ІНІСТЕРСТВО ОСВІТИ ТА НАУКИ УКРАЇНИ

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

КАФЕДРА КОНСТРУКЦІЇ ЛІТАЛЬНИХ АПАРАТІВ

ДОПУСТИТИ ДО ЗАХИСТУ

Завідувач кафедри, д.т.н., проф.

______Сергій ІГНАТОВИЧ

«__»____________2022 р.

ДИПЛОМНА РОБОТА

ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ «МАГІСТР»

ЗІ СПЕЦІАЛЬНОСТІ:

«АВІАЦІЙНА ТА РАКЕТНО-КОСМІЧНА ТЕХНІКА»

Тема: «Удосконалення ріжучих інструментів шляхом обробки імпульсним магнітним полем»

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Київ 2022

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL AVIATION UNIVERSITY
DEPARTMENT OF AIRCRAFT DESIGN

PERMISSION TO DEFEND
Head of the department,
Professor, Dr. of Sc.
____Sergiy IGNATOVYCH
«___»______________2022

MASTER DEGREE THESIS
ON SPECIALITY
"AVIATION AND AEROSPACE TECHNOLOGIES "

Topic: "Cutting tools improvement by pulsed magnetic field processing"

Fulfilled by: _____________ **Lulu WANG**

Supervisor:
PhD, associate professor _____________ **Vadim ZAKIEV**

Labor protection advisor:
PhD, associate professor _____________ **Katerina KAZHAN**

Environmental protection adviser:
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Kyiv 2022

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

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ЗАТВЕРДЖУЮ

Завідувач кафедри

д.т.н., професор

_____Сергій ІГНАТОВИЧ

«___» ___________2022 р.

ЗАВДАННЯ

на виконання дипломної роботи студента

Лулу ВАН

1. Тема роботи «Удосконалення ріжучих інструментів шляхом обробки імпульсним магнітним полем», затверджена наказом ректора від 05 жовтня 2022 року №1861/ст.

2. Період роботи: з 06 жовтня 2022р. по 30 Листопад 2022 р.

3. Вихідні дані до проекту: Твердосплавний ріжучий інструмент.

4. Зміст пояснювальної записки: Аналіз застосування ріжучих інструментів для виготовлення компонентів авіаційної промисловості, аналіз існуючих методів зміцнення ріжучих інструментів, методика зміцнення ріжучих інструментів шляхом обробки імпульсним магнітним полем, експериментальні результати випробувань на зносостійкість модифікованих ріжучих інструментів, охорона праці та навколишнього середовища.

5.Перелік обов’язкового графічного (ілюстративного) матеріалу: презентація Power Point, малюнки та схеми.

6. Календарний план-графік

№ пор.	Завдання	Термін виконання	Відмітка про виконання
1	А н а л із літератури для визначення сфер застосування ріжучих інструментів при виготовлені компонентів авіаційної промисловості	06.10.2022–18.10.2022	
2	Аналіз існуючих методів зміцнення ріжучих інструментів	19.10.2022-29.10.2022	
3	зміцнення ріжучих інструментів шляхом обробки імпульсним магнітним полем .	30.10.2022-07.11.2022	
4	випробування на зносостійкість модифікованих ріжучих інструментів	06.10.2022-31.10.2022	
5	Виконання розділів, присвячених охороні навколишнього середовища та праці.	01.11.2022-05.11.2022	
6	Оформлення дипломної роботи	05.11.2022-10.11.2022	

7. Консультанти з окремих розділів

Розділ	Консультанти	Дата, підпис	
		Завдання видав	Завдання прийняв
Охорона праці			
Охорона навколишнього середовища			

8. Дата видачі завдання: 5 жовтня 2022 р.

Керівник дипломної роботи: Вадим ЗАКІЄВ

Завдання прийняв до виконання: Лулу ВАН

NATIONAL AVIATION UNIVERSITY

Aerospace Faculty

Department of Aircraft Design

Educational Degree «Master»

Specialty 134 «Aviation and Aerospace Technologies»

Educational Professional Program «Aircraft Equipment»

APPROVED BY

Head of Department,

Dr. Sc., professor

____Sergiy IGNATOVYCH

«___»__________2022р

TASK

For the master degree thesis

Lulu WANG

1. Topic: «Cutting tools improvement by pulsed magnetic field processing», approved by the Rector's order 861 «05» October 2022 year.
2. Period of work: from 05 October 2022 year to 30 November 2022 year.
3. Initial data: Carbide cutting tools improvement.
4. Content of the explanatory note: Content of the explanatory note: Analysis of the application of cutting tools for the manufacture of components of the aviation industry, analysis of existing methods of strengthening cutting tools, methods of strengthening cutting tools by processing with a pulsed magnetic field, experimental results of tests on the wear resistance of modified cutting tools, labor and environmental protection.
5. List of mandatory graphic (illustrative) material: Power Point presentation, drawings and diagrams.

6. Thesis schedule:

№	Task	Time limits	Done
1	Analysis of the literature to determine the areas of application of cutting tools in the manufacture of components of the aviation industry	06.10.2022–18.10.2022	
2	Analysis of cutting tools improvement methodAnalysis of existing methods of strengthening cutting tools	19.10.2022-29.10.2022	
3	strengthening of cutting tools by processing with a pulsed magnetic field.	30.10.2022-07.11.2022	
4	wear resistance testing of modified cutting tools	06.10.2022-31.10.2022	
5	Execution of sections devoted to environmental and labor protection.	01.11.2022-05.11.2022	
6	Completion of the thesis	05.11.2022-10.11.2022	

7. Special chapter advisers

Chapter	Consultants	Date, signature	
		Task Issued	Task Received
Labor protection			
Environmental protection			

8. Date: 8 September 2022 year.

Supervisor: Vadim ZAKIEV

Student: Lulu WANG

РЕФЕРАТ

Магістерська робота «Удосконалення ріжучих інструментів шляхом обробки імпульсним магнітним полем»

81 с., 32 рис., 7 табл., 42 літератури

Об’єкт дослідження – Твердосплавний ріжучий інструмент.

Предмет дослідження – Підвищення міцності та зносостійкості різальних інструментів шляхом обробки імпульсним магнітним полем.

Мета магістерської роботи – Метою роботи є зміцнення твердосплавного різального інструменту імпульсним магнітним полем для підвищення ефективності.

Методи дослідження та розробки – Методологічною основою роботи є комплексний підхід до вивчення процесу зміцнення ріжучих інструментів шляхом обробки імпульсним магнітним полем.

Новизна результатів – запропонована методика удосконалення ріжучих інструментів шляхом обробки імпульсним магнітним полем та доведено підвищення їх зносостійкості та надійності.

Практична цінність – Розроблено метод об'ємного зміцнення твердосплавного різального інструменту, що дозволяє підвищити його ефективність.

РІЖУЧИЙ ІНСТРУМЕНТИ, ГЕНЕРАТОР, МАГНІТНИЙ ІНДУКТОР, ІМПУЛЬСНЕ МАГНІТНЕ ПОЛЕ, ТЕРТЯ ТА ЗНОШУВАННЯ

ABSTRACT

Master degree thesis "Cutting tools improvement by pulsed magnetic field processing"

81 p., 32fig., 7table, 42references

Object of study – Carbide cutting tool

Subject of study – Increasing the strength and wear resistance of cutting tools by pulsed magnetic field processing.

Aim of master thesis – The purpose of the work is to strengthen the carbide cutting tool with a pulsed magnetic field to increase efficiency.

Research and development methods – The methodological basis of the work is a comprehensive approach to the study of the process of strengthening cutting tools by processing with a pulsed magnetic field.

Novelty of the results – a method of improving cutting tools by processing with a pulsed magnetic field is proposed, and an increase in their wear resistance and reliability is proven.

Practical value – A method of volumetric hardening of a carbide cutting tool has been developed, which allows to increase its efficiency.

CUTTING TOOLS, GENERATOR, MAGNETIC INDUCTOR, PULSED MAGNETIC FIELD, FRICTION AND WEAR

CONTENT

INTRODUCTION

The aviation industry is booming and the future of aviation is bright. In 2017, airlines carried approximately 4.1 billion passengers worldwide. They transported 56 million tons of cargo on 37 million commercial flights. Every day, planes carry more than 10 million passengers and around $18 billion in cargo.

This demonstrates the significant economic impact of aviation on the global economy, as evidenced by the fact that the aviation industry accounts for 3.5% of global gross domestic product (GDP) ($2.7 trillion) and creates 65 million jobs worldwide. Aviation provides the only rapid global transportation network that fuels economic growth, creates jobs, and facilitates international trade and tourism.

Aviation has become an enabler of global affairs and is now recognized by the international community as an important facilitator in achieving the United Nations Sustainable Development Goals.

The aviation industry is growing rapidly and will continue to grow. According to recent estimates, the demand for air travel will grow at an average annual rate of 4.3% over the next 20 years [1].

With the continuous development of aerospace manufacturing industry, a large number of new difficult-to-process materials are used to manufacture major structural parts such as blades, discs and shafts, and casings. The efficient processing of these difficult-to-process materials has been a topic of research in enterprises.

The use of high-performance cutting tools in aerospace enterprises has led to the rapid development of machining technology in aviation manufacturing industry, but it is easy to buy good cutting tools, but it is difficult to use good cutting tools. The research on cutting cost and improving efficiency in aviation manufacturing industry becomes urgent.

Not only is the aerospace sector one of the biggest users of cutting tools, but it is also a major force behind their development. The aerospace sector is characterized by ongoing initiatives to boost production efficiency for aircraft parts, enhance flight safety, and lessen potential environmental harm.

The first part introduces the various cutting processes in mechanical engineering and which applied in aviation industry. The main aircraft elements are used to assemble a commercial aircraft which should apply kinds of cutting tools, also specific materials should choose correspond to its property. The cutting processes are worldwide applied in mechanical engineering, a better performance will be preferred. We are committed to the improvement of cutting tools.

The second part introduced different methods to improve the properties of cutting insets especially Pulsed Magnetic Filed Processing which s based on the fact that the vortex magnetic field interacts with the carbide insert, improves the structure and properties of the latter. With this hardening, the tool is placed in the inductor so that the center of gravity is shifted relative to the geometric center of the solenoid. Due to this, when the device is turned on, the tool is drawn by the field into the solenoid with acceleration and performs relative to its geometric center damped oscillations, the amplitude of which decreases over time under the action of friction and is zero.

The third part is about the experimental methods for cutting tools after processed by PMFP. It is found that in the preliminary processing of materials with FPMF strengthen cemented carbide tool, the tool is repeatedly processed, the wear process has several degrees of deceleration and acceleration, which proves that the strength and wear resistance of cemented carbide is reasonable.

To perform experimental research in this field, an engineer needs a properly equipped laboratory or workplace, in accordance with state sanitary rules and regulations, which makes demands to many parameters, such as air ionization, requirements to high voltage equipment, ergonomic requirements for the organization of workplaces and workplaces. Harmful factors affecting a person in the process of performing experimental research will be considered. More details on this will be discussed in terms of labor protection.

The last part, environmental protection, is devoted to the problems of the negative impact of aviation on the environment and living organisms, as well as ways to solve theseproblems.

PART 1

ANALYSIS OF CUTTING PROCESS IN AVIATION INDUSTRY

The aerospace industry is not only one of the largest consumers of cutting tools, but also one of the most important drivers of cutting tool development. The aerospace industry is characterized by continuous efforts aimed at increasing the efficiency of aircraft component manufacturing, improving flight safety and reducing potential environmental damage.

To achieve these goals, the aerospace industry must continuously improve the design of aircraft engines and fuselage structural elements to increase the protection of aircraft from damage caused materials cracks, dots and so on. This, in turn, has led to a range of industry requirements, including the introduction of engineering materials that require new production techniques, and the development of suitable machinery and cutting tools. Aircraft manufacturers have to deal with complex parts that are produced from different materials using different processing strategies. This is why the aerospace industry is considered to be a strong and dominant force driving advances in tool development.

In the main bearing structure of modern aircraft and engine, the proportion of the overall structural parts is increasing rapidly. This kind of parts usually adopts the overall blank (sheet or forgings) for cutting. The weight of the finished parts is only 10% ~ 20% of the blank, and the rest 80% ~ 90% of the material has become chips. Plane of the beam, frame, floor, wall panels, engine fan a are the key parts of modern aircraft, aviation engine, using materials of high strength aluminum alloy, titanium alloy, high temperature alloy, composite material, etc., mostly in the overall structure is given priority to, complicated structure, large amount of material removal, high precision and surface quality requirement, processing cycle is long. The machining process of these parts has an urgent need for efficient and accurate machining.

Machining has been one of the main technical means of parts processing, although with the development and the progress of science and technology, new processing methods emerge and are widely used, but the cutting is still the most used and most widely used processing method, the size and shape of the fitting accuracy is higher, the more need to use cutting means to complete, so far there is no better processing method [2].

Aviation manufacturing has always been one of the industries with a high density of advanced technologies, mainly because of the complex shape and structure of parts and components of aviation products, a variety of materials, and strict machining accuracy requirements. The manufacturing complexity of aviation parts is mainly reflected in:

- usually with complex theoretical shape surface, crisscross reinforcement structure, thin wall structure with small thickness, etc.;
- parts materials are mainly high-strength aluminum alloy, titanium alloy, high-temperature alloy, stainless steel, composite materials, honeycomb structure, most difficult processing materials;
- modern aircraft has long life and high reliability requirements, which makes the quality control requirements of parts surface more stringent;
- the overall structure design is more and more used, and the size of the outer profile of the parts is also larger and larger.

To meet the requirements of aviation product design performance and the use of parts and components manufacturing tend to adopt a variety of process methods, such as machining, electrical physical machining, electrochemical machining, the beam machining, precision casting, precision forging, etc., including machining is still present in the field of aviation manufacturing at most, the most widely used processing method.

At present, the proportion of outsourced high performance cemented carbide standard tools and cemented carbide non-standard tools is similar in the processing of engine disc parts, shaft parts and casing parts. Typical small and medium-sized components, blade parts and other standard tools. In the actual processing tool selection mainly consider the following factors: workpiece material, workpiece shape, processing requirements, processing machine tools, system rigidity, surface quality technical requirements. Taking turbine casing parts as an example, from the analysis of workpiece materials, deformation superalloy, cast superalloy and other difficult machining materials are widely used. These difficult to process materials have low thermal conductivity, high specific strength, high cutting temperature and easy to produce work hardening [3]. When cutting, tool wear is fast, tool life is short, tool consumption is large, so the tool geometry Angle must be chosen reasonably. From the workpiece structure, thin wall, poor rigidity, difficult to process.

Machining parts of the raised part, the tool system is easy to interfere with parts, fixtures. Therefore, it is necessary to optimize the tool path, such as replacing side milling with interpolation milling, fast cutting with empty stroke, optimizing the position of tool lifting, and using spiral interpolation for milling. In terms of machine tool selection, turbine casing needs to be processed in a high-power machining center. From the processing procedure analysis, the casing needs to go through rough machining, semi-finishing machining and finishing machining. In order to save the cost of cutting tools, in the manufacture of this kind of parts, rough machining can use high performance ceramic milling cutter, semi-finishing and finishing using standard carbide tools and non - elevation performance special tools, which can significantly improve the production efficiency. From the aspect of processing economy, the tool configuration scheme needs to be constantly improved, as far as possible to use the latest tool manufacturers developed products.

1.1 Types of metal cutting processes

Metal fabrication is a crucial phase in the production of all types of metal machinery, parts, and components. The necessary metal materials will nearly always need to be cut throughout the fabrication process, but there are a variety of metal cutting techniques from which to pick.

Which metal cutting technique is best for your application? Here's a look at some of the most often utilized metal cutting technologies and methods in cutting process.

*Grinding***.** Metal cutting is done by grinding, which is a fabrication technique. By deburring, smoothing out welds, and in some circumstances producing sharp edges, true metal grinding is used to remove rough edges from metal components.

Even though some larger enterprises have finishing machines they employ for the process, grinding is nearly always done by hand using a grinding machine. Bench grinders, cylinder grinders, surface grinders, bit grinders, and many other sorts of machinery are used for grinding. As a manual procedure, grinding is frequently one of the more time-consuming and expensive steps in fabrication.

Drilling. Another crucial step in the manufacturing of metal is drilling. To make precise holes in a metal component or surface, metal drilling is utilized. By exerting pressure and rotating the metal part or surface, the hole is really made.

It is frequently required to make holes for fasteners to pass through when designing parts and components that will be connected to other metal components or to components manufactured from other materials. Depending on the precise drilling requirements, various metals will call for differing pressure levels and tool types [4].

Turning. Metal turning, also referred to as metal spinning, is a metalworking technique in which a tube or disc rotates rapidly to help shape metal into the required shape. The specialists that execute turning are extremely competent at forming parts and components during the fabrication process. Turning is normally done by hand or with the use of a lathe.

*Waterjet***.** Water and metal abrasive are combined in the water jet process, which is then applied with great force to the metal component that needs to be formed. During manufacture, the water jet method enables exact metal surfacing. Because it is very quick and affordable, water jet forming and cutting are frequently used by professional fabricators. The clean surfaces and smooth edges that are characteristic of high-quality manufactured materials are also produced by the water jet technique.

*Plasma cutting***.** One of the more recent methods for cutting metal is plasma. Fabricators utilize plasma torches to cut materials with an electrical arc via oxygen or another inert gas. The metal surface needed for molding and shaping is simultaneously melted away and undesirable molten metal is blown away by this electrical arc. Different types of metal, including aluminum, brass, copper, and stainless steel, can be cut or formed using the plasma method [5].

Laser cutting. Choose laser metal cutting technology for your application if you want the highest level of control and precision. During the laser cutting procedure, a component is sliced to particular shapes and sizes using a highly concentrated light beam at a high temperature. Given the accuracy of laser cutting, the procedure is frequently controlled by a computer system.

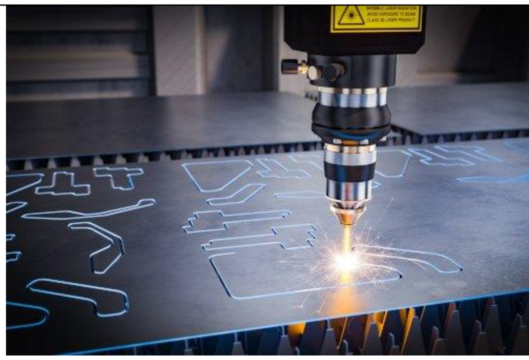
	
a) Grinding	*b) Drilling*
	
c) Turning	*d) Waterjet*
	
e) Plasma cutting	*f) Laser cutting*

Figure 1.1 Different cutting process applied in aircraft manufacturing

When precision in comparison to design drawings and adherence to plans are crucial, laser metal cutting technologies are frequently employed for manufacturing. One of the time-consuming and expensive methods for cutting metal is laser cutting [6].

Different cutting processes have their own advantages and limitations. Grinding is good for structural cutting but it has poor accuracy, slow cutting flat parts. and blades are expensive. Drillings could make deep holes and drilling stacks, but it is slow, one size at a time, accuracy poor for over a diameter of .03 inches, fixturing/locating time consuming. Plasma Cutting Good cutting is good at piercing and thick aluminum, but it has the limitations of heat along edges, not good for small diameter holes, UV Radiation, noisy.

1.2 Aircraft main components which are applied with cutting process

Reduced fuel consumption, longer range and the highest level of comfort, together with reduced noise levels and maximum safety: ideal characteristics for the perfect aircraft. To get as close to this ideal as possible, engineers are turning to the latest materials and embracing structured diets. The secret of their success: extensive use of lightweight materials such as fiber composites, aluminum as well as titanium and superalloys. However, these materials are extremely demanding in terms of machining and can only be produced economically using the latest tools and machining concepts.

Most passenger aircraft have between 3 and 6 million parts, often using light and strong materials. Most structural components are machined and the engine uses special alloys that can withstand extreme temperatures and pressures the need for efficiency, precision and quality makes it essential to have cutting tools specific to each material.

Many materials used to make aircraft parts have poor machinability. Titanium has an impressive strength-to-weight ratio, high temperature superalloys (HTSA) do not lose strength under high thermal loads, and composites are difficult to cut materials. To increase output and increase productivity, aerospace component manufacturers must use machine tools that can perform advanced machining operations. In this case, the role of the cutter increases significantly; However, cutting tools may be the weakest link in the overall manufacturing system because of their lower durability as system elements, which reduces productivity [7].

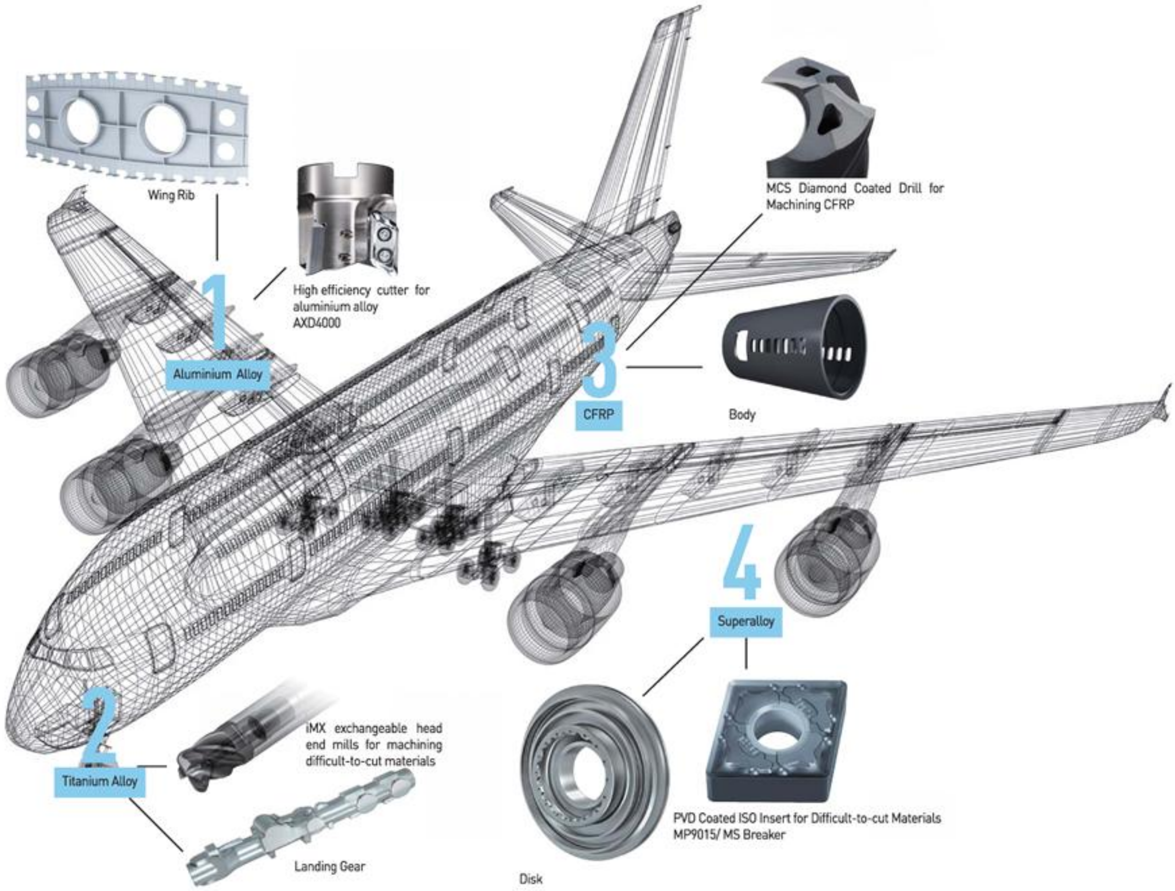


Figure 1.2 Main materials of elements use in cutting process of an aircraft.

- Aluminum Alloy: High efficiency machining at ultrahigh speeds of 300km/h Many of the panels and ribs (structure) of the airframe are fabricated from first-rate duralumin (A7075). High-performance tactics are vital to gadget additives from blocks of fabric. These machining tactics can occasionally lessen extra than 90% of the strong fabric into chips to go away the very last form required. Recently, reducing gear able to machining additives at a pace of 5,000m/min (300km/h) were commercialized. The chip evacuation fee of those tactics may be as much as 10,000cm3 in line with minute.
- Titanium Alloy: Increases withinside the ratio of use has created extra call for relatively green processing. Titanium alloy has the very best particular electricity (electricity/weight ratio) of all metal substances below four hundred deg. C, it's also light, sturdy and corrosion resistant. New passenger jets are the usage of a growing ratio of Titanium alloy Ti- 6Al-4V, this fabric is used for plane additives that require

excessive electricity, consisting of wing joints and touchdown gear. High performance machining of Titanium alloy is a task due to the fact its low thermal conductivity reasons machining warmth to pay attention on the brink of the reducing tool.

- CFRP: A fundamental new twenty first century fabric Ten instances more potent than steel (electricity/ weight ratio), CFRP is light, sturdy and corrosion resistant and its use has grown swiftly withinside the twenty first century. Large plane additives consisting of fuselage components are molded via way of means of layering sheets containing carbon fibers in unique pre-described paperwork after which via way of means of heating them in a vacuum. CFRP's excessive electricity but way it has low machinability residences and consequently calls for diamond or diamond lined gear for reducing them [8].
- Superalloy: A relatively useful metal fabric with intense durability even below excessive temperatures of as much as 1,000 deg. C. It is utilized in sections of the engine related to combustion and exhaust. Nickel primarily based totally INCONEL and WASPALOY are not unusual place examples. Superalloys preserve their electricity even below excessive temperatures however those residences additionally purpose low machinability. They additionally require excessive pleasant machining and consequently production tactics want cautious exam and making plans earlier than mass manufacturing is viable.

Additionally, aerospace machining has become more complicated, particularly for heat resistant super alloys (HRSA) and composite materials. Both categories have advanced considerably over the past decade, and as a result, these materials are seeing increasing demand in applications that produce high-value, lightweight parts. However, this upward trend has driven the development of many more material options attractive to aerospace engineers.

In the aerospace industry, HRSAs are generally utilized in warm phase turbine additives, which includes conventional blades, blisks, combustors and related static additives, however the excessive temperate tolerance and creep resistance of superalloys lead them to beneficial for different additives which includes valves and manifolds. As their call suggests, those substances do now no longer effortlessly behavior warmness, consisting of the warmth from slicing forces. As a result, that warmness is transferred extra unexpectedly to the slicing device—temperatures withinside the slicing area can variety from 1100 to 1300 C—which reduces device life. High temperatures withinside the slicing area additionally cause a extra tendency toward stress and paintings hardening withinside the element being machined as compared to extra traditional substances, which includes steel [9].

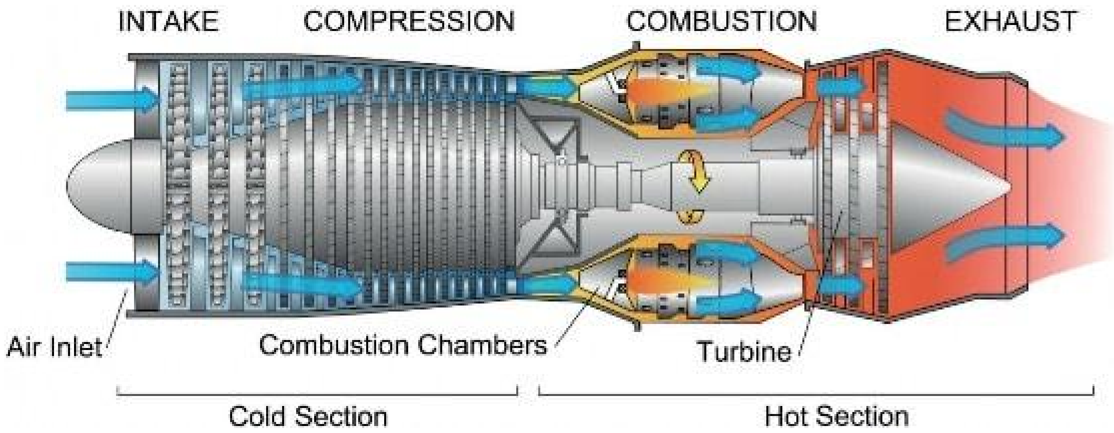


Figure 1.3 Diagram of a typical gas turbine jet engine.

Aircraft require powerful tooling solutions to achieve superior machining parameters for engine mounts, racks and fins. Due to their high material removal rates, these solutions reduce costs and use the latest cutting material grades to achieve very long tool life and fast processes.

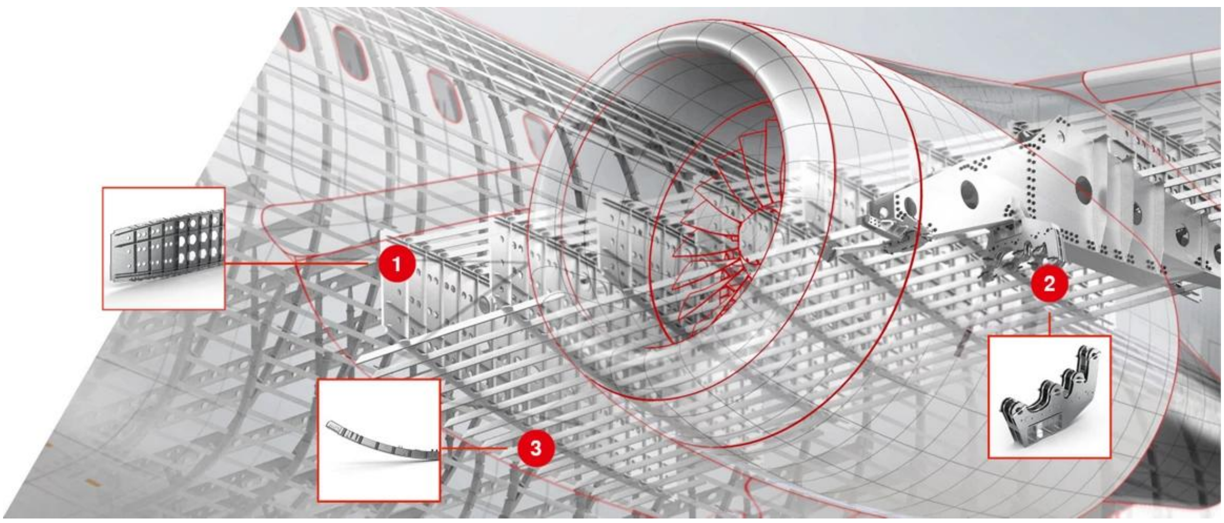


Figure 1.4 Aircraft structural components: 1- Wing rib; 2- Engine mount; 3- Frame.

Machining the wing rib. Together with the stringers, the wing ribs form the framework of the aircraft wings and are permanently exposed to enormous stresses while in the air. To save weight and counter the constant stress, aluminum wrought alloy has become the go-to material for wing ribs.

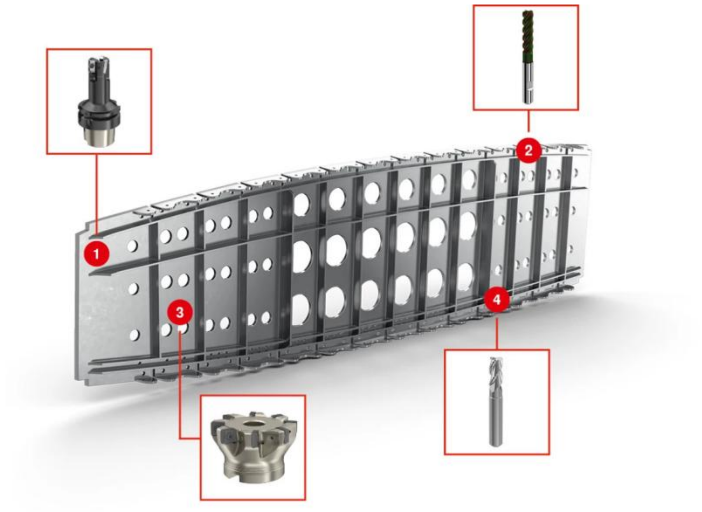


Figure 1.5 Different cutting tools to machine the wing rib

Engine mount. When it comes to safety, no tolerances are allowed -- especially in the development of engine mounts. They are under tremendous pressure during takeoff and landing, which is why only the toughest materials are used. These materials in turn need to be processed with the highest level of precision and process safety.

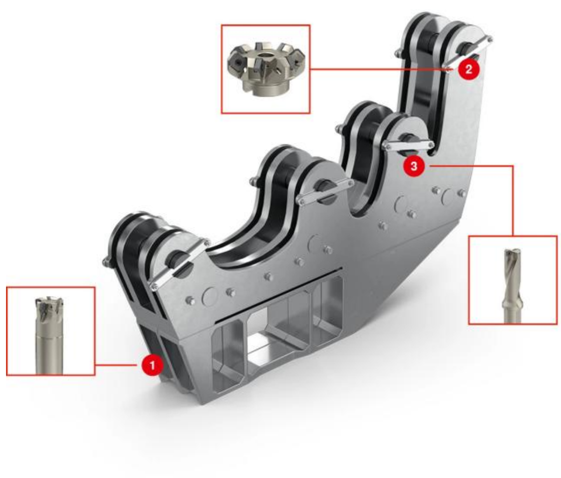


Figure 1.6 Different cutting tools to machine the engine mount.

Frame. The frame and stringers give the fuselage the necessary rigidity. Titanium is often used for framing because it is very light. Its high tensile strength also helps to reduce the number of components required. However, these positive features come at the cost of demanding processability, which in turn requires a corresponding level of expertise and high-performance tooling solutions.

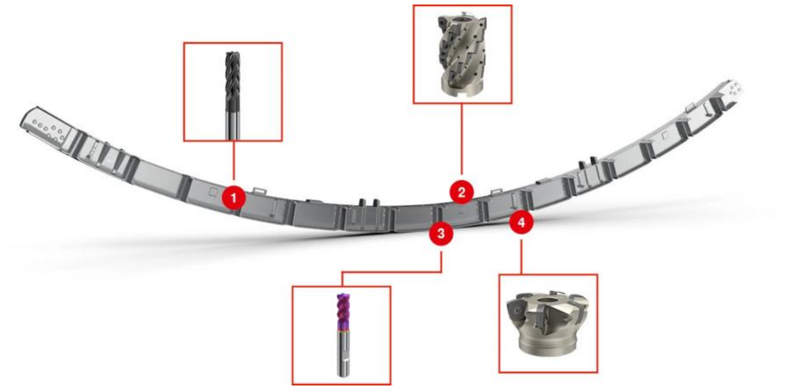


Figure 1.7 Different cutting tools to mill frames

Turbines provide the thrust needed by the aerospace industry. They are constantly being asked to provide more electricity while conserving resources. The same applies to cutting tools, so we now offer solutions that can be machined to the highest level of precision, quality and efficiency even for the most innovative materials.

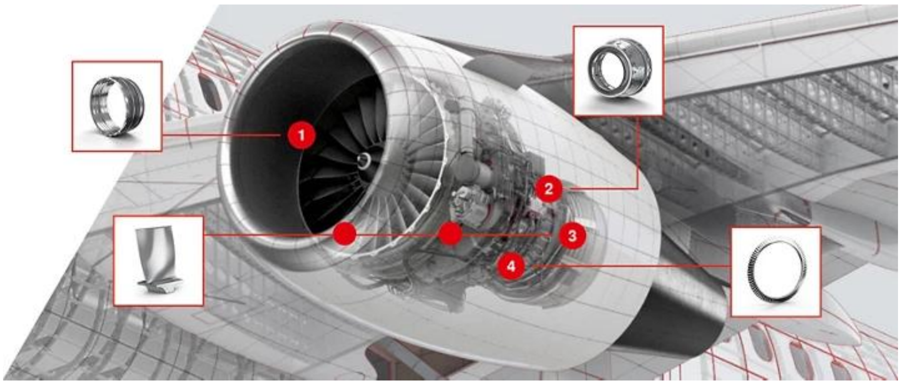


Figure 1.8 Aircraft engine parts: 1-Fan case; 2- Combustion case; 3-Turbine blade; 4-Blisk

Fan case. The size of modern turbofan engines and their turbofans is impressive. There are also challenges in machining annular fan housing, the housing of the largest turbine blades in the entire engine. The highest possible hardness and absolute safety is the top priority, which is why the fan housing is also made of titanium.

Figure 1.9 Cutting tools to machine the fan case

Combustion case. The combustion chamber in an aircraft turbine is a superlative system: when compressed hot air and kerosene are ignited, for example, the temperature and pressure become extremely high. This puts huge demands on building materials, meaning heat-resistant super alloys are the only option. However, these can only be processed with extremely hard tools[10].

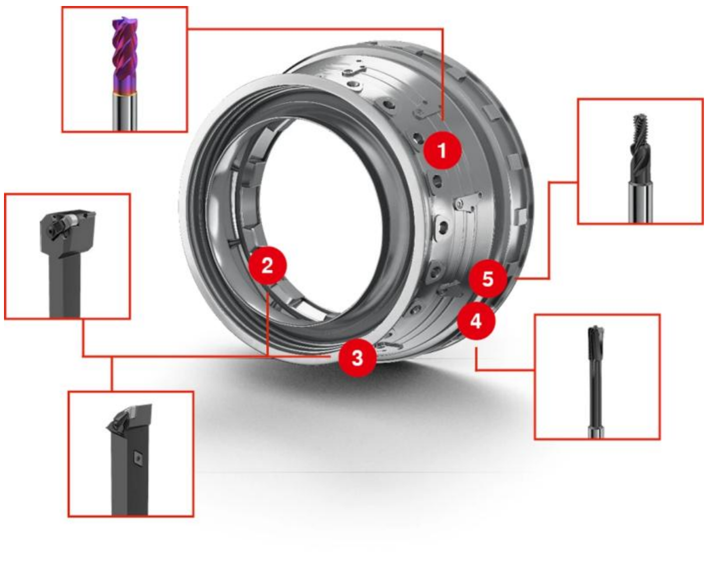


Figure 1.10 Cutting tools to machine the combustion case.

Turbine blade. Turbine blades are subjected to tremendous thermal stress and must always perform optimally throughout the life of an aircraft engine. Aircraft engineers are using super alloys, or titanium alloys, and a steady stream of newly developed materials to find new ways to make turbine blades harder. This in turn increases the stress applied during processing, as these materials are extremely difficult to cut and efficient manufacturing is essential.

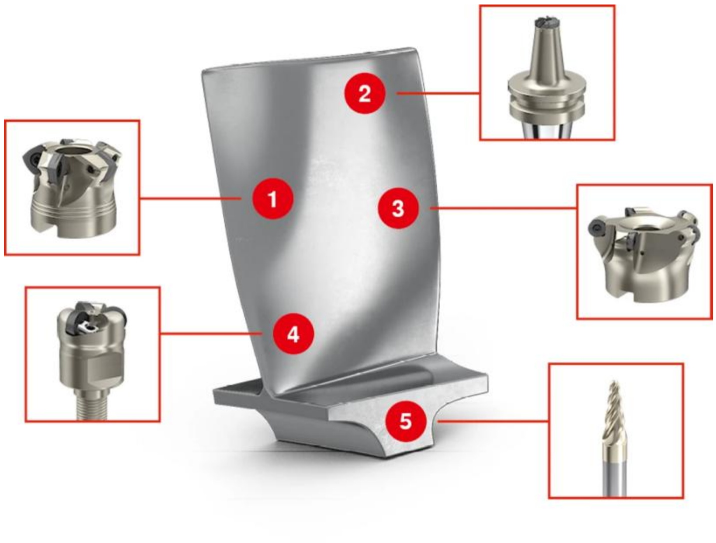


Figure 1.11 Cutting tools to machine the turbine blades

Blisk. Even though many can still be implemented using specific application standard tools, machining blisk, especially requires modification and customization of tool systems. Harsh profiles are found on a variety of different types of blisk, strict requirements for surface quality, tight component tolerances and high-quality materials that can only be met using specially modified tools.

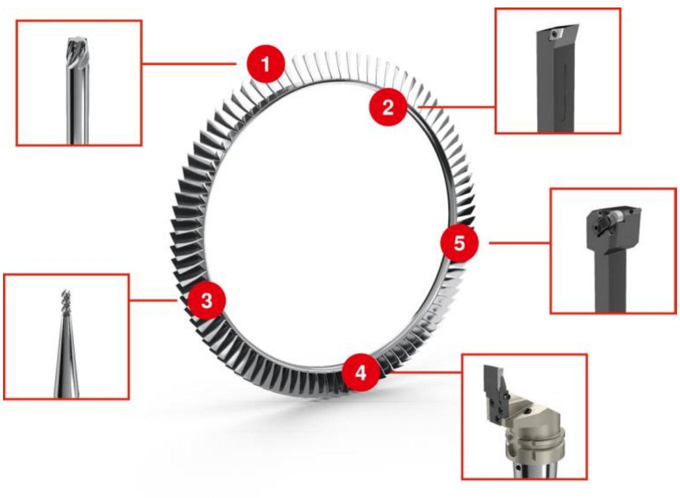


Figure 1.12 Cutting tools to machine the blisks

High alloy steel and titanium materials are often found in landing gear because of their rigidity. As a complete supplier, we are able to ensure that every operation is completed as planned and we are able to offer you a wide range of tool solutions for turning, milling and drilling applications, not to mention the choice of controllable tools.

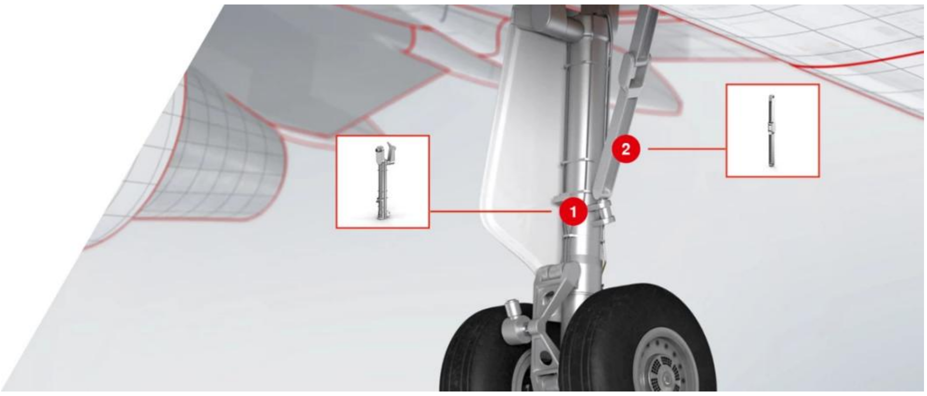


Figure 1.13 Landing gear parts:1-Main cylinder; 2-Landing gear strut

Main cylinder. The landing gear of an aircraft must support the total weight of the aircraft, cargo and passengers. Therefore, it must absorb and dissipate all the power, impact and load applied to it, especially during taxiing and landing. The main cylinder is the focal point of the landing gear. Such heavy-duty components are usually constructed of titanium or high-alloy steel. However, this is not just about materials; The components themselves are extremely complex. In addition to tool technology, there is also a need for an optimal machining strategy [11].

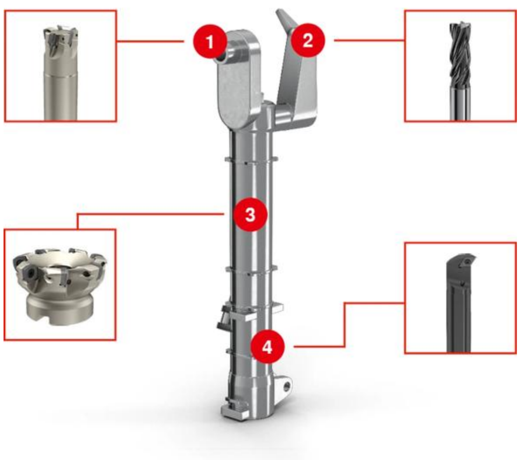


Figure 1.14 Cutting tools to machine the main cylinder

Landing gear strut. The landing gear strut retracts the gear into the fuselage after takeoff and extends the gear and locks it in place before landing. Titanium alloys are often used in their structures, allowing them to withstand the enormous forces exposed during takeoff and landing. The harsh processing characteristics of these alloys, coupled with the complex structure of the parts, make the processing process no easy task.

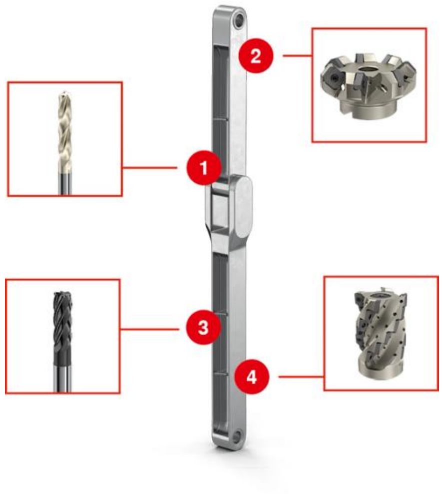


Figure 1.15 Cutting tools to machine the landing gear strut

Even the most modern aircraft assembly lines contain elements of manufacturing. To optimize different material combinations and production steps, we needed individual solutions that were tailored to each process step such as carbide, geometry and coating, and could be reused at any time. This allows the aircraft components to pass safely through all machining turbulence.

1.3 Requirements for cutting tools used in aviation industry

A production unit's primary activity today is manufacturing. Using the appropriate tool, the metal production process involves cutting, fabricating, and finishing. The machine tool must be robust enough to withstand the forces, heat, and climatic conditions during the machining operation. These qualities include red hardness, resistance to abrasion and wear, toughness, thermal conductivity, and many more. There are many cutting processes done under different conditions. Under these conditions and the general requirements of the tool, they require some unique properties. To achieve this performance, the cutting tool is composed of different materials.

The quality of tool performance depends on the material and structure of the tool. The cutting properties of tool materials must meet the following basic requirements:

Hot hardness. Hardness is typically assessed at room temperature. However, the term "Hot hardness" refers to hardness at high temperatures. We are aware that when temperature rises, hardness diminishes. Heat is produced during the cutting of metal. Nearly 600°C to 1800°C is a high raised temperature, and the tool material must be able to keep its hardness, wear resistance, and strength at this temperature [12]. The variation in hardness of several tool materials with temperature increase is shown in Figure 1.16.

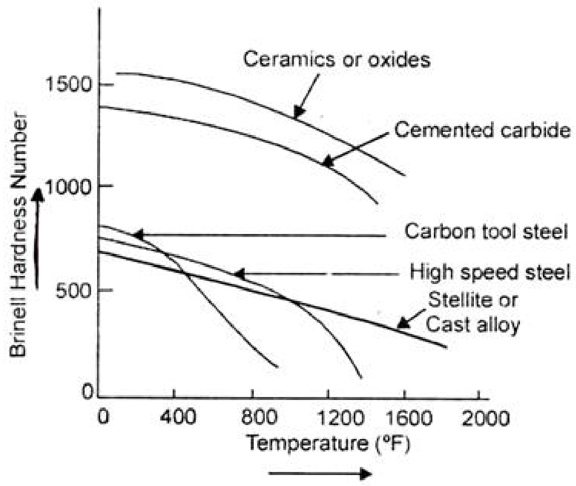


Figure 1.16 Variation of hardness with temperature

Toughness. The tool material must be tough enough so that it can work without fracture in impact forces occurs in interrupted cutting operations (such as milling, turning of splined shaft). It must be able to withstand vibrations occurred during machining.

Wear Resistance. The term wear means loss of material. The cutting edge of the tool, which is constantly in contact with the workpiece, and the rake face (over which the chip flows), gradually lose material over time as it continues to cut. So that a suitable tool life can be acquired before the tool is indexed or changed, the tool material must have wear resistance.

Chemical Stability or Inertness. To prevent any unfavorable reactions between the tool material and the work material, the tool material must be chemically stable or inert with respect to the work material.

Shock Resistance. Tool material must have high resistance against thermal and mechanical shocks, especially in intermittent cutting in which tool-work engages and dis-engages at regular intervals.

Low Friction. Tool material must have low coefficient of friction. So that the heat generated will be lower, and tool life increases.

Favorable Cost. In competitive industrial environment, tool material cost must be favorable for better profits. For example, diamond tools are not used for common applications due to its high cost [13].

A variety of different tool materials can only maintain their cutting performance in a certain temperature range, the main properties of common tool materials and normal operating temperature. Cutting tool material should be selected based on the properties requirements during the machining or cutting process. One should always take care during the selection of a type of cutting tool and its material properties.

Machining process, the tool cutting edge to withstand high cutting temperature, high pressure and high strain rate, which requires the tool should not only have higher hot hardness and wear resistance, and high strength and toughness, coating technology and surface treatment technology of tools is to meet the comprehensive performance of machining cutting tool material, and developed.

1.4 Methods to improve the cutting process

Cutting Tools damage not only affects the quality and efficiency of machining, but also may lead to serious machine tool and personal accidents. There are two kinds of tool damage wear and damage, processing products, the tool by cutting force, cutting heat and friction, will gradually wear or damage, finally lose the cutting ability. Aviation parts are generally difficult to process materials, the selection of high quality difficult to process materials tool, must have ultra-fine grain tool matrix, sharp cutting Angle, strong cutting edge, heat-resistant surface coating. According to the past processing of difficult to process materials application experience, processing methods and reasonable choice of parameters, for processing this kind of difficult to process materials is very important, the use of special processing skills to improve processing efficiency, prolong tool life is very effective.

With the wear of the tool, the machining accuracy of the workpiece gradually decreases, and the machined surface gradually becomes rough. Tool wear to a certain extent cannot continue to use, otherwise will reduce the workpiece dimensional accuracy and machining surface quality, but also increase the consumption of tools and processing costs.

Over time, cutting tools can chip and wear, eventually rendering them useless. Every tool has a lifespan and replacing tools is inevitable. However, there are some strategies that will help minimize damage and extend the life of your tools.

Control the Heat. Heat is produced during the cutting process by the friction of chip removal. Your tools may eventually become damaged by high heat. It's crucial to manage the heat created in this way as much as possible. The amount of heat produced during the cutting process can be managed with the use of a CO_2 coolant system, minimizing the harm done to the tool.

Get the edge ready. The majority of edge preparation entails material removal from the cutting tool. This procedure is crucial to reducing the likelihood of edge chipping, which can result in tool failure. In order to reduce this damage, the edge will be strengthened by preparation. The edge of the material can be prepared using a variety of techniques, including as brushing and nylon filament brush honing.

Design tools properly. Making ensuring a tool has a good design is one of the best methods to guarantee its durability. Cutting tools must remove large amounts of metal quickly and with little strain. These instruments must be able to withstand the strain of multiple simultaneous movements in different directions. A tool that has been appropriately constructed will be able to withstand the demands of the operation without being damaged.

Coating the inserts. Current coating technologies include:

- Titanium nitride (TiN) coating: This is a universal PVD and CVD coating, which can improve the hardness and oxidation temperature of the tool.
- Titanium carbon nitride (TiCN) coating: by adding carbon element in TiN, the hardness and surface finish of the coating are improved.
- Nitrogen aluminum titanium (TiAlN) and nitrogen titanium aluminum (AlTiN) coating: alumina (Al2O3) layer and the composite application of these coatings can improve the tool life of high temperature machining. Alumina coatings are particularly suitable for dry and near dry cutting. The AlTiN coating has a higher aluminum content and has a higher surface hardness than the TiAlN coating with a higher titanium content. AlTiN coatings are commonly used in highspeed machining [14].
- Chromium nitride (CrN) coating: This coating has good adhesion resistance, is the first choice of anti-chipping tumor solution.
- Diamond coating: diamond coating can significantly improve the cutting performance of non-ferrous materials tool processing, very suitable for processing graphite, metal matrix composites, high silicon aluminum alloy and other high abrasive materials. However, diamond coating is not suitable for processing steel parts, because its chemical reaction with steel will destroy the adhesion property of coating and substrate.

PVD-coated tools have gained market share in recent years, and their prices are comparable to CVD coated tools. CVD coatings are typically 5-15µm thick, while PVD coatings are about 2-6µm thick. When applied to the tool matrix, the CVD coating produces undesirable tensile stress. However, PVD coating helps to form beneficial compressive stress on the matrix. Thicker CVD coatings usually significantly reduce the cutting edge strength of the tool. Therefore, CVD coatings should not be used on tools that require very sharp cutting edges.

Use the appropriate feeds and speeds. It's crucial to research the appropriate feeds and speeds for your particular instruments and the metals those tools cut. Tools can be damaged as well as the material being worked on when they are used at the incorrect feed or speed. Even though you might assume the cut's sound and appearance are sufficient indicators of its accuracy, sometimes you won't realize the harm that is being done. Look up the feeds and speeds in advance and enter the correct ones into the computer software to prevent this damage and prolong the life of your tool.

Lubrication sticky materials. Metal cutting fluid (hereinafter referred to as cutting fluid) in the process of cutting, lubrication, reduces the rake face and chip, after the blade surface and the machined surface, the friction between form part of the lubricating film, so as to reduce the cutting force, friction and power consumption, reduce the surface temperature of the cutting tool and workpiece blank friction parts and tool wear and improve the machinability of workpiece materials.

Cutting fluid cooling is through it and fever due to cutting tool or grinding wheel, convection between the chip and workpiece and vaporization, the cutting heat away from the cutting tool and workpiece, effectively reduce the cutting temperature, reduce the thermal deformation of workpiece and tool, keep the tool hardness, improve the machining precision and tool life.

In the process of metal cutting, the cutting fluid is required to have a good cleaning effect. Remove generated chips, grinding chips and iron powder, oil and sand, prevent machine tool and workpiece, tool contamination, so that the cutting edge of the tool or grinding wheel to keep sharp, will not affect the cutting effect.

In the process of metal cutting, the workpiece and the environmental media and cutting fluid components decomposition or oxidation deterioration of the sludge and other corrosive media contact and corrosion, and the surface of the machine tool parts contact with the cutting fluid will therefore corrosion. In addition, after the processing of the workpiece or the process of temporary storage in the flow process, it is also required that the cutting fluid has a certain anti-rust ability, to prevent the environmental medium and residual cutting fluid in the sludge and other corrosive substances on the metal erosion. Especially in the wet and rainy season in southern China, we should pay more attention to the rust prevention measures between working procedures.

Conclusion to the part 1

In the aviation manufacturing industry, small batch processing of a single piece is not uncommon, therefore, damage to a piece of work will cause a great loss of production efficiency. Because the failure of an aircraft part can have catastrophic consequences, compliance controls and risk mitigation mechanisms make reprocessing damaged parts more complex in the aerospace industry than in other industries. Workpiece or machine tool damage due to tool breakage can have a significant impact on manufacturer profitability and customer satisfaction.

Many special machine tools used in aviation manufacturing industry are responsible for vital processing tasks. Because these machines are expensive and take a long time to prepare for processing, they are likely to be "bottleneck assets" for manufacturers, and if these machines are damaged due to tool breakage, it can have a significant impact on the production capacity of the enterprise.

Tool breakage can occur for many reasons in machining, but no solution can ensure 100% detection or completely avoid the occurrence of tool breakage. Specially developed tool damage recovery cycle procedures can save workpiece and production losses. In view of the characteristics of machine tool, material cost added in aviation manufacturing industry, in order to protect the investment of enterprises, it is necessary to develop different levels of tool breakage prevention and detection strategies.

In the aerospace industry, the value of the workpiece and the type of material being machined require that the best quality tools be used in most cutting operations.

Therefore, the urgent problem is to optimize the technology of materials and elements for extreme conditions in terms of strength and performance. Thus, the direction in solving the problem of extending the life of tools for heavy engineering is to increase surface and bulk strength and also its hardness. Ways to obtain tool materials with a set of characteristics required in the conditions of processing on heavy machines should be considered surface modification technologies that control the defects and strength of the surface layers of tool materials, as well as volumetric modification of materials and tools.

PART 2

ANALYSIS OF CUTTING TOOLS IMPROVEMENT METHOD

The fundamental purpose of machining is to cut off the excess material on the workpiece with the tool, so that it becomes the precision and surface quality of the technical requirements of the parts. Therefore, the contradiction of machining is between the tool and the workpiece. No suitable tool and then advanced control system can not complete the task of machining parts, machining system in the effectiveness of various "information flow" is through the knife specific products, this is the essence of machining. Therefore, we can not blindly pursue the investment and construction of computer-aided software and ignore the research and investment of cutting technology itself, which can only be "virtual manufacturing".

2.1Working conditions of cutting tools

Statistical studies have shown that when machining on heavy machines, the cutting force allowed by the machine mechanisms, torque (Fig. 1.1), are not restricted by cutting conditions and can reach extremely high values. The maximum values of forces up to 10 times exceed their average value, which is usually used to calculate the design parameters of cutting tool.

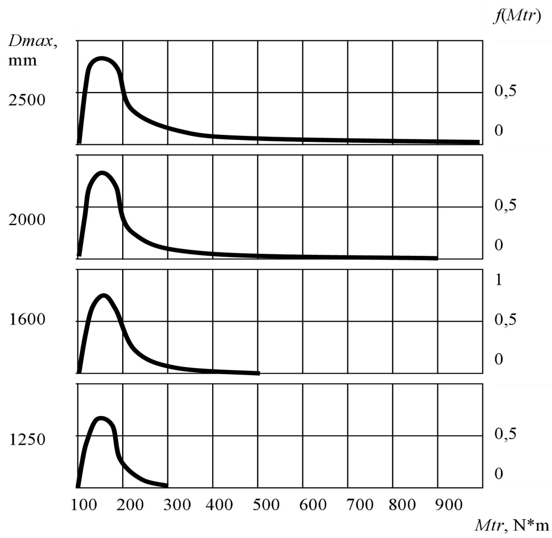


Figure 2.1 - Distributions of torque f (Mtr) values as function of working part diameter

Research into machining conditions of cutting tools in the processing of parts on machines shows that along with wear process significant place belongs to the destruction of the cutting part in the form of chipping, breakage and wear.

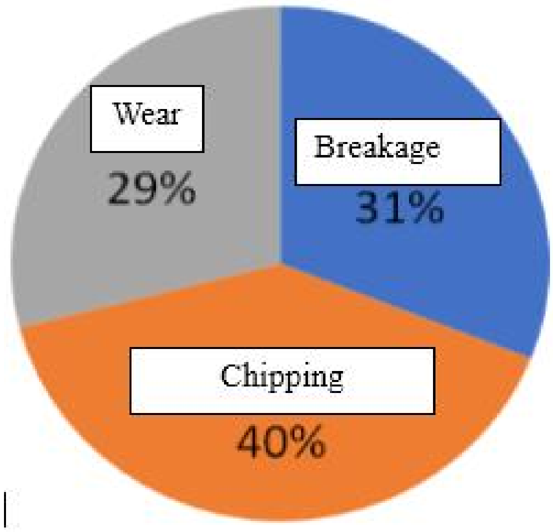


Figure 2.2 - Distribution of failures of cutting tools

The analysis of tool failures also revealed the heterogeneity of the degree of degradation of different parts of the variable plates of turning inserts and milling tools, inherent for machines.

Failures, including unforeseen, are due to random fluctuations in the physical and mechanical properties of the material being processed, especially during rough turning in the presence of crusts.

The efficiency of the cutting tool is also affected by the scattering of physical and mechanical properties of the tool material, its defect in the form of agglomerates of carbide grains and pores, which leads to instability of bending strength and hardness of tool cemented carbides.

The destruction of carbide inserts when machining on machines is due to the fact that large values of the undeformed chip thickness cause an increase in the magnitude and range of tensile stresses on the front surface of the tool[15].

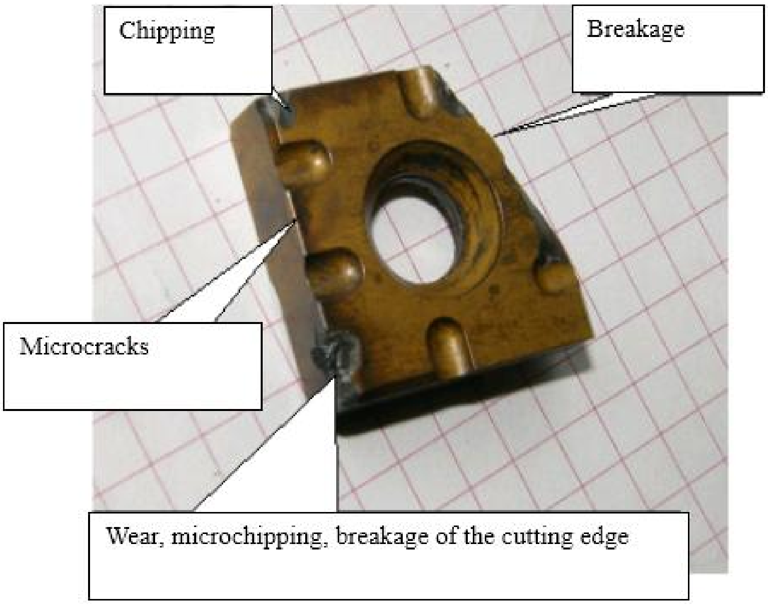


Figure 2.3 - Types of damage and destruction of replaceable plates

The presence of tool failures significantly affects the efficiency of turning large parts, because there is a need to spend unplanned time and money to restore them.

Therefore, the urgent problem is to optimize the technology of materials and elements for extreme conditions in terms of strength and performance. Thus, the direction in solving the problem of extending the life of tools for engineering is to increase surface and bulk strength and also its hardness. Ways to obtain tool materials with a set of characteristics required in the conditions of processing on machines should be considered surface modification technologies that control the defects and strength of the surface layers of tool materials, as well as volumetric modification of materials and tools.

2.2 Methods of improving the physical and mechanical properties of carbide tool materials

There are ways to improve the physical and mechanical properties of tool materials, although they can increase the wear resistance of the tool, but the costs compared to the efficiency of such methods remain significant, and in many cases uneconomical and impractical due to loss of other valuable properties. Therefore, the development of new advanced methods of strengthening the cutting tool is an important task to increase the service life of metalworking tools.

The main known methods of increasing the wear resistance and strength of carbide tools can be divided into the following groups: design methods; strengthening by mechanical shot peening; application of wear-resistant coatings; chemical and thermal processing; laser hardening; plasma arc hardening; radiation strengthening; ionic doping; magnetic abrasive processing, pulsed magnetic field processing.

The choice of a method of hardening depends on many factors that determine its effectiveness and cost of implementation in certain production conditions.

Among the design methods should be noted [16]:

- rounding of cutting edges, which leads to a change in the direction of cutting forces and reduce oscillations;

- increase in the sizes of dangerous section of a plate, or its thickening;

- increasing the stiffness of the support of the cutting insert in the holder, grinding or finishing the supporting surface of the plate, hardening of the holder, reducing the rear corner of the insert;

- application of substrates with high modulus of elasticity and resistance to compression at the temperature arising at a support.

These methods do not lead to an increase in production costs, but their efficiency depends on certain operating conditions (material being processed, cutting mode, characteristics of equipment, devices, etc.).

One of the promising ways to increase the strength of the tool is the processing of working surfaces by plastic deformation (SPD): vibration, shot peening.

When processing SPD is applied, a large number of blows are applied on cutting surfaces, resulting in plastic deformation and brittle-abrasive wear of these surfaces. All phase components of the cemented carbide are plastically deformed, but to the greatest extent - tungsten carbide. At the same time, the mosaic blocks are crushed, the microdeformation of the lattice increases and compressive stresses of the order of 100–130 N/m2 occur.

The use of SPD methods in the strengthening of carbide cutting tools allowed to increase the supply by 1.1-1.2 times.

The effectiveness of SPD methods is determined by the dependence of strength on geometric parameters, physical and mechanical properties of the material. At SPD there is a rounding of cutting edges that increases durability of the tool[17].

However, the efficiency of rounding of the cutting edges and the optimal value of the radius of rounding depend primarily on the thickness of the cut layer and the hardness of the material being processed. This limits the application of SPD.

The use of liquid in shot blasting increases the maximum radius of curvature by 20 percent. At the moment of reaching the maximum strength, the degree of deformation of the cutters of both types of processing is approximately the same, while the radius of curvature of the cutters, which are treated with liquid, is 10-15 percent higher. This provides an increase in strength by 1.17 times. Destructive supply during hardening without liquid increases 1.29 times, with liquid - 1.34 times.

Vibration processing is a mechanical process of removing the smallest particles of material from the surface to be machined, as well as smoothing of micro-irregularities by their plastic deformation by the working elements of the abrasive filler, which performs oscillating movements [18].

Improving the performance of carbide tools as a result of its vibration processing is achieved due to the fact that the latter provides rounding of cutting edges and other surfaces of the cutting part, a favorable change in physical and mechanical properties of the surface layer of the cemented carbide. As a result of research it was proved that about 60-70 percent of the effect when vibrating the tool is achieved by rounding the edges and 30-40 percent - by reducing the roughness and changing the properties of the surface layer. Vibration processing is very time consuming and therefore requires significant costs.

Shock wave energy has found application in the processing of metal-ceramic alloys to increase their strength and stability.

The cutting insert made of VK8 alloy was placed in a lead container, the choice of which as a pulse "trap" was due to the relative equality of the acoustic stiffness of the alloy VK8 and lead. The formation of a flat detonation front was performed by a plane-wave generator. The "running" on the surface of the detonation front, forms an oblique shock wave in the material, the intensity of which decreases as it passes - deep into the environment. With such a spread of the impact front in the material, favorable shear conditions are created in terms of thermodynamics, which lead to a marked strengthening of compact materials and inevitably cause the destruction of fragile media. This fracture accounted for 60 percent of the volume of the cemented carbide. The conditions for the complete preservation of the plate were achieved by means of the experimentally found law of attenuation of plane shock waves in copper.

Studies of the microstructure showed significant grinding of tungsten carbide grains and refinement of the cobalt bond due to its deformation, which led to an increase in microhardness by 1.4 times. As a result of tests, it was found that the tool life increased by 2 times. This is due to the grinding of tungsten carbides, the strengthening of the cobalt bond and the appearance of compressed stresses on the surface of the plate.

Applying a hard coating, resistant to abrasion, on carbide inserts can increase the durability of cutting edges several times compared to conventional inserts or at the same durability to increase the cutting speed.

Titanium carbide (TiC) coated plates with a thickness of 5–6 μm have a typical disadvantage: the presence of a decarburized brittle layer between the coating and the substrate. As a result, they could be used only for continuous cutting.

Coated cutting inserts did not have this disadvantage due to the advanced manufacturing technology. The coating thickness of these inserts was increased to 7–8 μm, and special grades of cemented carbide were used as a basis. This allowed the use of inserts for interrupted cutting.

Inserts having a coating thickness of up to 10 μm consist of 2 or more thin layers of different composition. Titanium carbide (TiC) is most often applied to the base, and titanium nitride (TiN) or alumina (Al2O3) is applied to it. The use of inserts with a multilayer coating allowed to increase the productivity of processing by 1.5 times compared to inserts with a single layer coating (TiC).

However, coated inserts have a number of disadvantages. When regrinding, all advantages over uncoated inserts are nullified. They should not be used where a very sharp cutting edge is required, as the cutting edges are always inevitably rounded when applied. They are not very suitable for light metals, wood and other materials with low hardness. Unsuitable coated inserts in cases where the viscosity of their base metal is insufficient for the selected machining operation.

One of the ways to increase the stability of the carbide tool is the heat processing of the cutting plate. The greatest effect when using this method is achieved by heat processing in a gaseous medium: N_2 (40-60%), CO (15-20%), H_2 (30-35%)

Titanium nitride (TiN) is formed on the surface of carbide inserts, which has sufficient thermal conductivity, resistance to oxidation at high temperatures, relatively low brittleness and high abrasion resistance.

Laser processing helps to grind and saturate the dislocations of the structure of the surface layer of the tool material, which leads to increased hardness and, consequently, a significant increase in wear resistance of the tool. Laser surface hardening is characterized by maintaining the original purity of the upper layer of the product and ensures the locality of the process. But the technological process of surface beam processing is complex, depends on a number of conventions, requires (when irradiating a multi-blade tool) significant energy costs and time-consuming[19].

Note the main disadvantages of surface laser hardening:

- hardening is carried out only at the junction of the working surface to the cutting edge;

- simultaneous strengthening of both surfaces (front and rear) is unacceptable;

- the cutting edge after laser heat processing is weakened against the action of brittle fracture forces;

- the process is long in time (when strengthening the multi-blade tool) and requires significant energy costs;

- when regrinding the tool, the established layer is removed.

Ion implantation method is used to change the mechanical properties of various metals. The method consists in implantation of ions of a number of elements (N +, B +, In +, (Ti + N), (Ti + B)) on the surface of carbide inserts and allows to apply multilayer coatings. Experiments have shown that the tool life of cemented carbide inserts with a multilayer coating increases by 1.4-1.8 times.

One of the promising methods of finishing polishing and hardening processing of the tool is the method of magnetic abrasive processing (MAP), when a comprehensive impact on the processed surface and the surface layer of parts is carried out. The analysis of MAP interaction conditions in the conditions of large magnetic slits is first of all processing at active frictional-shock interaction of the processed surface with the magnetic-abrasive tool (MAT) formed in the course of processing. In the implementation of the processes of predominant microcutting or microplastic deformation of the treated surfaces, a significant factor is the size, geometric characteristics and shape of the particles of magnetically abrasive powder materials. It is shown that MAP of drills after their regrinding with the use of round equilibrium powders provides opportunities to strengthen the surface layer, reduce the roughness of the working surfaces of the tool and increase their stability by more than 1.7 times.

However, due to the intensification of production, one of the most acute problems in the development and application of more effective methods of strengthening metalworking tools.

2.3 Pulsed magnetic field processing method

Pulsed magnetic field processing is based on the fact that the vortex magnetic field iteracts with the carbide insert, improves the structure and properties of the latter. With this hardening, the tool is placed in the inductor so that the center of gravity is shifted relative to the geometric center of the solenoid. Due to this, when the device is turned on, the tool is drawn by the field into the solenoid with acceleration and performs relative to its geometric center damped oscillations, the amplitude of which decreases over time under the action of friction and is zero.

Due to the heterogeneity of the crystal structure of the material, eddy currents are generated. In this case, the heat released is dissipated over the volume of the tool so that the thermal field gradient is higher, the more complex and heterogeneous the microstructure of the alloy. In places of structural inhomogeneity, as well as the concentration of stresses there is a reduced heat, which increases tenfold the local temperature of overstressed areas. As a result, the tool is subjected to "screw compression", in which electrodynamic forces compact and order the crystals of the structure, thereby reducing their internal overvoltage[20].

The use of magnetic fields in the processes of cutting and strengthening the cutting tool is a promising direction in the development of high technology in machining. Increasing the stability of the tool can be achieved due to the influence of the magnetic field or the conditions of the cutting process, or the structure and physical and mechanical properties of tool materials with ferromagnetic components. Accordingly, there are two directions of application of magnetic fields in machining. The first involves increasing the stability of the tool when cutting in a magnetic field, the second involves increasing the stability characteristics of the cutting tool after processing in constant, variable and pulsed magnetic fields due to changes in structure and physical and mechanical properties of tool material. Various researchers explain the increase in the period of tool life during cutting in a magnetic field by the removal of heat from the tool due to the manifestation of the thermomagnetic effect of Riga - Ledyuk [21], increasing the mechanical properties of the tool material due to the ordering of its grain size, the emergence of forces that cause bending of the chip roots, reducing the area of contact of the chips with the tool, changing the shear angle and reducing cutting. The effect of increasing the period of resistance to cutting in a magnetic field depends on the direction of magnetic flux, the magnitude of the magnetic induction [22] and cutting modes. The influence of the external magnetic field on the conditions of the cutting process allows, in addition to increasing the tool life of the tool, to increase the optimal cutting speed, reduce the optimal surface wear, to improve the quality of the treated surface.

On the other hand, in the works it is shown that the tool, which is subjected to magnetic processing, has an increased tool life and in the absence of an external magnetic field in the cutting zone. In this case, the increase in the tool life is due only to changes in the structure and physical and mechanical properties of the tool material after magnetic processing. The literature provides various information about the increase in the tool life of the cutting tool as a result of magnetic processing and its causes. The increase in the stability of cutting tools and drills made of high-speed steels after processing in constant and alternating magnetic fields is explained by the decay of residual austenite in the surface, re-hardened layer of steel formed by sharpening the tool. In the works the effect of increasing the tool life of the high-speed tool after processing in constant magnetic fields is associated with the polarity of its working part after magnetization. In the works the increase of the tool life of the steel tool at processing by a static magnetic field or with one-time influence of the field, or with the movement of the tool which is strengthened, in a magnetic field is specified[23]. In the reduction of wear of tool steels as a result of remagnetization by relatively weak fields is noted, which is explained by the authors in terms of changes in structure and properties of steel surface due to diffusion of tungsten atoms and other elements from internal volumes of material after field exposure.

The most promising direction of using magnetic fields to increase the tool life of the cutting tool from materials containing ferromagnetic components is pulsed magnetic field processing (PMFP), which allows to obtain the most stable increase in tool life by changing the physical and mechanical properties of tool material. the results of the implementation of a set of structural changes that have a magnetostrictive nature. The pulsed nature of the magnetic field in PMFP allows you to easily make an intense energy impact on the material with the help of electromagnetic waves. A kind of pulsed electromagnetic shaking of condensed systems with many real defects accelerates the rate of relaxation and structural adjustment in them. The choice of a pulsed magnetic field has also simplified the requirements for power supplies and made installations compact and portable. In this case, the equipment for PMFP can be installed in the mechanical shops of the enterprise, and the parameters of the processing modes vary depending on the tool material in order to optimize the characteristics of the plate [24].

The change in the properties of ferromagnets after PMFP is achieved due to the directed orientation of the free electrons of matter by the external field, as a result of which there are physical preconditions for changes in the structure and stress state of the material. Based on the works it can be argued that the PMFP has a complex effect on the material of magnetostrictive processes and mechanical deformations caused by them, thermal and electromagnetic vortex fluxes localized in places of magnetic flux concentration and directionally oriented processes, spin characteristics of outer electrons of boundary zone atoms. PMFP is a combination of electromagnetic and thermodynamic methods of controlling the imbalance structure of material. Changes in the structure of the material as a result of PMFP can be due to force (magnetostrictive) or thermal factor. As shown in, structural changes in the material occur as a result of activation of dislocation or diffusion processes.

According to S.M. Postnikov [25], at the PMFP of high-speed steels there is an interaction of the elastic field caused by magnetostrictive deformation with the elastic field of the material's own real dislocation structure. This interaction leads to the appearance of local overvoltages, in the locations of which the probability of thermofluctuation rupture of interatomic stress bonds increases sharply. In those places where local overstrains exceed the limits of elasticity of the material, sources of plastic deformation are formed and the processes of reproduction and displacement of dislocations are intensified. With increasing dislocation density, the steel acquires a kind of slander, which is expressed in changes in the parameter of the crystal lattices of martensite. The increase in the mechanical characteristics of high-speed steel as a result of PMFP is due to the release from the metal matrix of fine carbide particles as a result of magnetic dispersion hardening due to the above structural processes. It is Postnikov's concept of magnetostrictive hardening and magnetically dispersion hardening of high-speed steels that is the only integral scientific theory of the PMFP of a cutting tool.

The results of studies of the influence of PMFP on the tool life of the cutting tool and the physical and mechanical properties of tool materials are presented in [26].

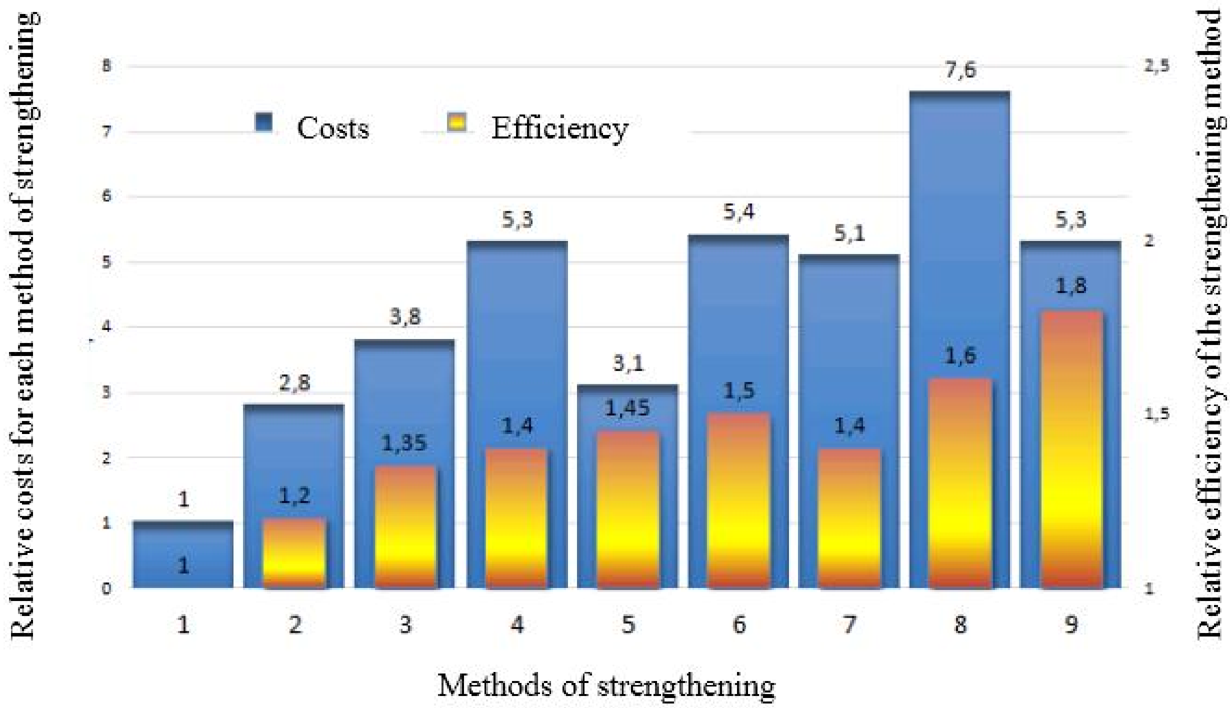
Effect of magnetic field strength on service life of cutting tools and physical and mechanical properties of tool materials with PMFP in [26]. There is a fairly narrow range of pulse field strength values, the treatment of which improves the cutting properties of the tool. The extreme dependence of the physical and mechanical properties of tool materials, the wear of high speed steel, and the resistance of cutting tools on magnetic field strength. Maximum steel hardness, tool life and minimum steel wear due to the specific and optimum magnetic field strength. This confirms the theoretical statement of B.V. Maligin [27] is absorbed by the material during magnetic processing, maximizing its mechanical properties, for the presence of any material with a certain value of magnetic field strength (and hence value of magnetic energy).

The question of the influence of cutting modes on the stability of the tool subjected to PMFP or which is in the external magnetic field, are best considered in the studies of representatives of the scientific school A.D.Makarov. In them, in addition to increasing the length of the cutting path, there is an increase in the optimal cutting speed as a result of PMFP.

Conclusion to the Part 2

There are many factors could influence the choice to strengthen the properties of cutting inserts. So we need take the deficiency of improvement into account.The below figure has show the cost and efficiency which correspond to their method of strengthening.

As can be seen from Figure 2.4, the best combination of cost and production efficiency is observed in the method of pulse magnetic field processing. The high efficiency is due to the volumetric nature of the hardening, as a result of which the increase in stability persists after regrinding. For other post-regrinding methods, reinforcement must be repeated to increase stability.



1 - constructive methods; 2 - strengthening by mechanical slander; 3 - application of wear-resistant coatings; 4 - pulsed laser processing; 5 - plasma arc hardening; 6 - radiation hardening; 7 - ionic doping; 8 - surface laser hardening; 9 - pulsed magnetic field processing.

Figure 2.4 - Dependence of costs and production efficiency on methods of strengthening cutting tools from a cemented carbide VK6

PART 3
WEAR RESISTANCE INVESTIGATIONS OF CUTTING TOOLS MODIFIED BY PULSED MAGNETIC FIELD PROCESSING

The magnitude of the effect of increasing the mechanical properties of the tool material, as well as the magnitude of the effect of increasing the tool life of the cutting tool, depends on PMFP modes (pulsed magnetic field strength, PMFP duration, exposure time after PMFP), with magnetic field strength.

The influence of magnetic field strength on the tool life of the cutting tool and the physical and mechanical characteristics of tool materials after PMFP noted in [26]. There is a rather narrow range of values of the pulsed magnetic field strength, the processing of which improves the cutting properties of the tool. The extreme nature of the dependence of physical and mechanical properties of tool material, wear of high-speed steels and resistance of cutting tools on magnetic field strength with a certain optimum magnetic field strength, which provides maximum steel hardness, tool life and minimum steel wear. This confirms the theoretical statement of B.V. Maligin [27] on the existence for each material of a certain value of the magnetic field strength (and hence the value of magnetic energy), which is absorbed by the material during the time of magnetic processing and maximizes its mechanical properties.

As the duration of the PMFP increases to a certain extent, the stability of the tool and the physical and mechanical properties of steel increase. To complete the conversion of electromagnetic energy into energy of internal transformations in the material and stabilize the new structure and properties acquired by the material after PMFP, the tool must be kept for a certain time not less than the stabilization time t_{st}, which changes physical and mechanical properties of the material. And in its turn this is a manifestation of the general nature of long-term relaxations of physical parameters of condensed media after exposure to magnetic fields [28]. The influence of the magnetic state and polarity of the working part of the tool on its stability is not significant.

Pulsed magnetic field processing(PMFP) of carbide cutting inserts is carried out at an installation consisting of a pulse generator, power supply and inductor. For processing of small parts the inductor is established on a horizontal dielectric diamagnetic surface (plastic, a tree, rubber, etc.), the axis of the inductor has to be vertical. The products are placed in the middle of the inductor and a processing session lasting 120 s is carried out.

3.1 Pulsed magnetic field processing of cutting insert

Technical characteristics of the generator and inductors are given in table. 3.1–3.2. The technological parameter of the unit control is the operating voltage of the installation (capacitor discharge voltage, magnetic field pulse generation circuits), displayed on the front panel of the generator unit (Fig. 3.1, a).

Various designs of the magnetic inductor are developed for realization of processing (fig. 3.1, b). The analysis of the geometry of solenoids for magnetic inductors in terms of their optimality and ability to provide the required values of magnetic field strength and pulse frequency. As the length of the solenoid increases, there is a weakening of the magnetic field in the working gap.

Table3.1 - Brief technical characteristics of the complex for PMFP

Complex parameter	Parameter value
Magnetic field strength range, A/m	0.2·105–2.2·105
Operating voltage	100–900V
Inductor inductance	225 μH
Pulse frequency, Hz	1–10
Impulse time, ms	60

A)

B)

C)

Figure 3.1 – Experimental setup for generating a pulsed magnetic field a - generator unit b, c - design of the magnetic inductor

The magnetic field strength in the center of the inductor is determined by the formula:

$$H = \mu_0 I_0 \frac{W}{l}, \tag{3.1}$$

where I is the current in turn, A; L - inductance, H; W - number of turns; l is the length of the winding, mm; μ0 is the magnetic constant (for vacuum $\mu 0 = 4\pi \cdot 10^{-7}$ H/m).

Table 3.2 - Brief technical characteristics of inductors

Parameters	Parameter value	
	Inductor 1	Inductor 2
Inductance, μH	220	220
Length, mm	90	70
Number of turns, mm	90	103
Conductor diameter, mm	3	3
Internal diameter of the inductor, mm	40	32

For preliminary assessment of the effect of pulsed magnetic field processing on the wear resistance of carbide tools, express test methods were used [29]. Unlike full durability tests, express tests reduce test time, tool costs, and material being processed.

At the heart of the express methods are the physical principles of reliability theory, namely: Sedyakin's principle, Miner's hypothesis. The basic physical principle of reliability is based on the fact that the real system loses performance due to various influences, at the same time, each element of the system and the system as a whole before operation has some margin of safety - resource. During operation, this resource is consumed at a certain rate due to the modes and conditions of operation.

Sedyakin's principle takes place under the following conditions:

- with the transfer of the tool from one mode of operation to another it should not be a radical change in the processes occurring in the material of the tool;

- the same destructive factors must operate in different modes of operation of the tool, and only the intensity of these factors can change.

The principle of load extrapolation for carbide tools can be implemented by stepwise (gradual) increase in feed rate and by methods of stepwise and stepless (end turning) increase in cutting speed. In the first case the influence of gradual increase of loading on characteristics of durability of tool material is investigated, and in the second - intensity of wear of material at various range of speeds of cutting

3.2 Wear resistance investigations under step-increasing conditions

Tests for wear resistance under the method of step-increasing cutting speed were to determine the cutting speed at which wear reached the normative wear criterion.

The initial cutting speed V_1 was set equal to the normative value for specific grade of the tool material which is tested. During tests, V_1 will be increased in steps. The coefficient of geometric progression of a number of cutting speeds φ_{st} was taken equal to 1.26 in accordance with the design of the gearbox of the machine tool mark 1K62.

The speed was adjusted so that the number of stages of cutting speeds before wear was equal to 3-5. The duration of work on the step was assumed to be equal to 60 seconds. The minimum number of experiments is n = 7 [29].

After each cutting step, wear was measured on the main clearance face. During the tests, the cutting speed at which wear reaches the specified criterion of wear land width was recorded.

According to the test results, we calculated the average value of the cutting speed at which wear occurred for each batch of cutting tools and the wear rate, which was defined as the ratio of the increase in wear to the time during which this increase occurred:

$$V_з = \frac{\Delta\delta}{\tau_i} \tag{3.2}$$

where $\Delta\delta$ is the increase in wear over time τ_i.

The main idea of the strength tests of the cutting tools by the method of step-increasing feed consisted in determination of the feed, the achievement of which causes the destruction of the cutting tool.

The tests were performed as follows. The feed was set equal to the standard for roughing of structural steel, and then increased in steps. The coefficient of geometric progression of a feed values was taken be equal to 1.21. Based on the diameter of the workpiece and the height of the toolholder, the initial feed rate was taken equal to 0.58 mm/rev. The cutting speed was assumed to be 18–24 m/min.

The choice of cutting depth was made taking into account the size of the toolholder, the size of the machine tool, the maximum and minimum diameter of the workpiece and the thickness of the insert. In our case, the depth of cut was taken to be 2 mm.

The tests were performed in the same sequence as in the tests by the method of step-increasing speed of cutting. That feed, during which the cutting tool was chipped or broken, was accepted as the limit.

The results of testing tools using the step-increasing cutting speed method are presented in Figure 3.2 (confidence interval: ΔVu = ± 0.016 mm/min). It can be seen from these data that at more at low cutting speeds (V = 68–88 m/min) wear rate for of tools that are strengthened by PMFP is significantly reduced (by 2–2.3 times) compared to unreinforced tools. With further increase cutting speed, the wear rate of hardened cutters, on the contrary, will be 2-3 times higher compared to unreinforced incisors.

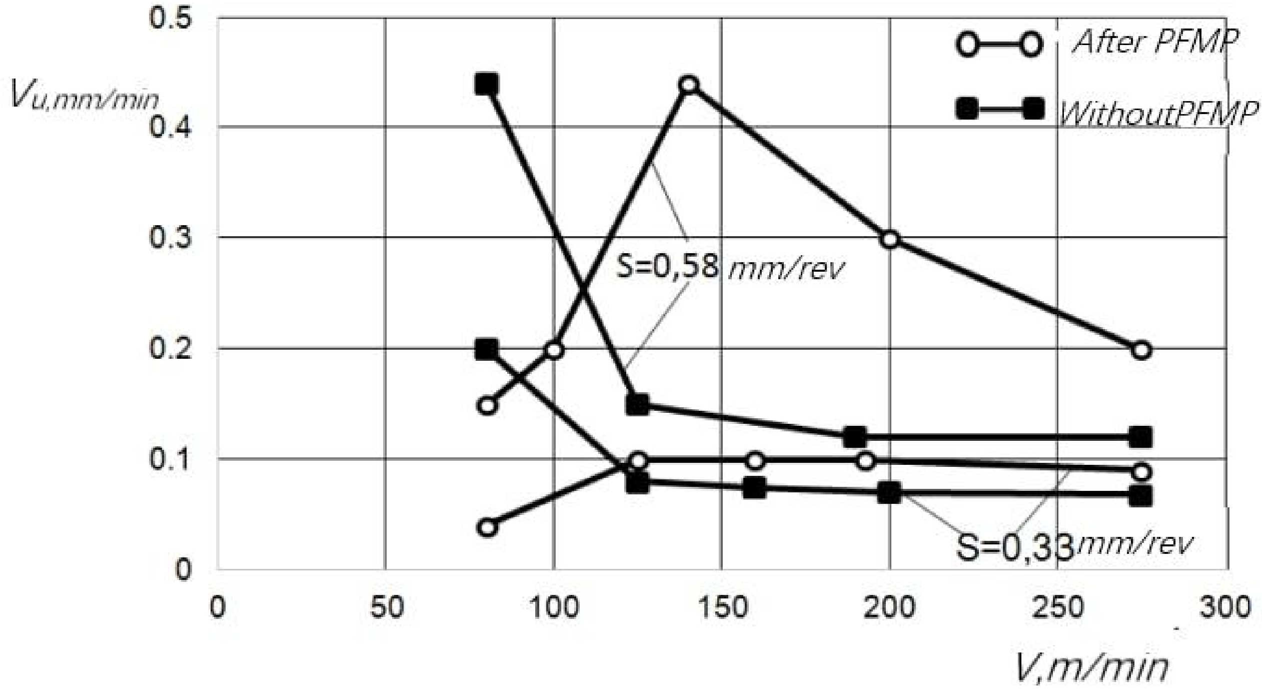


Figure 3.2 – Effect of cutting speed on wear rate of hard alloy tool

From this, it was concluded that the strengthening effect is really manifested at lower cutting speeds, i.e. during preliminary processing, which occurs, as a rule, at a higher feed. Strength testing of incisors by the step-increasing method submissions was to determine the submission that causes destruction of the cutting part of the cutter at constant values of speed and depth cutting in a time that is less than the time of work on the degree

3.3 Wear resistance investigations by continuous increase of cutting speed

The methods of continuous increase of cutting speed include the method of end face turning. When tested by this method it is possible to reduce the error of the results in comparison with the method of stepwise increase of the cutting mode, however, the duration of the tests increases [31].

Tests of cutting tools were carried out on cylindrical samples (Figure 3.2), which are fixed in the chuck of the lathe.

Figure 3.2 - Scheme of tests of cutting tools at continuous increasing the cutting speed

The end surface of the cylindrical sample with the central hole D_n was divided into sections. The diameter D_i of each ring was calculated by the formula:

$$D_i = D_н \cdot \varphi_i, \quad (3.3)$$

where φ – coefficient of proportionality; i – number.

The number of sections and the diameter of the last ring D_k was equal to the outer diameter of the workpiece. The diameter D_n is determined so that the initial velocity Vp correlated with the normative V, as

$$\frac{V_п}{V} = 0{,}5...0{,}7. \quad (3.4)$$

Tests of the cutting tools were performed by turning the end surface of the workpiece from the center to the periphery of each section. The spindle speed for each pass of the end surface was determined by the formula:

$$n_q = n_{n1} \cdot \varphi_1^{q-1}, \quad (3.5)$$

where q – number of the passage during end turning; n_{n1} – number of revolutions for the first pass;

During the tests there was a monotonic increase in cutting speed, so after turning of each ring, it was measured wear of the cutting tool on its clearance face. Turning of the end surface was carried out until the wear of the cutting tool on the clearance face reached the established criterion of the tool wear. If the wear of the cutting tool on the clearance face didn't meet the established criterion in the first pass, the turnig began again from the center to the periphery (second pass) with the spindle speed determined by formula (3.5) and so on. The speed at which the cutting tool reached the established criterion of the tool wear was considered the limiting speed *Vgr*, which was taken as a parameter of wear resistance of the tool[32].

The brands of cemented carbides inserts which were tested: T5C10, T15C6, WC8, WC6OM, TT20C9.

3.4 Tool life and performance testing of cutting inserts reinforced by PMFP

The cutting tools were selected from a batch of 18-20 pieces, hereinafter referred to as the sample.

The strength test of the cutting tools was intended to determine the feed, the achievement of which causes the destruction of the cutting insert. The feed was set at the normative level for pre-treatment and further increased by degrees[33].

The coefficient of geometric progression of the series of feeds φ_{st} is taken equal to 1.21 or closest according to the design of the feed box of the machine tool. Initial feeds are given in table. 3.3.

The workpieces were installed in the chuck and rear center to ensure maximum rigidity of the technological system of machining. Duration of work at each stage t_{st} = 6 s.

Table 3.3 - Values of initial feeds when testing cutting tools for strength

Toolholder height *H*, mm	40	50	63	80
Minimal diameter of workpiece *Dmin*, mm	400	500	600	700
Initial feed rate, mm/rev.	1,1–1,5	1,5–1,8	1,8–2,0	2,0–2,2

According to the current values of the cutting speed at which the wear occurred, and the destructive feed obtained by the number of experiments equal to 7, calculate the average values of the cutting speed at which the wear took place v_u and destructive feed *Sp*:

$$\bar{v}_u = \frac{1}{n}\sum_{i=1}^{n} v_{u_i}. \tag{3.6}$$

Coefficient of variation of cutting speed

$$V_{v_u} = \sigma_{v_u}/\bar{v}_u, \tag{3.7}$$

where σ_{v_u} – standard deviation of the cutting speed.

$$\sigma_{v_u} = \sqrt{\frac{\sum_{i=1}^{n}\left(v_{u_i}-\bar{v}_u\right)^2}{n-1}}. \tag{3.8}$$

Confidence intervals for cutting speed

$$\overline{v_u} \pm \Delta, \tag{3.9}$$

where $\Delta = \pm\, t_k\sigma_{v_u}/\sqrt{n}$, t_k – Student's criterion which equal 1.94 for

$f = n - 1 = 6$ and $P = 0.9$.

where f – degree of freedom, P – confidence level.

In the comparative assessment of the wear resistance of batches, the significance of the difference in their wear resistance is determined by the Student's criterion (with less than 20 items).

$$t_k = \frac{\left|\bar{v}_{u_1}-\bar{v}_{u_2}\right|}{\sqrt{n_1\sigma_1^2+n_2\sigma_2^2}}\sqrt{\frac{n_1 n_2(n_1+n_2-2)}{n_1+n_2}}\ , \tag{3.10}$$

where $\bar{v}_{u_1}$, $\bar{v}_{u_2}$ – the average values of the cutting speed at which the wear occurred for the first and second batch, respectively; n_1, n_2 – sample sizes.

3.6 Method of estimating of the tool properties by destructive feeding

The method establishes organizational and methodological principles of collecting and processing information about the reliability of cutting tools in operating conditions.

The minimum amount of observations N for estimating the average reliability with a relative error of δ <0.15 and a confidence level of $P \leq 0.9$ is 15.

The amount of observations is N = 18. The number of tools with indexible inserts is recommended to be equal to $N_K = 6$.

The following failure criteria were adopted during operational tests: achievement of the maximum allowable amount of wear, destruction of the cutting part of the tool. When comparing different design and technological options, tools of different types were randomly alternated. In the case of tests on several spindles and machines, the same number of tools was tested on each of them.

During the observations, the tool life (time of trouble-free operation or the number of machined parts) between regrinding or reinstallation of the indexible inserts, as well as the nature of the failure of the tool are recorded.

For tools with indexible inserts, the actual number of periods of insert tool life and its total tool life is recorded.

The main indicators of tool failure are the averagetool life T, the coefficient of variation V_T and gamma percentage of a tool life T_Y.

Average tool life:

$$T = \frac{1}{N} \sum_{i=1}^{n} T_i , \quad (3.11)$$

where T is the tool life of the tool in the *i*-th test; N - the amount of observations.

Coefficient of variation of a tool life:

$$V_T = S/T, \quad (3.12)$$

where S is the standard deviation

$$S = \sqrt{\frac{1}{N-1} \sum_{i=1}^{n} (T_i - T)^2} . \quad (3.13)$$

Upper T_b and lower T_n confidence limits:

$$Tb = \sqrt[b]{r_1}T, \ Tn = \sqrt[b]{r_3}T, \quad (3.14)$$

where β is the Weibull distribution parameter due to V_T.

Gamma percentage of a tool life $T\gamma$ – is the tool life that has and exceeds the specified percentage of cutting tools γ:

$$T_\gamma = a(-\ln(\gamma/100))^{\frac{1}{\beta}}, \quad (3.15\ )$$

where α is the Weibul distribution parameter, $\alpha = T/Kb$.

Average number of tool life periods for the tool being regrinded:

$$K = \frac{1}{N} \sum_{i=1}^{n} K_i, \quad (3.16)$$

where N is the amount of observations; K_i is the actual number of grindings of the i-th tool.

The average number of periods tool life of the inserts for the prefabricated tool:

$$K_{pl} = \frac{1}{N} \sum_{i=1}^{n} K_{pl\,i}, \quad (3.17)$$

where N is the amount of observations;

K_{pl} - the number of tool life periods of the inserts;

$$K_{pl1} = \frac{1}{N} \sum_{i=1}^{n} K_{pl1\,i}, \quad (3.18)$$

where K_{pl1} - the average consumption of inserts per 1 tool holder, due to consumption standards or estimated statistically.

$$K_K = M_{pl} / K_K, \quad (3.19)$$

where K_K - average monthly or average annual consumption of inserts; Mk – consumption of the toolholders for the same time period.

The main indicator of the maintainability of the tools with indexible inserts is the average recovery time:

$$t_b = \frac{1}{N}\sum_{y=1}^{l} t_{bi} r_y , \qquad (3.20)$$

where l is the number of structural elements of the cutting tool: indexible insert, support insert, mounting, tool holder; t_{bi} - time to eliminate the failure of the i-th element; r_y - the number of failures of the j-th element during the test

$$\sum_{y=1}^{l} r_y = N , \qquad (3.21)$$

where N is the amount of observations.

The purpose of experimental research was to establish the dependences of the destructive feed rate and the probability of destruction of the tool on the cutting conditions.

As the feed increases, the probability of breakage of the cutting tool grows, which is quantified as the ratio of the number of breakages to the observed quantity of a tool life periods. With a certain value of feed rate, the probability of failure will be equal to 1.0; that is, all cutting tools will collapse in the first period of tool life. This feed is called destructive and its value is established by the step-increasing feed cutting test according to the test methodology developed at the Donbas State Machine-Building Academy [34].

At each feed, the cutter works for a certain time, after which the feed is increased to the next step and so on, until there is a breakdown of a cutting tool. Before testing in accordance with the method of selection and diagnosis of the cutting tools.

Studies have shown that the destructive feed depends on both the time of machining on each feed and the number of feed stages that precede the destructive action. For most trials, a run time of 2 minutes was adopted, which provided both sufficient reliability and experimental performance.

Table 3.4 - Mechanical properties of parts materials

Mark of the processed material	Mechabical properties				
	Yield strength, N/mm^2	Ultimate tensile strength, N/mm^2	Relative elongation, δ_s%	Relative narrowing, ψ%	Impact strength, N·m/cm^2
40X	400	600	17	35	60
55X	350	650	10	30	–
40XH	300–350	650–700	18–20	45–50	–
90XΦ	690	950	1,2	1,0	6

Indexible inserts of one batch were tested, their main characteristics are given in table 3.5.

Table 3.5 - Mechanical properties of cemented carbide grades

Grade	Mechanical properies		
	Bending strength,MPa	Specific weight,g/cm^3	Hardness, HRA
T5C10	1469	12,72	90
TT7C12	1550	13,0	87
WC8	1650	14,8	88

3.6 Method evaluate the resistance to failure and wear after PMFP

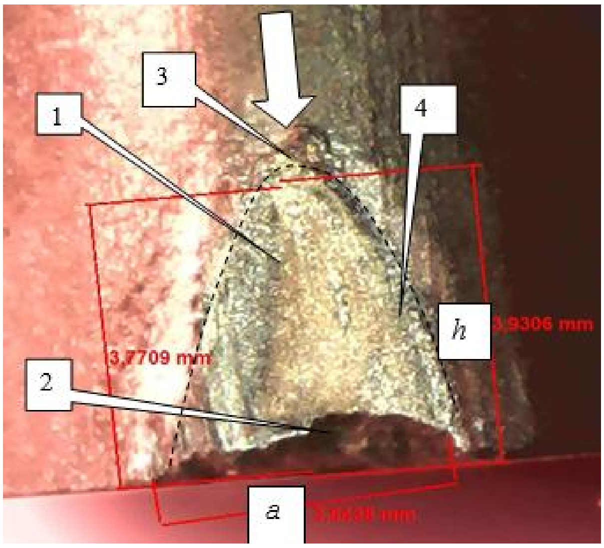
The specifics of tool failures on heavy machines and the use of modification methods that can be quickly implemented and optimized in production conditions, requires the development of comparative methods that allow one to quickly obtain a set of parameters that characterize wear resistance and resistance to destruction under heavy load.

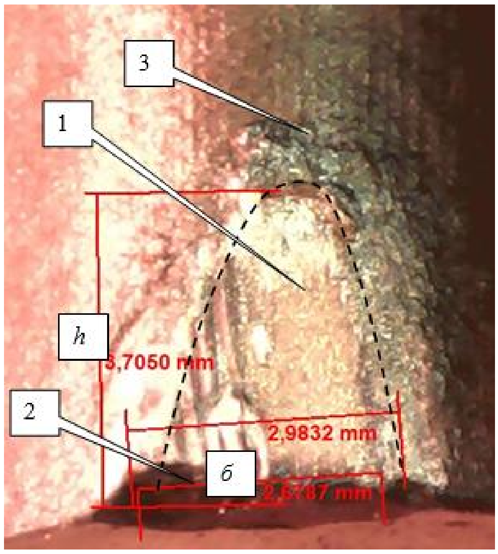
The proposed approach involves testing cutting inserts under conditions of high contact pressure with friction at elevated temperatures using equipment used in machining. A massive cylindrical workpiece mounted on a lathe is used as a counterbody. The tested insert is fixed in the tool holder in such a way to minimize chip formation (Fig. 3.4). The design of the tool holder allows the installation of a dinamometr, which controls the force *P* of pressing the insert to the counter body. Due to the high level of contact load, the formation of a chamfer on the clearance face of the cutting insert is ensured. The wear parameter is defined as the area of the wear land *S* formed during a certain test time. Specific pressure (ratio of compression force to the area - *P/S*) and ratio of force to wear land width P/b are taken as characteristics of resistance to failure. The parameter *P/S* characterizes the resistance to scattered contact damage, and the value of *P/b* - resistance to chipping[35].

Figure 3.4 - The position of the insert relative to the processed part in determining the resistance to failure and wear under contact load on lathes

When assessing the damage and wear resistance of the inserts, the presence of microcracks on the wear surface, changes in the geometry of the counterbody in the contact zone are also taken into account.

The technique was used to assess the effect of PMFP on the resistance to destruction of the inserts from WC8 cementet carbide. Indexible square inserts in the initial state and after PMFP in two different modes were tested on the 1K62 lathe. The counter-body was a shaft with a diameter of 47.8 mm made of 40XH steel, which rotated with a frequency of 800 rpm. Modes: feed rate 0.07 mm/rev, speed 120 m/min, force P = 150 N, test time was 6 minutes. The dimensions of chips and chamfers formed as a result of tests were analyzed (Fig. .5).





a) b)

1 - semi-elliptical chamfer, 2 - chip at the exit of the contact.

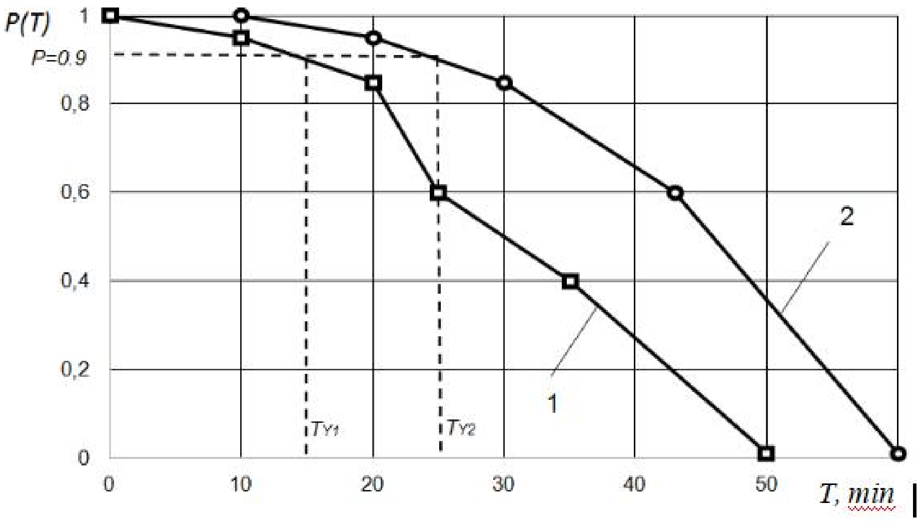
3, 4 - sticking of the metal of the counterbody on the contour of the chamfer

(dimensions are given with the calibration factor k = 3.175)

Figure 3.5 - Semi-elliptical chamfers (wear lands) formed during tests of cemented carbide inserts WC8 in the initial state (a) and after PMFP (b)

Conclusion to Part 3

The next figure shows the probability of the failure-free operation *P(T)* of tools that are strengthened by PMFP. At the probability P(t)=0.9, it has shown us that tools after PMFP strengthened could work longer than tools without strengthening.



1 – tools without strengthening, 2 – strengthened tools

Figure 3.6 – Probability of failure-free machining

It is found that in the preliminary processing of materials with FPMF strengthen cemented carbide tool, the tool is repeatedly processed, the wear process has several degrees of deceleration and acceleration, which proves that the strength and wear resistance of cemented carbide is reasonable. Cutting tools reinforced by PFMF.

Tests of hard alloy samples showed that tools strengthened by PMFP have a 1.2–1.22 times increase in strength, as well as higher homogeneity and uniformity of the distribution of defects by body volume. Studies on abrasive wear showed that after processing with a pulsed magnetic field, the abrasive wear resistance of carbide tools increases by 1.3–1.4 times and the coefficient of variation of wear decreases by 1.5 times.

PART 4
LABOR PROTECTION

4.1 Introduction

To obtain results about actual efficiency and another performances of pulse plasma generator and dielectric barrier discharge plasma actuators, prototype, special equipment should be manufactured and some experimental investigations may be conducted. Such equipment use extremely high voltage sources (>10 kV peak to peak for actuators, etc.) which may cause serious injury or even be fatal. Other dangerous factors is the increased level of electromagnetic radiation and generation of ozone in high concentration. The subject of this work is an engineer who works with such equipment. In this chapter will be considered working conditions in aerodynamic laboratory and some precautions for it's workers.

4.2 Analysis of working conditions at the working place

A person's health and performance during the labor process are influenced by a variety of elements related to both the labor process and the working environment. Certain harmful production variables of the working environment can become dangerous depending on the quantitative characteristics and duration of activity. Think about the traits and accepted norms of the threats and stressors you encounter.

Machinery employs huge and complex machines to mass-produce high-end products that are usually manually operated. Ensuring the health and safety of workers working in environments full of large moving parts is critical.

Machines and slicers are highly efficient but can be dangerous due to moving components, high speeds, size and sharp tools. To protect your employees from harm, you must understand the various risks and safety hazards associated with operating machinery[36].

Here are some of the most common hazards associated with cutting process:x

- Amputation Risks

- Crushes/Pinch Points
- Impairment Of Eyesight
- Deep Cuts And Scratches
- Inhalation Of Toxic Chemicals And Gases
- Injuries Caused By Repetitive Motion
- Electrocutions

The work machine has a working temperature during the cutting process. At this temperature, the working standard absorbs considerable heat in body parts and pipelines, and a large amount of heat is released to the environment. Therefore, it is imperative to provide adequate protection against heat dissipation.

Noise and vibration are also important. The manifestation of noise can lead to poor performance and hearing impairment. Control room noise is aerodynamic and mechanical in nature. A mechanical sound generated when cutting metal.

The sound when the blade shaft touches the metal at high speed. In normal operation, noise should not exceed a certain range. The emergence of oscillating turbine plants negatively affects the central nervous system.

4.3 Analysis of main hazard factors

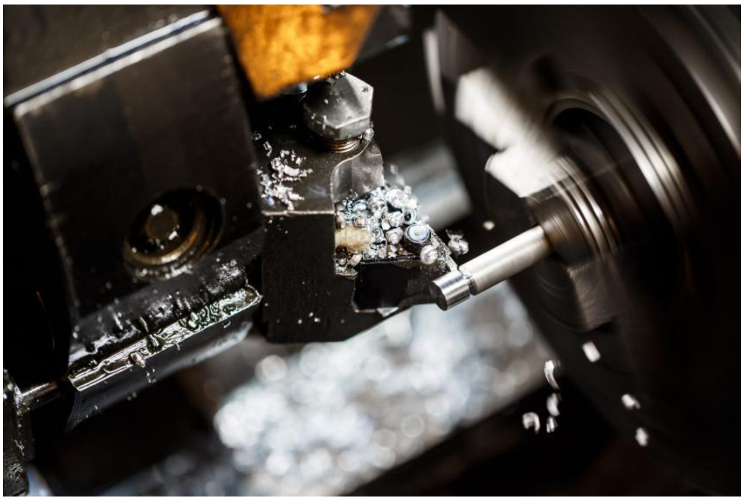
- Amputation Risks

Machines that can cut wood, metal, or plastic will cut meat and bone easily, increasing the risk of cutting. Components such as scissors, saws, presses, metal formers, and bending machines can amputate various body parts, such as fingers, toes, and even entire arms. Therefore, workers must keep a safe distance from moving parts to avoid accidental contact.

- Crushes/Pinch Points

Crushes and pinch points frequently happen when large, heavy equipment is unintentionally dropped. Additionally, workers run the risk of being run over by faulty machinery or large company vehicles. Cruses must be avoided at all costs because they almost always result in fatalities.

You can prevent catastrophes brought on by crushes and pinch point injuries by training employees on how to correctly lift and handle equipment. Additionally, you must supply your workers with sturdy lifting tools so they can move large objects.



4.1 Machining of cutting tools

- Impairment Of Eyesight

One of the most frequent health problems in a machine shop is vision impairment. Projectiles like screws, burs, material fragments, or exposure to harmful chemicals are the main causes.

All workers who frequently come into contact with solvents, caustic chemicals, and cleaning agents must be outfitted with safety eyewear because most machine shops use these substances. Additionally, workers using welding equipment must have UV radiation protection for their eyes.

- Deep Cuts And Scratches

When machinists operate equipment incorrectly, without the proper technical knowledge, or with poorly maintained equipment, cuts and lacerations frequently happen.

However, not all accidents and injuries in machine shops are the result of incorrect equipment handling. If handled improperly, metal components and completed goods can be razor-sharp and cause lacerations.

Gloves, welding face masks, and other safety gear should be provided to all employees who handle machinery with moving parts or completed metal components.

- Inhalation Of Toxic Chemicals And Gases

Machine shops frequently release dangerous fumes and substances that can be inhaled. Chemicals, solvents, metal vapors, dust, and oil mist are the most common inhalation dangers.

Employers are responsible for protecting employees from toxic waste and gases by providing them with protective gear and monitoring the indoor air quality.

To maintain breathing air and shield your workers from harmful exposure, you can install mist collectors, dust collectors, air filters, scrubbers, biofilters, and other pollution-controlling machinery.

- Injuries Caused By Repetitive Motion

Most health hazards are caused by improper handling of equipment and toxic air quality, but some can also be caused by repetitive motion. Activities such as prolonged lifting and poor posture while operating machinery can lead to repetitive motion injuries.

These injuries significantly impair an employee's performance and negatively affect their quality of life. About 35% of workplace injuries are caused by repetitive motion, so it's important for employers and workers to feel confident at work.

Repetitive strain injuries can occur after engaging in strenuous activity, overusing muscle groups, or staying in the same position for long periods of time. A wise strategy to avoid such injuries is to maintain a fit posture consciously and take enough rest breaks.

- Electrocutions

Heavy equipment is equipped with high electrical load requirements, air filters, adequate lighting, and air quality improvement equipment to ensure adequate worker safety and health.

Such high electrical loads consumed by the machine can be very dangerous if the operator of the machine carelessly handles the potentially exposed wires. Employers should ensure that workers are protected from electrocution and electrocution by hiring an industrial electrician to maintain wires in a timely manner.

Power lines and heavy machinery are not accessible to the public. A professional industrial electrician can develop a plan to adequately meet the electrical needs of your business while keeping your workers safe[37].

techniques for preventing electric shock. Electric installation design, technological means of protection, organizational procedures, and technical operations are all done in compliance with DSTU 7237.2011 to safeguard people against the effects of contact potential and currents. To prevent unintentional contact with live components, the following techniques and tools must be used: variables, take into account their traits, and follow accepted standards.

The following potential physical dangerous and detrimental factors in accordance with GOST 12.0.003-2015 should be taken into account when working with actuators:

- protective fences (temporary or permanent);
- safe location of live parts;
- protective shells;
- insulation of live parts (working, additional, reinforced, double);
- workplace insulation;
- low voltage;
- protective shutdown;

Separator for conductive parts of electrical equipment. Rarely doubled or reinforced, it prevents electricity from appearing on non-conductive metal parts of electrical equipment, spills to the ground, and protects persons from current penetration in the event of accidental contact with live parts. Attached to the outlined hardware were several strategies for protecting people from electric shock. A high-voltage excitation step-up transformer filled with epoxy tar that also provides high isolation, where all wiring connecting the actuator and plasma generator is double reinforced wire that can provide up to 30kV isolation. However, some parts cannot be separated or attached to the security wall due to special reasons. Warning labels are attached to these parts (Fig. 4.1). All parts of the body of equipment are interconnected and must be grounded to reduce electromagnetic effects and to protect against electric shock when touching non-energized metal parts.

Figure 4.2 Caution signs on wing bracing which has high voltage rails

4.4. Organizational and technical measures of harmful and dangerous factors mitigation

Occupational safety is a system of organizational measures and technical measures to prevent the action of hazardous industrial factors, and each organization and enterprise must comply with these measures to ensure safe working conditions. It is divided into the following variants:

Chemistry Lab belongs to Category B - Combustible Manufacturing. Because work with flammable and explosive materials under hoods or under exhaust screens is carried out without the use of open flames or open flame equipment, chemical laboratory facilities should be classified as Class B-16 according to the Electrical Equipment Code. belongs to

Chemistry laboratories should be located in separate buildings, special annexes to production buildings, or on upper floors of production buildings and isolated from other facilities. The building fire resistance level must be at least 3. The walls and ceilings of chemical laboratories are stained with paint to prevent adsorption of toxic substances and to allow cleaning, cleaning and degassing. It is recommended that desktop floors and surfaces be made of non-combustible or combustible anti-corrosion materials. The work surface should be supplied with cold and hot water, gas, direct and alternating current, compressed air.

All chemistry laboratories should have the ability to separate gas, water and electricity supplies. Cranes and cutouts are located outside the work area for easy access. All facilities in the

Chemistry Laboratory shall be equipped with common suction and suction, suction cabinets, and local suction pumps from workstations as required. All laboratories have a list of substances that should be handled in the hood. When working with acids and alkalis, it is necessary to equip the premises with special hydrants (faucets, wells, hoses) and wash the affected areas of the skin and eyes with a stream of water for a long time.

When working with glass and glassware, towels should be used during mechanical and heat treatment of glassware - goggles or protective mesh to protect hands from cuts and glass breakage when cutting. Thin-walled chemical jars and jars cannot be heated over an open flame without a special asbestos net[38].

When work is carried out in glassware under high pressure, temperature or vacuum, there is a risk of glass breakage, so the equipment shall be protected by protective screens made of organic glass, metal sheaths and some particularly dangerous devices. is needed. It should be protected with a metal mesh that prevents the glass from breaking.

Containers containing substances that cause burns, such as acids and alkalis, must be transported in two separate baskets or carts. Consume solid lye only with laboratory tongs or rubber-gloved hands. Use dense material (ribbons) when crushing large pieces. Work must be carried out using personal protective equipment.

Injection and filling of corrosive liquids must be done using rubber bulbs, syringes, or special siphons. These liquids cannot be pipetted by mouth as they can cause oral burns and poisoning. Concentrated acids and bases and strong fumigants (reagents) may only be stored and transfused in a hood under ventilation.

Flammable and combustible liquids should be stored in thick-walled bottles or containers with threaded bottoms. Such containers should be stored in metal boxes (closets) with a layer of sand on the bottom and lined with asbestos. The total stock of combustible and combustible liquids in the laboratory should not exceed the daily requirement.

A mechanical fume hood should be used when handling these materials, and the use of open flame sources is prohibited. Spent flammable liquids and reaction products are collected in specially designed and sealed containers and reclaimed or destroyed. Keep flammable and combustible liquids out of the drain.

4.5. Conclusions to Part 4

Therefore, after completing the Occupational Health and Safety chapter of the diploma, it can be said that the working conditions of petrochemical professionals are quite satisfactory, although some adjustments are necessary. After analyzing the workplace situation, some minor shortcomings in the worker protection system in the cold season microclimate supply part and inadequate equipment and protective clothing for workers were identified. Since this work is primarily non-commercial and would be extensive and costly to completely repair an entire building, we propose the following solution. Rehabilitate technical equipment in the workplace

Hopefully these relatively simple and inexpensive measures will rectify the situation. With respect to other factors and fire safety, the workplaces considered were in line with legislation and current norms and standards.

Caution and precautions are paramount as machines can pose unprecedented health risks and hazards. The machine shop is jam-packed with heavy machinery with parts moving at high speed. These parts can cause serious injury or death if handled improperly or without protective equipment.

Machine operators must implement multiple safety measures and distribute appropriate equipment to reduce risk. As a machine shop owner, you must properly maintain your machinery and equipment and provide your workers with personal protective equipment and training to reduce the risk of injury.

PART 5
ENVIRONMENTAL PROTECTION

5.1 Cutting process impact on environment

Metal machining machining process, will produce a lot of pollutants, the main is chip and cutting fluid. Chips are mainly forming chips and dust chips, forming chips account for a larger proportion, the greater the amount of processing, the more serious the waste of resources, the more energy consumption. And waste cutting fluid, accelerate tool wear, unfavorable to the ecological environment. Dust chips (including tool wear dust) are more harmful to the operators in the processing site, and can cause human respiratory diseases and chronic poisoning. In the traditional cutting process, it is also necessary to use a large amount of metal working liquid pouring in the cutting area to play the role of cooling, lubrication, cleaning, chip removal, rust prevention and so on. With the high social attention to environmental protection, its impact is mainly manifested in[39]:

(1) increased manufacturing costs. In the automobile manufacturing industry, the cost of metal working fluid accounts for 16.9% of the total manufacturing cost, including the cost of buying cutting fluid, the cost of the equipment required to use metal working fluid, the cost of maintenance and waste liquid treatment, etc., while the tool cost only accounts for 7.5% of the total manufacturing cost.

(2) Containing mineral oil, sulfur, phosphorus, chlorine and other additives harmful to the environment, such as untreated or improper treatment before discharge, will cause environmental pollution. Usually discharged untreated cutting fluid, common oxygen consumption up to 20000mg/L, chemical oxygen consumption (COD) up to 18000mg/L, biological oxygen demand (BOD) up to 9300mg/L. In addition, it also contains a lot of sodium nitrite, triethanolamine and other buffer and surfactants.

(3) Contain harmful ingredients (such as sulfur, nitrite, formaldehyde, phenol substances), in the use of direct contact with the human body, will induce a variety of skin diseases; The smoke caused by heat volatilization can cause many diseases of

workers' respiratory tract and lungs. After parts machining, parts are generally cleaned. Parts cleaning solution is generally used PA30-QL degreaser and PA80-3 solid passivation agent. According to the number of cleaning parts, add a certain amount of cleaning agent and rust inhibitor every 1 ~ 2d, and replace the tank every 2 weeks, so that a large number of parts cleaning liquid is used in the cleaning process of parts, which will cause pollution to the environment when discharged.

In the process of metal machining art, there will be a lot of pollutants, including chips and cutting fluid, chips including forming and dust two kinds of chips, mostly for forming chips, the more it produces in the process of processing is a waste of resources, which will waste cutting fluid, tool wear speed up, not conducive to the ecological environment. And dust chips will harm the operator, easy to cause human respiratory disease or chronic poisoning. In the process of traditional cutting, additives such as mineral oil, sulfur and phosphorus will be used to pollute the environment, which will harm the environment if not properly handled. In the process of parts machining, parts need to be cleaned, which needs to use a lot of cleaning liquid, discharge will pollute the environment[40].

In the mechanical processing will inevitably appear noise, vibration and other conditions, also belongs to the environmental pollution problem, so in the prevention of the implementation of effective measures in this respect can not be ignored, in the processing as far as possible to choose the necessary isolation, muffler, sound absorption and other measures or placement device, from the equipment to the process to take appropriate measures, to avoid too big impact, Reduce vibration and noise.

5.2 Cutting fluid impact on environment during cutting process

Cutting fluid, because of its good cooling, lubrication, cleaning and chip removal, rust prevention, has long been regarded as an important process factor to improve tool life and production efficiency and ensure processing quality. But cutting fluid also has a certain negative effect, especially in recent years with the large number of applications of CNC machine tools, machining centers and other advanced equipment in production, cutting speed is getting higher and higher, the amount of cutting fluid is also increasing, the negative effect is becoming more and more obvious, has been difficult to adapt to the requirements of environmental protection.

Figure 5.1 Cutting fluid during cutting process

1. Impact on ecological environment

The harm of cutting fluid to the ecological environment mainly shows that waste oil and waste liquid are discharged directly without effective treatment, which will cause serious water pollution. In addition, the cutting fluid used in machining will more or less remain on the chip, a large number of accumulated chips with cutting fluid will pollute the soil; Toxic and harmful components of cutting fluid can also pollute the environment during chip recycling.

2. Impact on human health, safety and hygiene

The harm of cutting fluid to human body is mainly manifested as follows:

① some additives in cutting fluid (such as phenol substances commonly used as bactericidal additives) are toxic to human body;

② The degreasing effect of mineral oil and surfactant in the cutting fluid and the irritant of anti-corrosion and bactericidal additives will make the human skin dry, degreasing, cracking, and even cause redness, swelling, purulent etc.;

③ Mineral oil in oil-based cutting fluid and alkaline substances in water-based cutting fluid have certain harmful effects on human respiratory organs.

3. Impact on production safety

Because the cutting fluid contains various additives, it is easy to corrosion and rust the equipment in the process of its use, and the oil-based cutting fluid is easy to cause fire, posing a threat to the safety of production.

So Oil - based cutting fluid was developed by replacing mineral oil with vegetable oil. Vegetable oil is a renewable resource, and can be degraded, almost no pollution to people and the environment. Compared with mineral oil, the use of vegetable oil is restricted by the instability of oxidation and hydrolysis and aging properties, but it is not volatile. After adding certain antioxidants and other additives, the performance of vegetable oil can meet certain processing requirements, and it has a broad market prospect. In addition, ester oil can also be used to replace mineral oil. Among all kinds of ester oil sold on the market now, the degradation rate can reach 90%-100%, but the market price is relatively high. After a period of research, it is certain that a fully degraded product can be developed at an appropriate price, so it is now the focus of all countries to compete for research[41].

Strive to develop new efficient non-toxic additives.The new additive is an effective way to improve the quality and level of cutting fluid, which has attracted the attention of scholars all over the world And do a lot of work, achieved a certain effect. Green manufacturing of cutting fluid systems should also accelerate research to reduce environmental impact.

New antiseptic fungicides: water, workpieces, air and dust all have the potential to introduce bacteria into the cutting fluid, breeding bacteria. Bacterial reproduction will consume emulsifier, make the oil phase precipitation, the concentration decreases, the lubrication performance also decreases; Oxygenophile bacteria exhale C02, which reduces PH value and rust resistance, and further promotes bacterial reproduction. Bacterial growth not only makes the cutting fluid ineffective, but also causes adverse effects on the environment, such as bad smell. The new antiseptic fungicide can reduce the growth of bacteria and mold, kill the existing bacteria in the cutting fluid, so as to extend the service life of the cutting fluid.

Look for alternatives to traditional cutting fluids

（1）Liquid nitrogen cooling

Liquid nitrogen temperature at minus 180°C or so, in the cutting process will be liquid nitrogen to the cutting area, instead of the traditional cutting fluid, can ensure that the workpiece, tool and cutting area in a low temperature state of cutting processing, and make full use of the material's toughness and brittle transition characteristics, in the case of material toughness reduction, plastic reduction of the workpiece processing. However, this processing method must take into account the cost, safety, stability and convenience of liquid nitrogen, and it is still difficult to popularize it.

(2) Steam cooling

The traditional coolant relies on the evaporation of the cutting fluid to take away most of the cutting heat, but the experiment shows that the cooling efficiency of this method is not very high, because after the coolant enters the high temperature cutting zone, the heat quickly forms a layer of steam film on the cutting surface, the machining surface is blocked by the steam film, and the subsequent coolant can not contact with the machining surface. Reduced heat exchange efficiency with cutting area. At the same time, the existence of the vapor film will also prevent the cutting zone heat transfer. When the steam is cooled, the steam will not produce a steam film. The water steam is sprayed to the high temperature cutting area in the form of a gas and quickly disperses, taking away the heat at the same time, skipping the process from liquid evaporation to gas, so there is no steam film effect on cooling. However, it should be noted that the cooling effect of steam cooling is indirect cooling based on lubrication, and its cooling effect is very limited.

5.3 Electromagnetic pollution during cutting process

Electromagnetic pollution refers to natural and man-made electromagnetic interference and harmful electromagnetic radiation. During Pulsed Magnetic Filed Processing. Pulse discharge, discharge generated when cutting off a large current circuit has a large transient current and will produce a strong electromagnetic. It is essentially the same as lightning, but affects a smaller area.

1. Electromagnetic radiation pollution is harmful to human health

In the radio frequency electromagnetic field, the biological body will absorb the radiation energy, resulting in thermal effect, non-thermal effect and cumulative effect. When the radiation intensity of radio frequency electromagnetic field is controlled within a certain range, it can have a good effect on the human body, such as using a physiotherapy instrument to treat diseases. But when it exceeds a certain range, electromagnetic radiation on the human visual system, body immune function, cardiovascular system, endocrine system, reproductive system and genetics, central nervous system have different degrees of influence, such as can activate photo-oncogenes, induce cancer, is one of the causes of childhood leukemia. Multiple frequency electromagnetic waves, especially high frequency waves and strong electromagnetic fields act on the human body. The direct result is that the energy and physical strength of the human body will be weakened, the body clock will be disturbed, the memory, thinking and judgment ability will be decreased, and the cataract, brain tumor, cardiovascular disease, abortion and infertility of women, and even cancer and other diseases will be caused.

2. Interference with communication systems

Due to poor management of electromagnetic radiation, high-power electromagnetic waves will interfere with each other in the regional environment, resulting in damage to the communication system and even serious accidents, such as missile mislaunch and plane crash, resulting in unpredictable and catastrophic consequences. If the interference and damage of signals are caused, the normal operation of electronic equipment and instruments will be directly affected. Cause information error, control failure, poor communication[42].

3.causing an explosion

High levels of electromagnetic induction and radiation can cause control failure of explosive materials and explosive weapons and accidental explosion. Electromagnetic radiation can also cause harm to volatile substances. High level electromagnetic induction and radiation can cause accidental combustion of volatile liquids or gases.

Conclusion to the Part 5

Mechanical cutting occupies a very important proportion in the stable development of the aviation industry, but the important part of the manufacturing process of cutting and machining will cause some pollution to the environment. In the process of metal parts cutting and machining to parts cleaning, the implementation of environmental pollution prevention measures, has a certain effect. It can be concluded that, in the process of continuous technological progress, by making full use of it, improving the metal machining process, reducing the waste of resources, but also avoid excessive pollutants, which is conducive to the development of manufacturing industry, but also avoid the pollution caused to the environment.

GENERAL CONCLUSION

After experimental tests ,we can see that from the comparative that cutting tools after reinforced by PMFP have more advantages then traditional cutting tools:

1. The effect of volumetric strengthening of a carbide cutting tool by processing with a pulsed magnetic field has been established.

2. Tests of hard alloy samples during cantilever bending showed that tools strengthened by PMFP have a 1.2–1.22 times increase in strength, as well as higher homogeneity and uniformity of the distribution of defects by body volume. Studies on abrasive wear showed that after processing with a pulsed magnetic field, the abrasive wear resistance of carbide tools increases by 1.3–1.4 times and the coefficient of variation of wear decreases by 1.5 times.

3. It was found that the modification of the TiC5-Co10 hard alloy by processing with a pulsed magnetic field, depending on the applied modes, leads to an increase in the bending strength limit under static load by 16–27%, which allows predicting an increase in the endurance limit.

4. Defects in the structure of the surface layer have a significant effect on the strength and destruction of the studied hard alloy indexable inserts. It was established that the modification of hard alloys by processing with a pulsed magnetic field leads to an increase in their homogeneity, a decrease in the thickness of the cracked layer, stabilization of mechanical characteristics, and an increase in the bending strength limit.

5. The use of modeling methods made it possible to establish optimal regimes and conditions of strengthening depending on the brand of hard alloy and geometric parameters of the tool. The optimal values of the magnetic field strength and pulse frequency depending on the geometrical parameters of the tool were determined.

6. On the basis of production tests of carbide cutting tools, it was established that the use of processing with a pulsed magnetic field contributes to:

– increasing the wear resistance of cutting tools by 1.2–2 times;

- 2.7 times reduction in the number of chippings and breakages in the area of tool fitting;

REFERANCE

1. CIRP Dictionary of Production Engineering II (2004) Material removal processes, vol 2, 1st edn. Springer, Berlin.
2. Denkena B, Toenshoff HK (2011) Spanen: Grundlagen [Cutting: fundamentals]. Springer, Berlin (in German).
3. Karmarsch K (1837) Grundriß der Mechanischen Technologie [Outline of the mechanical technology], vol 1. Helwingsche Hof-Buchhandlung, Hannover/Wien.
4. H. Ernst, "Physics of metal cutting," Machining of Metals (American Society for Metals, 1938), p. 24.
5. H. Ernst, "Physics of metal cutting," Machining of Metals (American Society for Metals, 1938), p. 24.
6. J.M. Antonini, in Comprehensive Materials Processing, 2014.
7. Gene Mathers, in The Welding of Aluminium and its Alloys, 2002.
8. D.A. Belforte, in Encyclopedia of Materials: Science and Technology, 2001.
9. D.A. Belforte, J.M. Jafferson, in Reference Module in Materials Science and Materials Engineering, 2016.
10. Explain Cutting Tools Archived 2019-05-12 at the Wayback Machine, https://mechanicalsite.com, retrieved 2019-05-12.
11. Stephenson, David A.; Agapiou, John S. (1997), Metal cutting theory and practice, Marcel Dekker, p. 164.
12. Bartarya G, Choudhury SK. State of the art in hard turning. Int J Mach Tool Manu 2012;53(1):1–14.
13. Bouzakis K-D, Michailidis N, Skordaris G, Bouzakis E, Biermann D, M'Saoubi R. Cutting with coated tools: Coating technologies, characterization methods and performance optimization61(2). CIRP Ann-Manuf Techn; 2012. p. 703–23.
14. Kitamura T, Tanaka R, Yamane Y, Sekiya K, Yamada K. Performance evaluation method for cutting fluids using cutting force in micro-feed end milling. Precis Eng 2020;62:232–43.
15. Zhao J, Liu Z, Wang B, Hu J, Wan Y. Tool coating effects on cutting temperature during metal cutting processes: comprehensive review and future research directions. Mech Syst Signal Pr 2021;150:107302.
16. Kursuncu B. Influence of cryogenic heat-treatment soaking period and temperature on performance of sintered carbide cutting tools in milling of Inconel 718. Int J Refract Met H 2020;92:105323.
17. Bataineh O, Klamecki B, Koepke BG. Effect of pulsed magnetic treatment on drill wear. J Mater Process Technol 2003;134(2):190–6.

18. Liu J, Wei C, Yang G, et al. A novel combined electromagnetic treatment on cemented carbides for improved milling and mechanical performances. Metall Mater Trans A 2018;49(10):4798–808.
19. Yuan M, Wang J, Wang M, Huang K, Wang L, Tian Y. Enhanced carbide tool life by the electromagnetic coupling field for sustainable manufacturing. Int J Adv Manuf Technol 2020;108(11):3905–14.
20. Ma L, Zhao W, Liang Z, et al. An investigation on the mechanical property changing mechanism of high speed steel by pulsed magnetic treatment. Mat Sci Eng A-Struct 2014;609:16–25.
21. Cai, Huang X. Residual stress reduction by combined treatment of pulsed magnetic field and pulsed current. Mat Sci Eng A-Struct 2011;528(19):6287–92.
22. Wu S, Lu A, Zhao H, Fang H, Tang F. Micromechanism of residual stress reduction by low frequency alternating magnetic field treatment. Mat Sci Eng A-Struct 2002; 328(1):133–6.
23. Shao Q, Wang G, Wang H, Xing Z, Fang C, Cao Q. Improvement in uniformity of alloy steel by pulsed magnetic field treatment. Mat Sci Eng A-Struct 2021;799: 140143.
24. Huang Y, Liang SY. Effect of cutting conditions on tool performance in CBN hard turning. J Manuf Process 2005;7(1):10–6.
25. Yallese MA, Chaoui K, Zeghib N, Boulanouar L, Rigal J-F. Hard machining of hardened bearing steel using cubic boron nitride tool. J Mater Process Technol 2009;209(2):1092–104.
26. Harris TK, Brookes EJ, Taylor CJ. The effect of temperature on the hardness of polycrystalline cubic boron nitride cutting tool materials. Int J Refract Met H 2004; 22(2):105–10.
27. Olortegui-Yume JA, Kwon PY. Crater wear evolution in multilayer coated carbides during machining using confocal microscopy. J Manuf Process 2007;9(1):47–60.
28. Chen W. Cutting forces and surface finish when machining medium hardness steel using CBN tools. Int J Mach Tool Manu 2000;40(3):455–66.
29. He CL, Zong WJ, Zhang JJ. Influencing factors and theoretical modeling methods of surface roughness in turning process: state-of-the-art. Int J Mach Tool Manu 2018;129:15–26.
30. Li GR, Li YM, Wang FF, Wang HM. Microstructure and performance of solid TC4 titanium alloy subjected to the high pulsed magnetic field treatment. J Alloys Compd 2015;644:750–6.
31. Chen Z, Li B, Huang Q, Zhang L, Fei H, Liu J. The effect of the electric pulse treatment on the microstructure and mechanical performance of the Al–Zn alloy. Mat

Sci Eng A-Struct 2020;796:140016.
32. Donnelly A, Jones M, O'Mahony T, Byrne G. Selecting environmental indicator for use in strategic environmental assessment. Env Imp Ass Rev 2007;27:14.
33. Weinert K, Inasaki I, Sutherland JW, Wakabayashi T. Dry Machining and Minimum Quantity Lubrication. CIRP Ann - Manuf Technol 2004;53:511–37.
34. Sutherland JW, Kulur VN, King NC, Von Turkovich VF. An Experimental Investigation of Air Quality in Wet and Dry Turning. CIRP Ann – Manuf Tech 2000;49:5.
35. Rangarajan A, Dornfeld D. Efficient Tool Paths and Part Orientation for Face Milling. CIRP Ann – Manuf Tech 2004;53.
36. Campatelli G, Lorenzini L, Scippa A. Optimization of process parameters using a Response Surface Method for minimizing power consumption in the milling of carbon steel. J Clean Prod 2014;66:309– 16.
37. Campatelli G, Scippa A, Lorenzini L. Workpiece orientation and tooling selection to reduce the environmental impact of milling operations. Procedia CIRP 2014;14:575–80.
38. Campatelli G, Scippa A, Lorenzini L, Sato R. Optimal workpiece orientation to reduce the energy consumption of a milling process. Int J Precis Eng Manuf Technol 2015;2:5–13.
39. Feng S, Hattori M. Cost and Process Information Modeling for Dry Machining. Int. Work. Environ. Conscious Manuf., 2000.
40. Klocke F, Eisenblätter G. Dry Cutting. CIRP Ann - Manuf Technol 1997;46:519–26.
41. Rajemi MF, Mativenga PT, Aramcharoen A. Sustainable machining: selection of optimum turning conditions based on minimum energy considerations. J Clean Prod 2010;18:1059–65.
42. Dahmus JB, Gutowski TG. An environmental analysis of machining. ASME Int Mech Eng Congr Expo 2004:643–52.