A REVIEW OF ADVANCING MANUFACTURING TECHNOLOGY

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ABSTRACT: Reviewed in this paper are some of the major developments in cutting technology and the most modern methods used in metal cutting technology research, as well as methods already established in daily application. Metal cutting process modeling and simulation methods and the application of artificial intelligence, micromachining, cutting process tracking, high speed cutting (HSC), high speed cutting, productivity (HPC), material machining are discussed. hard and dry cutting lubricant or minimal micro-spray (MMS)

Keywords: *modeling, simulation, monitoring, HSC-machining, HPC machining, MMS-systems, Dry machining*

INTRODUCTION

In the current scenario, transformation industries are developing rapidly in the world of work. Welding emerged as a viable manufacturing process in the mid-nineteenth century,

Studies [1] have concluded that there should be a strong integration of technology and management using information technology (IT), for example, the integration of planning and process management. Production planning, simulation of manufacturing systems, agile manufacturing, rapid redesign of new products, performance modeling of manufacturing equipment including human operator, functional analysis of products, machining algorithms and virtual inspections, etc.

Material removal processes can take place at considerably higher throughput levels in the range up to Qw = 150 - 1500 cm3 / min for most workpiece materials at cutting speeds up to approximately 8,000 m / min. min. Super hard cutting tool materials exhibit hardness levels between 3000 and 9000 HV with a toughness greater than 1000 MPa.

Fig. 1. Primary aspects associated with advancing cutting technology

The main drivers of change in the case of cutting technology include: reduced component size, improved surface quality and tighter tolerances and manufacturing precision, reduced costs, reduced component weight, and reduced batch sizes (Figure 1). These factors of change have a direct influence on the main inputs to the cutting process, namely the cutting tool and tool material, the workpiece material, and the cutting fluid.

In addition to achieving greater manufacturing precision, there has been significant development in downsizing engineering components. One of the major problems associated with miniature components is that the surface / volume ratio increases.

The cutting tool is one of the key parts of the cutting process. The development of materials for cutting tools has allowed a significant increase not only in the speed of cut but also in the advances.

In recent years, the focus has been on High Performance Cutting (HPC). The following aspects of cutting have been identified as being of particular importance in the pursuit of high performance cutting with high levels of productivity:

- Non-productive time (NPT) in the cutting process,
- Dry and quasi-dry cutting (use of minimal amounts of cutting fluids),
- Chip formation and handling process and
- Burr minimization strategies.

The economic efficiency of production facilities is a central issue for cutting technology. Conventional processes such as grinding and turning have come under scrutiny from a productivity standpoint, and process chains have been analyzed and redesigned to minimize processing times. In recent years, the trend has been towards integrated processes. The requirement for integrated processes poses new and demanding challenges in the design and technology of cutting processes.

MODELING AND SIMULATION

In general, the terms modeling and simulation have been used interchangeably in manufacturing research literature. In the case of cutting, there are many phenomena that are not easily observable or are not subject to direct experimentation, so the models are developed in such a way that they can simulate the influence of a certain number of process parameters using this template. . The models currently in use are based on Eulerian or Lagrangian finite element techniques. Four main categories of cut modeling methodologies are evident:

- Analytical modeling (determination of the relationship between cutting forces based on cutting geometry and including experimentally determined values of cutting angle, friction conditions and chip flow angle;
- Slip line modeling (predicts mechanical response and temperature distributions based on assumptions about slip line field geometry in the cut zone and around the tool;
- Mechanistic modeling (predicts the cutting forces for a wide range of complex machining processes assuming that the cutting forces are the product of the uncut chip area and the specific cutting energy where l the specific cutting energy is derived empirically from the workpiece material, cutting parameters and cutting geometry;
- Finite element modeling (fem techniques use small mesh representations of the material and tools as the basis for determining material stress and strain conditions and ultimately material flow based on assumptions of continuity between adjacent elements)

The application of these modeling techniques covers the range of cutting processes and interests, including cutting forces (static and dynamic), power, wear and tool life, flow / waviness / chip shape angle, embedded edge, temperatures, surface conditions, and workpiece. integrity, tool geometry, coating and design influences, burr formation, part distortion and precision, tool deflection, dynamic stability limits, and thermal damage. Modeled processes range from orthogonal cutting to multi-tooth milling, hard turning and drilling. Understanding the mechanisms of chip formation combined with the thermomechanical influence of the work tool area is essential to control the generation of a machined surface of pure plastic deformation required in this application. The cutting simulation includes realistic tool materials and a friction model developed to account for sticking and sliding conditions. Chip flow, chip morphology, cutting forces, residual stresses, and cutting temperatures are foretold.

Burr Formation: Understanding of the mechanics of burr formation has been greatly improved by modeling the burr formation process analytically, mechanically, and with finite element techniques.

Chipping: Much attention has been paid to understanding chip-forming mechanisms and the role of influencing parameters. However, many advances are being made and models, especially finite element models, have an impact on the ability to understand this complex aspect of cutting. The increasing use of high speed machining has also encouraged shaping of chip formation since the optimizing high speed cutting with exotic materials is not easy. Tool temperature and wear during cutting: in addition to burr formation, the cutting forces and the chip formation quality of the cutting process are determined by the wear behavior of the tool and the thermal load on the tool and the part [5]

A new class of sectional modeling at the nano level is called molecular dynamics modeling. With the rise of micromachining to create molds and other features for a variety of components, it is interesting to see the "scalability" of larger-scale phenomena at the nanoscale, and thus the ability to control the quality of these components.

HIGH SPEED MACHINING

HSM inventor C. Salomon discovered that above a certain cutting speed, machining temperatures begin to drop again. His fundamental research has shown that there is a certain range of cutting speeds where machining cannot be performed due to excessively high temperatures. For this reason, HSM can also be referred to as cutting speeds beyond this range. According to modern knowledge, some researchers have modernized high-speed machining as machining in which conventional cutting speeds are exceeded by a factor of 5 to 10.

With the extensive use of CNC machines, as well as high-performance AD / C AM systems, high-speed machining (HSM) has proven its superior advantages over other rapid manufacturing techniques. In addition to increased productivity, HSM can generate high-quality surfaces, burr-free edges, and virtually stress-free components after machining, and can be used to machine thin-walled parts because the cutting forces involved under HSM conditions are lower. Another important advantage of high speed machining is the minimization of the effects of heat on machined parts. Most of the cutting heat is removed, reducing thermal deformation and increasing the life of the cutting tool. In many cases, the need for a refrigerant is eliminated. In addition, the elimination of cutting fluids reduces the post-contamination contribution and facilitates the recovery and recycling of such expensive materials as aluminum-lithium alloys. As HSM has many advantages, it is widely used in the aerospace industry, the automotive industry, the precision mechanical industry for machine tools, equipment and tools used in the manufacture of household appliances, optics, etc.

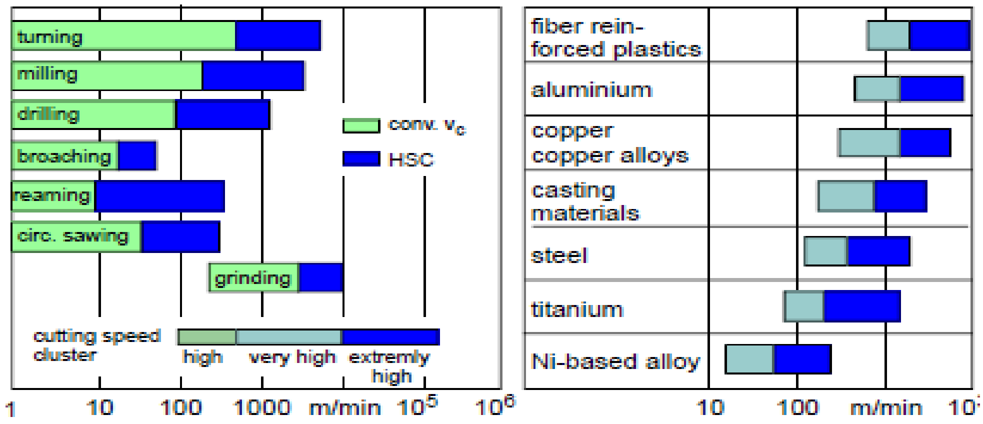

Fig. 2. Achievable cutting speeds [8]

Although high-speed aluminum milling has been applied successfully in industries for over a decade, high-speed applications on difficult-to-cut materials such as titanium alloys are still relatively new. Boeing's Military Aircraft Group has begun applying its aluminum expertise to faster polishing of titanium. And they concluded that, compared to aluminum, titanium imposes certain limitations. Speed is limited because heat builds up faster. But within these limitations, there is still plenty of room for faster cutting.

Titanium alloys have been used extensively in the aerospace, biomedical, automotive, and oil industries due to their good strength-to-weight ratio and superior corrosion resistance. However, it is very difficult to machine them due to their poor machinability. When machining titanium alloys with conventional tools, tool wear progresses rapidly due to its low thermal conductivity and high chemical reactivity, resulting in a higher cutting temperature and strong adhesion between the tool and the work material. Titanium alloys are generally difficult to machine at cutting speeds greater than 30 m / min with high speed steel (HSS) tools and greater than 60 m / min with cemented tungsten carbide (WC) tools, which gives as a result very low productivity.

ADVANCES IN MECHANICAL MICROMACHINING

PROCESS PHYSICS

Micromachining incorporates many features of conventional machining. At the same time, micromachining poses many problems mainly due to size or scale. The reduction of the machining scale does not modify the general characteristics of the process within a reasonable limit. However, when the relationship between the size of the part to be produced or the size of the microstructure of the work material in relation to the dimension of the tool used (say the diameter) becomes small (approaching a single digit), the Sizing effects can change the entire look of the machining. There are two different aspects of size effects that are of concern, for example. when the depth of cut is of the same order as the radius of the tool edge, and when the microstructure of the part material has a significant influence on the cutting mechanism

MICRO-TOOLS

Commercially available microdrills generally have a diameter of the order of 50 μm and have a torsional geometry similar to that of conventional drills. Flat drills with simplified geometries are more common for diameters less than 50 m.

Another challenge in micromachining is micromachining. Inaccurate geometry and tool irregularity often negate the benefits of ultra-precise process control, advanced machine tools, and ultra-fine tuning of process parameters.

Due to its hardness, monocrystalline diamond is the preferred tool material for micro-cutting. Diamond cutting tools were used in most early micromachining research due to their exceptional toughness (for wear resistance) and the ease with which a sharp edge may be generated by grinding. However, since diamond has a very high affinity for iron, micro-cutting is primarily limited to machining non-ferrous materials such as brass, aluminum, copper, and nickel. Therefore, micromachining tests have been limited to non-ferrous materials. In [10] he developed a machine tool manufacturing process that uses ELID grinding technology to manufacture various cross-sectional shapes of the tool with high surface quality, Figure 3.

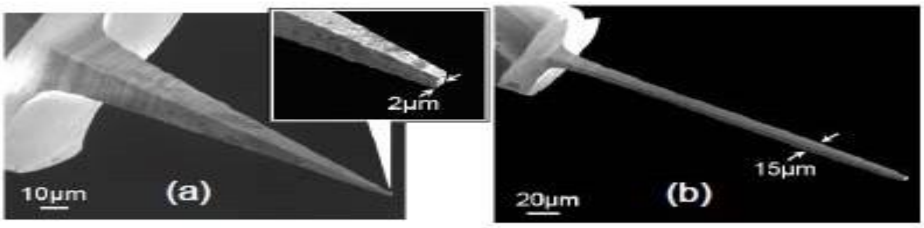

Fig. 3. Overviews of produced micro-tools under optimum machining conditions: (a) Ultra precise tool (b) Extremely large aspect ratio micro-tool [10].

MICROFACTORIES

In general, micromachining is done on precision machine tools with conventional dimensions. However, the work size and power required for processing are relatively much smaller for micromachining. Reducing the size of the machine tool itself has been pursued by various machine tool manufacturers and researchers to achieve economic benefits such as structural cost savings, floor space savings, energy reduction, and performance benefits, including reduction of thermal stress, improvement of static. stiffness and dynamic stability. what's more.

A one-time effort is to build a micro-factory system where one or more machine tools are small enough to fit on the desk. In the late 1980s, Japanese researchers began prototyping micro-factories, and the first realization of the concept was a microtower smaller than a human palm with a 1.5 W spindle motor [11], followed more powerful and precise portable and desktop machines.

TURNING OF HARDENED STEEL

The machining of hard steel parts is of great importance. The main objective is to replace the technology of grinding by turning, milling or drilling. Turning operations are called hard turning, which are performed

- To meet the required shape and surface roughness,
- Replace the grinding operation, in a piece of hard steel with at least 45 hrc, by tools made of carbide, ceramic or polycrystalline cubic boron nitride (pcbn),
- On CNC lathes or rigid conventional lathes.

The occasional appearance of white coatings in the machining of tempered steel demonstrates that short-term metallurgical processes can be induced by the respective chip formation mechanisms. The occasional appearance of white coatings in the machining of tempered steel demonstrates that short-term metallurgical processes can be induced by the respective chip formation mechanisms.

Table 1 shows the advantages and disadvantages of hard turning [7].

Table 1. Advantages and disadvantages of hard turning

Hard turning	
Advantages	Disadvantages
Short operation	Heavy tool wear
Less investment	Cutting edge is reactive to break
Free grindingcapacities	Rigid machine tool with highspindle speed
High accuracy incase of accurate blank	Up-to-date CNC control is needed(tool break control)
The heat of cuttingis removed by chips	Tool holders for high speedmachining is required
2-4 times higher material removal speed	Application of up-to-date toolmaterials and coats
Good surfaceroughness	Inhomogeneous part material isunfavorable
More operation elements are performed in onesetup	In case of grinding the sparking process can increase accuracy anddecrease surface roughness
Appropriate for drymachining	In certain cases, better surface roughness is produced by grinding

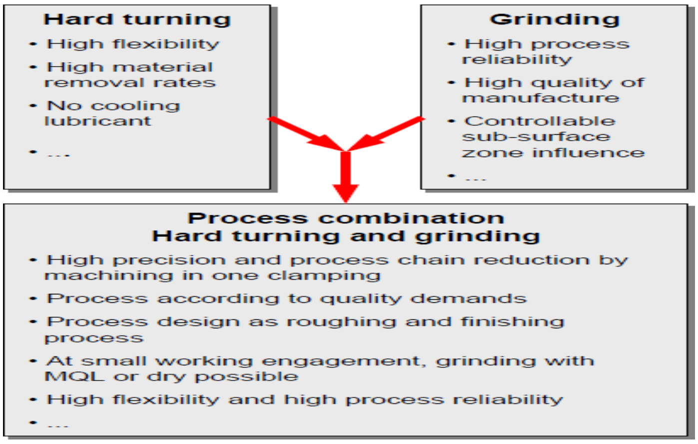

Fig. 4. Utilization of process specific advantages byprocess combination [7]

Chip formation mechanisms in hard machining were first investigated by Ackerschott [7], who postulated high compressive stresses in the surface layer causing cracks in the front of the cutting tool underneath an angle of 45 ° to the surface. At the same time, the material is plastically deformed by the rounded cutting edge. Sliding a chip segment along the crack reduces compressive stresses until a new crack is induced due to continuous tool movement.
Due to their characteristics, hard turning and grinding processes are not arbitrarily interchangeable. Rather, they complement each other. This has motivated the development of machine tool concepts, which allow hard turning and grinding operations on a single chuck. Consequently, the advantages of each method can be combined, Figure 4. [7].

MONITORING OF CUTTING OPERATIONS

The complex interactions between machines, tools, parts, fluids, measurement systems, handling systems, humans and the environment in cutting operations require the use of sensors to ensure efficient production, protect investments, indicate maintenance needs and protect workers and the environment. Early developments have shown that process monitoring is essential for economical production. Most important for uptime and quality are tool wear and tear. An excellent overview of machining monitoring for tool health monitoring can be found in [3]. Standard approaches to process monitoring are the measurement or identification of the interaction between the process and the machine structure. In particular, vibratory behavior plays an important role, since it greatly affects the precision of the part as shown by simulation and experimentation, for example. in 3].
Tönshoff presented an indication of the evolution of surveillance systems in manufacturing. Frankly, there hasn't been much progress on the part of the state described by Tönshoff. But now there are additional requirements for more flexibility. Specifically, sensor systems must be capable of interfacing with open-system architecture controllers for machines, and systems must be designed to meet the needs of so-called "reconfigurable" systems. Most of the activity in these two fields is still in the research phase with few industrial applications.
To achieve the "intelligent machine tool", which aims to be able to maintain optimized cutting performance, a sensor and control systems with the ability to accumulate knowledge are needed to store the "experience" acquired for use in future productions.
Furthermore, given the development of reconfigurable systems, monitoring strategies must be flexible enough to accommodate different machine configurations and processes. Logically, this would be related to the hardware and software that control the machine in an "open" environment. In that sense, it would be an example of a “smart sensor”.
Recent developments point in different directions. Some are based on new production areas, others use new sensor concepts. Most process monitoring systems are designed for limited complexity processes such as drilling, tapping, or straight-pass milling. Considering that the solutions for sculptures, surface coating, especially ball end finishing operations, are not yet commercially available. These are of great importance in finishing dies and molds with only small process forces. The new approaches use special sensors to measure force or accelerations to monitor the milling process of sculpted surfaces.
The standard fixed threshold method has been adapted to be more universal. Dynamic limits combined with neural networks. Neural networks have been shown to be effective for small productions. In particular, tool flank wear during milling can be controlled by neural networks.

It seems like an obvious solution to use dynamic systems for monitoring a dynamic process such as a cutting process. Probably due to stability issues, the output of pure dynamic networks is limited. One promising approach is a model in which a static network and a dynamic network are hierarchically combined as a "state space representation" of the cutting process. The field of high speed cutting (HSC) introduces new dynamic effects in process monitoring. Standard Fast Fourier Transform (FFT) dominated analysis methods are extended with wavelet transforms and cepstrum analysis, and the latter has been shown to be particularly sufficient for monitoring machines and processes.

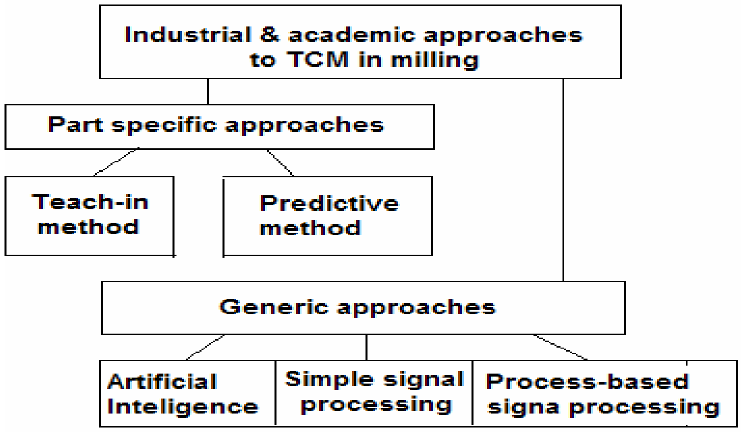

Fig. 5. TCM Classification

Considering the range of sensors and applications in the cutting process, the machine tool requires a large number of sensors. Today, integrated sensor systems can multitask and work together to ensure process optimization. Reducing overall performance requires reducing process and non-production times, verifying and maintaining process capacity, while reducing direct production costs and ensuring environmentally friendly production.

SUSTANABILITY CONCEPTS INMACHINING

The paradigm of making products toward low costs and high profits is unlikely to change significantly in the near future. Integration of environmental requirements at each stage of the product, Early development is a very likely approach, not only will it add some limitations, but it will identify new environmental characteristics of a product that have the potential to improve the overall quality of the product in the eyes of the customer and eventually lower the total. cost. In the field of technologies, processes and products, efficiency has an economic, ecological and social dimension. The cost of energy and materials has an impact on economic efficiency. The reduction of resources is a contribution to economic and ecological efficiency. The way to help companies improve their economic, environmental and social performance is [12]:

- Minimizing waste and increase reusing or recycle
- Using materials, water and energy more efficiently,
- Avoiding or improving managements of cooling andlubricating fluids and hydraulic oils
- Adopting lean manufacturing and other sustainabletechniques
- Improve working conditions and use best practicemachining
- Train employees about sustainable practices, etc

DRY MACHINING AND MINIMUM QUANTITYLUBRICATION

A shift in environmental awareness and increasing cost pressure on industrial companies has led to a critical consideration of conventional cooling lubricants used in most machining processes. Depending on the part, the production structure and the production site, the costs associated with the use of cooling lubricants range from 7% to 17% of the total cost of the manufactured part [2]. By moving away from conventional cooling lubricants and using dry machining or minimum quantity lubrication (MQL) technologies, this cost element can be significantly reduced. In addition to improving the efficiency of the production process, this technological change contributes to the protection of the workforce and the environment. Reducing substantial exposure to cooling lubricants in the workplace increases job satisfaction while improving job outcomes. In addition, a company can use economically advantageous production processes for advertising purposes, which gives it a better image in the market.

Implementation of dry machining cannot be achieved simply by cutting off the supply of lubricating coolant. This is because the cooling lubricant performs several important functions that, in its absence, must be performed by other components of the machining process. Cooling lubricants reduce friction and therefore heat generation and dissipate generated heat. Additionally, cooling lubricants are responsible for various secondary functions, such as conveying chips and cleaning tools, parts and accessories. They guarantee a smooth and automated operation of the production system. Additionally, cooling lubricants help provide a uniform temperature field within the workpiece and machine tool and help meet specified tolerances.

MQCL

In many machining operations, minimum quantity quench lubrication (MQCL) is the key to dry machining success. Any movement to manufacture functional components under dry machining conditions depends on understanding the MQCL as a system, the individual components (power technology, MQCL media, parameters, tools, and machine tools) mutually affecting the operation of all the others (Figure 6). All components of the MQLC system must be coordinated very carefully to achieve the desired result, which is optimal, both technologically and economically.

In MQCL operations, the medium used is typically pure oil, but some applications have also used emulsion or water. These fluids are supplied to the tool and / or the machining point in small quantities. This is done with or without the aid of a means of transport, for example air. In the case of the former, the so-called airless systems, a pump supplies fluid to the tool, generally oil, in the form of a rapid succession of precisely metered droplets.

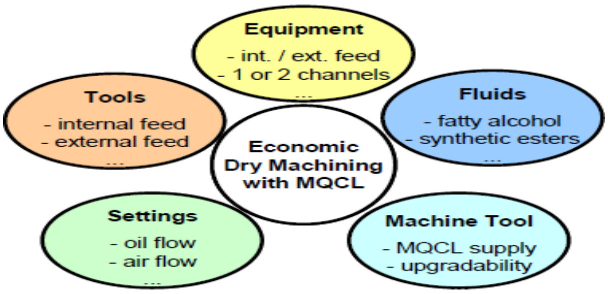

Fig. 6. Minimum quantity cooling lubrication system

In the latter case, the medium is atomized in a nozzle to form extremely fine droplets, which are then transported to the machining point in the form of an aerosol.

In the context of dry machining, the term MQCL is generally used to designate the supply of cooling lubricant in the form of an aerosol. Depending on the type and main function of the supplied fluid, a distinction can be made between the minimum quantity of lubrication (MQL) and the minimum quantity of cooling (MQC).

SUPPLY SYSTEMS

In the minimum quantity lubrication technique a distinction is made between external supply through nozzles mounted separately in the machine area and internal fluid supply through channels integrated in the tool (Figure 7). Each of these systems has specialized individual fields of application.

Fatty alcohols and synthetic esters (chemically modified vegetable oil) are the most widely used media in MQL applications. The substrate chosen depends on the type of supply, the material involved, the machining operation, and the subsequent finishing operations required by the part (e.g. annealing, coating and paint).

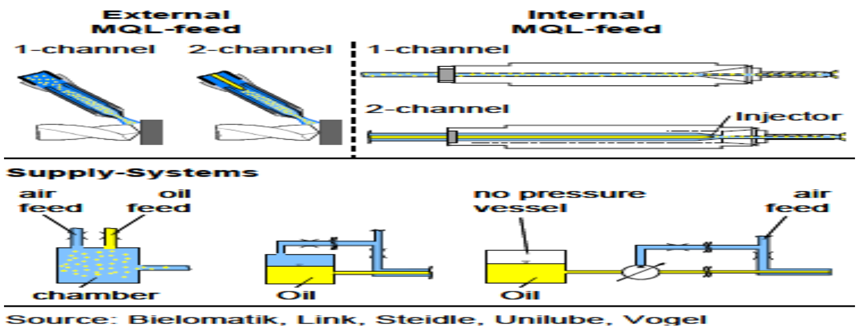

Fig. 7. MQL-feed systems [2]

CRYOGENIC MACHINING

Cryogenics expresses the study and use of materials at very low temperatures, below -150 ºC. However, the normal boiling points of permanent gases such as helium, hydrogen, neon, nitrogen, oxygen, and normal air as cryogens are below -180 ° C. Cryogenic gases have a wide variety of applications in industry, such as healthcare, electronics, manufacturing, the automotive and aerospace industries, particularly for cooling purposes. Liquid nitrogen is the element most used in cryogenics. It is produced industrially by fractional distillation of liquid air and is often referred to by the abbreviation LN2. Nitrogen melts at -210.01 ºC and boils at -198.79 ºC, it is the most abundant gas, constituting around four fifths (78.03%) of the volume of the atmosphere. It is a colorless, odorless, tasteless and non-toxic gas. Some potential advantages of cryogenic machining are [14]:

- Sustainable machining (cleaner, safer and more environmentally friendly)
- Higher material removal rate without increasing tool wear
- Increased tool life thanks to less abrasion and chemical wear,
- Improve the integrity of the workpiece surface

- Improved chip breakage
- Decreased BUE and probability of burr formation Cryogenic cooling approaches in the material

Machining operations can be classified into four groups according to the researchers' applications: cryogenic precooling of the part by repellent or in a closed bath and cryogenic cooling of the chips, indirect cryogenic cooling or retrocooling of the tool or by remote conduction. cooling, cryogenic jet cooling by injection of cryogen in the cutting area by general flooding or on the edges or faces of the cutting tool, at the tool-chip and tool-part interfaces by means of micro nozzles, figure 8. [13].

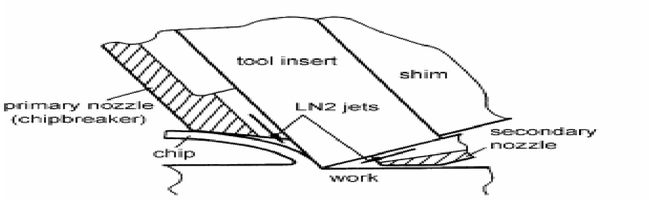

Fig. 8. Schematic diagram of LN2 nozzle system

HIGH PRESSURE JET ASSISTED MACHINING

High pressure jet assisted machining is an innovative method of cooling and lubricating the cutting area. It relates to supplying oil or water base at relatively low flow rates at extremely high pressure up to 300 MPa. CLFs subjected to such pressure penetrate closer to the area of the plow and cool it Figure 9. [14]. This helps control chip breakage by forming a physical hydraulic effect between the cutting face and the chips. HPJAM includes a high pressure pump, a high pressure tube and an outlet nozzle. Some potential benefits are:

- Sustainable machining through lower rates of fluid and providing better cooling and lubricant mechanisms,
- Decrease cutting tool contact length
- Lower cutting forces and extend tool life
- Improve chip breakability and decrease BUEformation

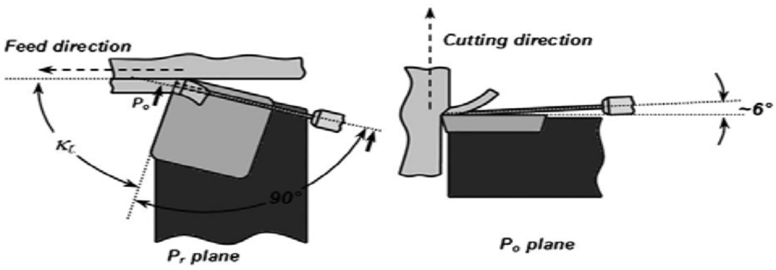

Fig. 9. Cutting fluid jet injection position

CUTTING MATERIALS

Particularly in dry machining processes, cutting edges and guide shoes are subject to high mechanical, thermal and chemical loads. To ensure good performance and high wear resistance, cutting materials must meet certain requirements regarding their physical properties. Figure 10 illustrates an ideal cutting material, combining properties such as high hardness, good toughness, and chemical stability. However, these requirements represent opposite properties, so an optimal and universal cutting material is not technologically feasible.

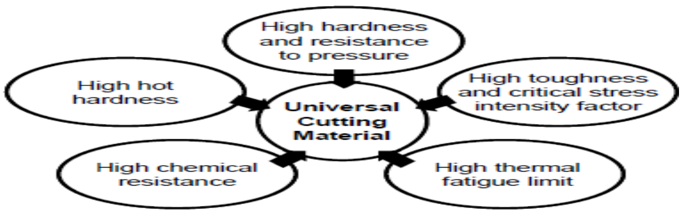

Fig. 10. Optimal cutting materials for dry machining

CONCLUSIONS AND FUTURE SCOPE

It is obvious that cutting technology has advanced significantly in recent years. The drive will continue toward the application of higher performance cutting tool and part materials, the use of minimal amounts of cutting fluid, greater precision and the application of microsystems. The technological capabilities of cutting systems will continue to develop and higher performance will occur with better standards of safety and environmental cleanliness and lower manufacturing costs.

Disparate sensor systems under open architecture control will contribute to the development of "smart" machining systems with learning capabilities. Specific cutting processes and process effects will benefit from continuous modeling research, including cutting hard materials, burr formation, and chip formation. Molecular dynamics modeling offers the potential to couple the characteristics of micro- and nanoscale processes with macro-scale processes. Improving the ability to model processes from macro to nano scale improves simulation and understanding of processes.

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