressure. Despite being a form of tool degradation, it is considered the preferred failure mode because it occurs in a gradual and predictable manner.

Mechanical failures result from insert wear, which is triggered by intense physical interaction between the cutting insert and the workpiece.

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Mechanical Chipping Mechanical chipping typically arises from an unstable machining setup—such as an overextended tool holder or boring bar that exceeds the optimal length-to-diameter ratio, or from inadequately supported workpieces.

This type of failure is best diagnosed by examining chip formation on the tool surfaces. Chipping tends to be more pronounced on the flank face, as cutting forces are primarily directed downward onto the rake face, resulting in a smaller chip there and a larger one on the flank.

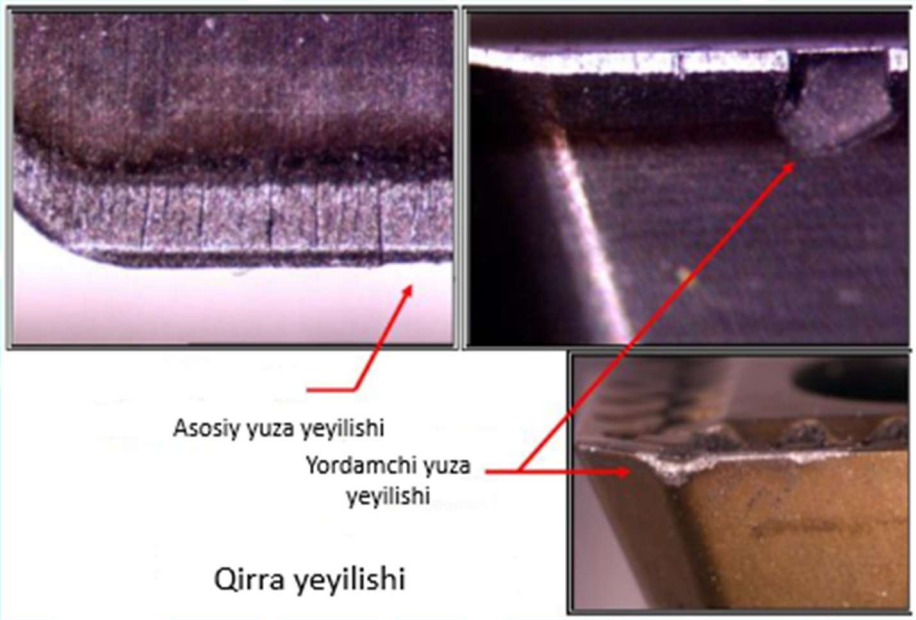
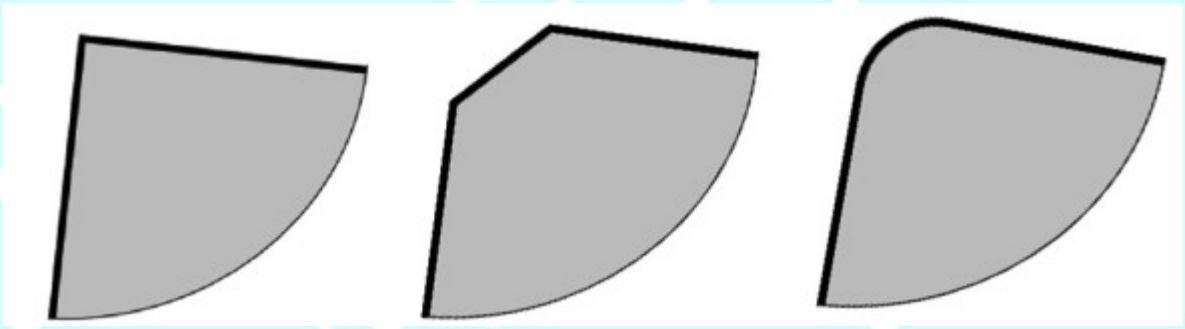


Fig.2 cutting side wearing

High-performance machining is inseparable from the excellent properties of cutting tools [4]. With the continuous advancement of machine tool design, tool control, and system monitoring, machining operations have been developing rapidly in ultraprecision cutting, high-speed cutting, near-net machining, and dry cutting of difficult-to-machine materials [5]. Stringent requirements have been proposed for cutting tools. Defects, including small chippings and burns (Fig. 1(a)) [6], are generated in the manufacturing process of the cutting edge. These defects can easily concentrate stress at the cutting edge during the cutting process, subsequently aggravating the wear and collapse of the cutting edge, shortening the service life of the tool, and deteriorating the surface quality of the machined parts. Cutting edge preparation during tool manufacturing or before the use of tools is necessary to ensure excellent cutting performance. Figure 1(b) illustrates the purposes of edge preparation, which are to remove the microdefects generated by the cutting edge in the initial forming process, improve the stress state of the tool surface, and obtain a high stability edge with a certain microshape.

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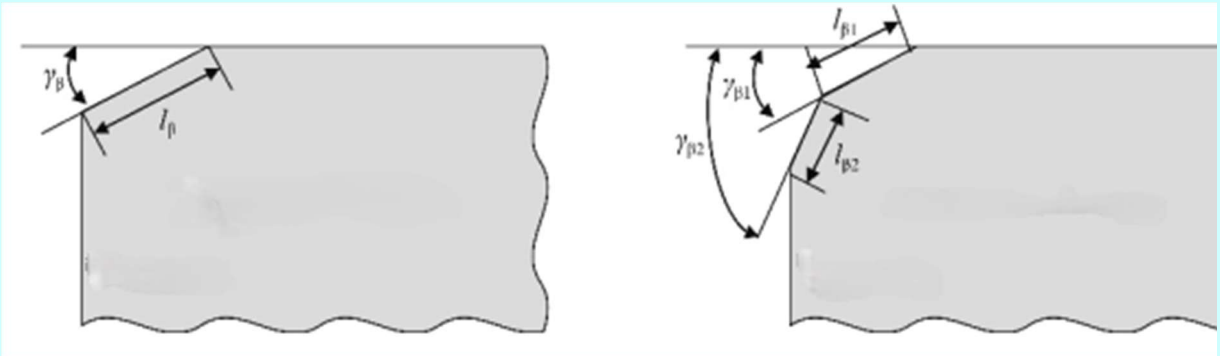
Sharp edge **Chamfer edge** **Round edge**

Fig.3 types of cutting tool edges

Edge characterization serves as the foundation for analyzing the morphology and microgeometry of a cutting tool's edge. It establishes a connection between the edge preparation technique and the cutting performance. Unlike the tool's macroscale dimensions, edge morphology must be assessed at the microscale level. As illustrated in Fig. 3, cutting edge shapes generally fall into three categories: sharp, chamfered, and rounded.

1. A **sharp edge** is formed by the direct intersection of the rake and flank faces, resulting in a straight, unmodified edge.
2. A **chamfered edge** resembles a miniature cutting surface, created by beveling or chamfering the edge.
3. A **rounded edge** features a smooth, curved cross-section, forming an arc-like profile.

The chamfer edge is formed by grinding a micro-chamfer at the tool edge. Chamfers can be classified according to their number, i.e., a single-chamfer edge and a double-chamfer edge (Fig.4). In general, the chamfer edge is characterized by the length of the chamfer edge and the angle between the chamfer edge and the rake face γβ.



Single chamber edge **Double chamber edge**

Fig.4 cutting tools edge difference

We also tested our cutting tool for temperature diagram. We can see that the Tside represents the highest temperature recorded on the cutting tool, specifically located on the rake-face as indicated in the thermal map of Figure 5-a. During orthogonal cutting, the temperature gradually rises until it reaches a peak value,

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after which it levels off. Once this stabilization occurs, the cutting process is regarded as having entered a steady-state condition, meaning the temperature remains consistent for the remainder of the operation.

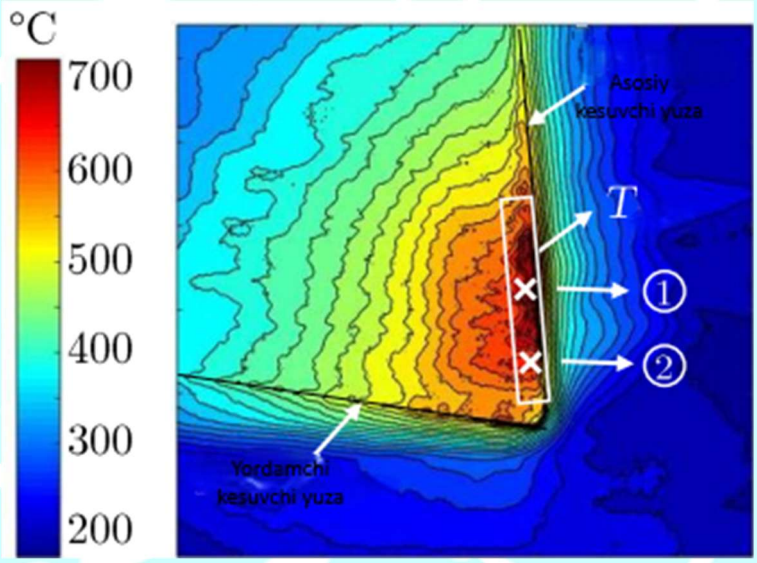


Fig.5 Thermal field of tool side.

Temperature effects to cutting tools as following:

Tool Wear Acceleration High temperatures—especially at the tool-workpiece interface—intensify wear mechanisms such as flank wear, crater wear, and thermal cracking. This shortens tool life considerably.

Reduced Tool Strength Heat can lower the hardness and yield strength of cutting tool materials, making them more prone to deformation and chipping under load.

Surface Integrity Issues Excessive heat affects the quality of the machined surface, potentially causing burn marks, dimensional inaccuracies, and poor finish.

Thermal Fatigue and Cracking Repeated heating and cooling cycles can lead to thermal fatigue, resulting in microcracks along the cutting edge.

Chip Formation and Cutting Forces Temperature influences chip morphology and cutting force dynamics. Higher temperatures may soften the workpiece material, altering chip flow but also increasing adhesion and friction.

Conclusion: In modern manufacturing, the longevity and reliability of cutting tools are pivotal to achieving precision, efficiency, and economic viability. This study underscores that while wearing especially flank and rake face degradation—is an inherent aspect of machining, its progression and impact can be significantly mitigated. Through a comprehensive understanding of wear mechanisms, particularly those driven by thermal and mechanical stresses, engineers can adopt strategies that enhance tool resilience. Key interventions include selecting appropriate tool materials, refining edge geometry (e.g., chamfer and rounding techniques), and implementing robust temperature regulation during cutting operations. Moreover, edge preparation and microgeometry

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characterization play a critical role in preventing premature failure and ensuring consistent surface quality. As machining technologies evolve toward high-speed, ultraprecision, and dry cutting applications, the integration of thermal mapping, tool monitoring, and optimized setup configurations becomes indispensable. Ultimately, proactive tool management not only extends service life but also supports sustainable, high-performance manufacturing in increasingly demanding industrial environments

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