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A review on introduction to hybrid machining process

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Abstract
Machining is any of various processes in which a piece of raw material is cut into a desired final shape and size by a controlled material-removal process. Machining is a part of the manufacture of many metal products, but it can be used on materials such as wood, plastic, ceramic and composites. Sometimes interchangeability of parts is needed that a big requirement for which specific tolerances, dimensional accuracy and surface finish so on. So machining involves the removal of some material from the work piece in order to produce a specific geometry at a definite degree of accuracy and surface quality. The idea of hybrid machining is to combine different machining processes to manufacture components with a better machining performance. The objective of hybridizing processes is the positive effect of the hybrid process is more than double advantages of the single processes. In this paper review the state research on hybrid machining process and classifies the existing methods to develop the machining of micro to nano range.

Keywords: material removal process, interchangeability, tolerances, dimensional accuracy, hybrid machining

1. Introduction

Hybrid machining is combine different machining processes to manufacture components with a better machining performance. The objective of hybridizing processes is the positive effect of the hybrid process is more than double advantages of the single processes [12]. Hybrid processes developing due to the advent of novel materials with extreme properties, requirements of enhanced machining precision and complex shaped parts which earlier difficult or not possible to machine with existing conventional and non-conventional machining technologies. The term “hybrid process” in machining is related to the combination of different process energies or assisting a specific process by using another process energy.

A hybrid process can be used in different terms:
1. Combination of different active energy sources which act at the same time in the processing zone (laser-electrochemical machining).
2. Processes which combine process steps that are usually performed in two or more process steps (grind-hardening).
3. Hybrid machines, integrating different processes within one machining platform (sequential milling and electric discharge machining).

1.1 Classification of hybrid machining processes

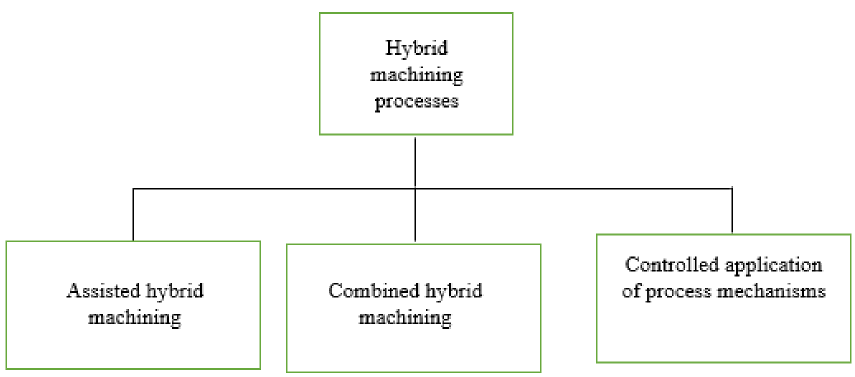

Fig1

Fig.1 shows the broad classification of hybrid machining processes. In assisted hybrid machining, one process energy assists the main process energy which is responsible for material removal. For instance, in laser-assisted turning a laser facilitates material removal by cutting tool. In combined hybrid processes, the process energies react simultaneously with the workpiece and participate in material removal. For example, in mechano-electrochemical machining the material removal takes place by both cutting action and anodic dissolution. Other hybrid processing techniques include controlled application of process mechanism with the objective to reduce the process chain or to combine two different processes on the same machine platform. For example, in grind hardening the two-step processes of grinding and heat treatment are combined at one machine platform by utilizing the heat treatment are combined at one machine platform by utilizing the heat generated in the grinding operation for hardening of the work piece.

2. Principle of hybrid machining processes

In hybrid machining processes, first it can shorten the existing process chains by combining two or more processes on the same machine platform thereby minimizing problems of referencing, clamping, alignment at different workstations. Second it can combine the process capabilities of different processes into one hybrid pro-cess so as to realize complex products and obtain machining performance such as high material removal rate (MRR) and high surface finish simultaneously. Conventional mechanical machining technologies are limited by the strength of the tool and mechanism of chip removal which mainly involves plastic deformation. These technologies are not suitable for machining hard-to-machine materials, including highly brittle materials. Similarly nonconventional machining processes also have limitations, especially due to their process physics and material removal mechanisms. For example, laser machining is limited to certain aspect ratios, EDM and electrochemical machining (ECM) are limited to machining of conductive materials, and the precision of water jet machining is limited by hydraulic jump of the jet. Therefore, in order to satisfy challenging machining needs, two or more hybrid processes can be combined to meet one or more machining objectives. Advanced machining capabilities can be realized through hybridization of two or more machining processes. Fig.2 shows the hybrid processes that improve the production in terms of shortening of process chain or improvement of product qualities.

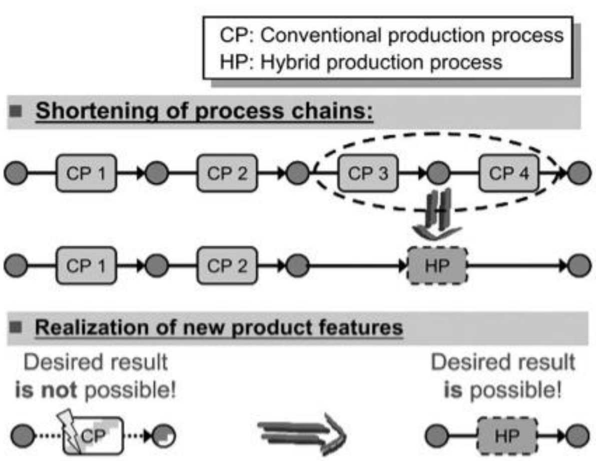

Fig 2

3. Assisted Hybrid Machining

For assisted hybrid machining, the major machining process is superimposed with input from one or several types of energy such as ultrasonic vibration, laser, fluid, magnetic field, etc. so as to improve the constituent machining process.

3.1 Vibration-assisted machining

Vibration-assisted machining uses vibrations to facilitate material removal and improve process performance. In this process, a small vibration is added to the tool or workpiece movement [3]. The vibrations may be in one or two directions. A small-amplitude high-frequency tool displacement is given to the cutting motion of the tool in the case of conventional machining and to the tool-electrode, workpiece and working fluid in the case of nonconventional machining processes. Fig.3 shows an ultrasonic-assisted ECM system where electrolyte flushing and removal of by-products is enhanced by application of ultrasonic vibrations to the tool. The ultrasonic vibration to the tool also offers the possibility to decrease electrode polarization. In most systems, especially in cutting and grinding operations, the amplitudes are in the range of 1-15 mm and vibration is within a frequency range from 18 to 25 kHz and the source of vibration are piezoelectric elements within the tool holder, spindle, or workpiece holding system. The vibrations are of ultra-sonic frequency.

The main advantages of vibration-assisted machining are as follows:

- Improvement in surface quality and machining time.
- Improved machining of brittle materials like ceramics and glass.

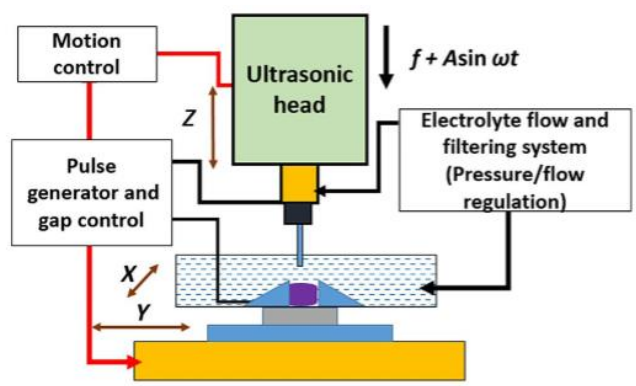

Fig 3

3.2 Laser Assisted Machining

The application of a laser beam as a secondary process is advantageous for various primary processes. The laser beam strongly influences the processing zone (e.g., material softening in cutting, material elongation and bending in forming, etc.) so machining becomes easier. The laser assistance may be applied to both conventional and nonconventional machining processes. In conventional machining, the laser beam is focused on the workpiece in front of the cutting edge of the tool [7]. The flow stress and strain hardening rate of materials normally decrease with the increase of temperature due to thermal softening. Therefore, laser-assisted machining facilitates the material removal when machining hard-to-machine materials. The heat from the laser softens the workpiece and the cutting process becomes easier with-out compromising on hardness and microstructure. In the case of non-conventional machining such as ECM, the laser enhances the precision of material removal by localizing the electrochemical dissolution.

The main advantages of laser-assisted machining are as follows:

- Reduction of cutting forces and tool heating while machining hard materials.
- Improved machinability of hard and difficult to cut materials by localized softening of material by laser.
- Reduction of grinding forces and improved surface quality during grinding of ceramics.
- Increase in MRR.

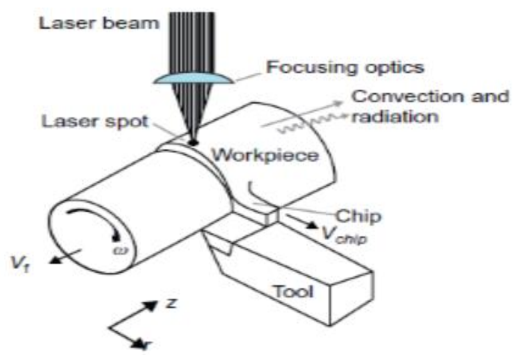

Fig 4

4. Combined Hybrid Machining

In combined hybrid processes, two or more processes are combined together and they act simultaneously Table.1 gives an overview of combined hybrid machining processes, suitable workpiece materials, and process characteristics. Some of the combined hybrid machining processes are discussed.

Table 1: Overview of Combined Hybrid Machining Processes

Combined hybrid machining Processes	Suitable work piece materials	Characteristic of process
ECDM	Glass, steel, quartz, silicon nitride	Suitable for micromachining of nonconductive materials
ECM - grinding	SS321	Achieved surface roughness
Laser drilling-ECM	321 stainless steel	More than 90% reduction in recast

4.1 Electrochemical Grinding

The development of combined ECM and grinding was to obtain a material removal process for difficult-to-cut aerospace alloys and cemented carbides. The combination of ECM and grinding is more advantageous than conventional grinding due to low residual stresses, large depths of cut, and increased wheel life. The combined process also performs better than ECM process as it higher material removal rates can be realized by combined grinding and ECM. In electrochemical grinding (ECG), a rotating grinding wheel is made the cathode [9]. When the wheel comes closer to the workpiece, its abrasive particles touch the workpiece surface and a gap is formed between the workpiece and the wheel. The electrolyte flow takes place in this gap. At first, the material removal occurs due to electrochemical dissolution and this leads to formation of a passivating layer. The use of pulsed power supply in ECG is better than conventional ECG as it helps in adjusting the balance between electrochemical and mechanical actions. The pulse parameters such as pulse-on-time and duty cycle act as additional parameters for better control of the material removal process.

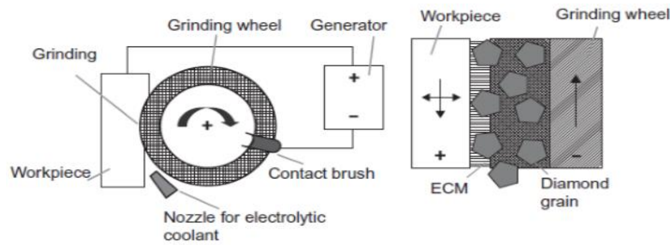

Fig 5

4.2 Electro discharge grinding and abrasive-EDM processes

In electro discharge grinding and abrasive-EDM processes, the material removal is accomplished by combination of spark erosion and abrasive action. Fig. 6 shows the basic principle of hybrid processes during EDM grinding and abrasive-wire-EDM. The combination of EDM and grinding is particularly useful in machining of electrically conductive cemented carbides with a metal bonded diamond grinding wheel. The material removal due to abrasive action and spark erosion depends on process parameters. The spark of EDM process results in thermally induced softening of the material in the grinding zone. Thus, the process is benefiting from reduced cutting forces and the requirement of the low spindle power. This process is particularly useful for the aerospace industry as it produces machined surfaces.

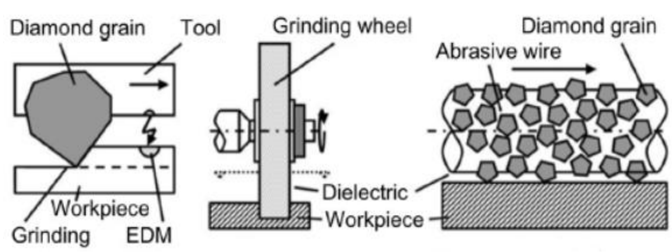

Fig 6

4.3 Mechano-Electrochemical Machining

The mechano-electrochemical machining (MECM) process exploits dual benefits by a combination of mechanical and electrochemical material removal. Fig. 7 shows a sketch of a hybrid MECM setup. The process is realized by design of a special ECM tool with a cutting edge. The process is especially useful for machining hard metals such as Ti-6Al-4V, which suffer from surface passivation during ECM process. The mechanical process facilitates removal of the passivation layer by a cutting edge, thereby enhancing surface quality and process stability. The process needs a dedicated tool design and machine tool.

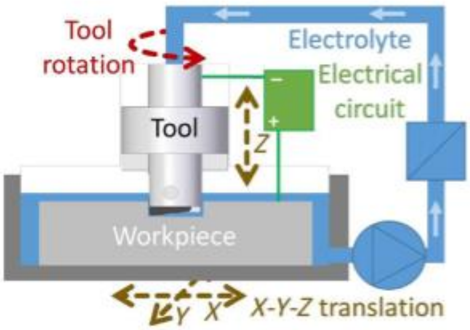

Fig 7

4.4 Abrasive-Waterjet Milling

Abrasive-waterjet machining (AWJM) is widely used in the cutting of hard and low machinability materials like titanium alloys, ceramics, metal matrix composites, concrete, rocks, etc. The process makes use of the impact of a waterjet as well as the impact of abrasives for improving the machinability of certain materials. Fig. 8 shows a sketch of a setup for AWJM [13]. The main element of an abrasive-waterjet setup is the reciprocating pump which is used to pump pure water at extremely high pressure. The abrasive particles are introduced into the waterjet from a hopper in the mixing chamber. The combined impact of waterjet and abrasives is useful in cutting or machining of composites, toughened steels, and some ceramics. The main challenge in abrasive-waterjet machining lies in controlling the depth of cut.

The advantages of abrasive-waterjet machining over conventional machining methods are listed below:

- The AWJM process produces very small stresses and negligible heat and is suitable for heat-sensitive materials such as plastics.
- The process is suitable for cutting complex contours on wide range of materials.
- The process has the capability to cut thin pieces with least bending.

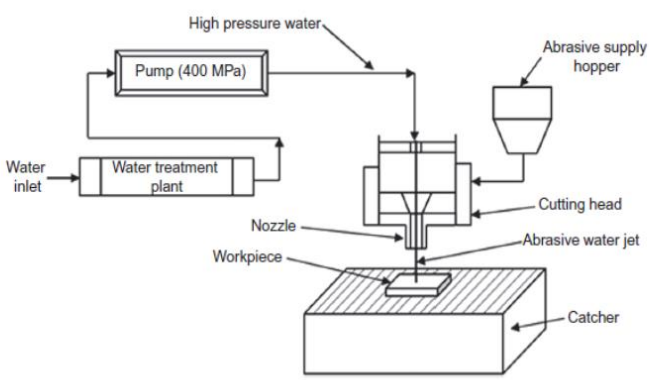

Fig 8

5. Combination of controlled processes

In this hybrid processes, the processes are developed where a controlled combination of effects occurs that are conventionally caused by separated processes.

5.1 Grind Hardening

Grinding is a machining process which removes material in a finishing regime. Heat treatment is the final step of many process chains, and it is usually expensive and time consuming. To shorten these process chains, the concept of grind-hardening has come up. Grind-hardening has the advanced capability for process integrated surface layer hardening by grinding with a subsequent finishing in one clamping. In grinding process, ample heat is generated in the contact zone between the grinding wheel and workpiece due to deformation, shearing, and friction. This heat can be utilized for short-time surface hardening of the machined part. In order to achieve high heat input rate, the grinding operation is per-formed with a higher depth of cut and slow feed speed [4].

6. Summary

In this study we see an overview of hybrid machining processes. The motive behind developing a hybrid machining process is discussed and the advantages of hybrid machining processes are highlight. The principle for hybrid machining processes are also discussed comprehensively. Three different categories of hybrid machining processes are discussed in this study i.e., assisted machining, combined machining, and controlled application of process mechanisms. With the developments in hybrid machining technologies, machining issues with novel materials and complex shapes can be addressed effectively. The development of hybrid machining processes is starting from basic research to industrial implementation.

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