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INVESTIGATE THE EFFECTIVENESS OF HYBRID MACHINING PROCESSES

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Abstract : Although machining may be used in the production of many different items, it is most frequently utilised with materials including wood, plastic, ceramic, and composites. Advanced engineering materials, such as fiber-reinforced composites, super alloys, and ceramics, among others, have a variety of qualities, including mode of strengthening, corrosion resistance, and strength to weight ratio. These characteristics have made it possible to design goods with improved characteristics, but because sophisticated materials are so challenging to work with during conventional machining, we employ hybrid machining instead. The fundamental premise of the hybrid machining process is that by combining the strengths of the different machining processes, a more effective material removal rate may be achieved. The key points of the literature on hybrid machining methods have been distilled in this article. The mechanical, thermal, and electrochemical processes assist the material removal feature of the machining procedures in general. Discussed are the many working theories and procedures for removing clothing from current hybrid processes.

KEYWORDS: Hybrid Machining, Vibration Assisted Machining

I. INTRODUCTION

Hybrid machining combines two distinct machining techniques to produce components more effectively and with superior machining performance. The goal of hybridising machining processes is to increase their benefits above those of single processes by more than twofold [12]. Due to the introduction of novel materials with extreme properties, the need for increased machining precision, and the development of sophisticated shaped parts that were previously impossible or impractical to machine using current conventional and non-conventional machining techniques, hybrid processes are emerging. The phrase "hybrid process" in machining refers to combining several process energies or utilising process energy to support a particular process. A hybrid technique is frequently used in a variety of ways:

1. the combination of many working energy sources at that moment in the processing or working zone (laser electrochemical machining).

2. Methods that integrate the strategy steps that are often carried out in more than one manner (grind hardening).

3. Hybrid machines, which combine many operations into a single machining platform (sequential milling and electric arc machining).

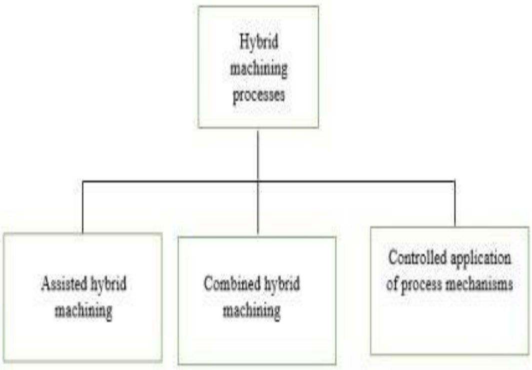

Figure 1: Hybrid Machining Classification

II. PRINCIPLE

Figure 2 illustrates hybrid procedures that facilitate assembly by streamlining the supply chain or enhancing the quality of the final product. By merging two or more operations on the same machine platform and avoiding issues with reference, clamping, and alignment at several workstations, hybrid machining methods can reduce the current process chains. In order to produce complicated products and assess machining performance such high material removal rate (MRR) and high surface polish concurrently, it may integrate the technique capabilities of several processes into one hybrid process. Traditional mechanical machining techniques are constrained by the tool's strength and the chip removal process, which primarily relies on plastic deformation. These methods don't seem to be appropriate for cutting extremely brittle or difficult-to-machine materials. Similar constraints apply to unconventional machining techniques as well, in part because of the physics involved in those processes and the mechanisms used for material removal. Examples include the restriction of laser machining to specific aspect ratios, the limitation of EDM and electrochemical machining (ECM) to the milling of conductive materials, and the limitation of the accuracy of water jet machining due to the hydraulic leap of the jet. Therefore, two or more hybrid processes are integrated to fulfil one or more machining objectives in order to satisfy complex machining demands. Hybridizing two or more machining techniques allows for the realisation of advanced machining capabilities.

Vibration Assisted Machining (VAM)

By introducing small-amplitude, periodic vibrations to the cutting action of the tool, vibration-assisted machining (VAM)

Tool displacement at high frequencies when cutting [7]. A tiny reciprocating motor with a moving centroid that travels in the direction of the cutting velocity is used to drive the tool tip. The tool periodically loses touch with the chip when the cutting velocity, tool amplitude, and frequency are properly balanced. Thinner chips can be produced and machining forces can be decreased as a result. This results in increased form accuracy, superior surface finishes, and almost no burr. By imparting small-amplitude, high-frequency tool displacement to the tool during cutting, vibration- aided machining (VAM) helps the tool's cutting motion [7]. A tiny reciprocating motor with a moving centroid that travels in the direction of the cutting velocity is used to drive the tool tip. The tool periodically loses touch with the chip when the cutting velocity, tool amplitude, and frequency are the right values. Thinner chips can be produced and machining forces can be lowered as a result. This results in increased form accuracy, superior surface finishes, and almost no burr.

III. HYBRID MACHINING PROCESS DESIGN PRINCIPLE AND METHODOLOGY

Designing hybrid machining techniques and associated technology has two goals. By adding two or more processes to an existing process chain on the same machine, it is first possible to change the current process chains while reducing concerns with reference, clamping, and alignment at various work platforms. In order to create complicated products and/or achieve paradoxical machining performance, such as high material removal rate (MRR) and high surface polish at the same time, it may then combine the technique capabilities of many processes into a single hybrid machining process. Conventional mechanical machining techniques are restricted by the power of the tool and process of metal removal, which mostly involves plastic deformation. These methods are not appropriate for cutting extremely brittle or difficult-to-machine materials. Similar to conventional machining, nonconventional machining techniques also have restrictions, particularly in terms of how they remove material from the workpiece. For instance, electrochemical machining (ECM) and laser machining are constrained to specific aspect ratios, EDM and ECM are only permitted for the milling of conductive materials, and the accuracy of water jet machining is constrained by the hydraulic jump of the jet. Therefore, two or more hybrid processes are frequently coupled to achieve one or more machining goals in order to satisfy complex machining demands. It is common to combine two or more machining techniques to provide advanced machining capabilities. Figure 2 illustrates the areas where hybrid processes might enhance assembly in terms of streamlining the supply chain or enhancing product quality [4]. To achieve the aforementioned goals, the design of a hybrid machining process must adhere to at least one of the following principles: 1. Extending the current process window for material processing (i.e. machinable materials). 2.enhancing current processes available (i.e. attainable surface finish, surface integrity, tool life, etc.). A hybrid machining process' design must also include cost-effectiveness, safety, and the avoidance of waste and hazards. Because it necessitates the planning of a variety of processes, taking their process physics into consideration, as well as the design of specialised machine tools, design for hybrid machining may be a multidisciplinary area. For instance, LECM procedures need the design of optics in addition to ECM accessories. Furthermore, through the interplay of their respective process energies, these two processes can potentially affect one another. On the other hand, as milling may be a contact-based process that involves machining forces, and EDM may be a noncontact machining method that involves no machining forces, combined mechanical milling and EDM processes require specialised machine tools. The majority of the design features for hybrid machining operations are shown in Fig. 2.

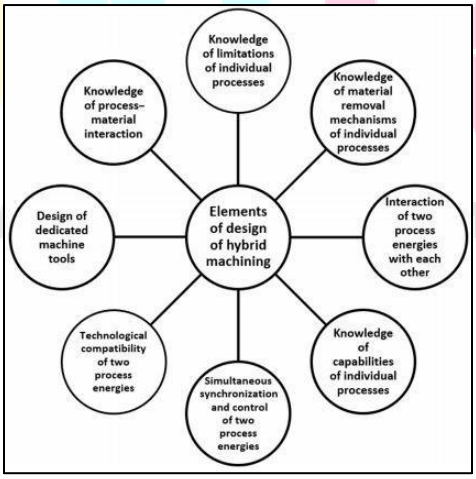

Figure 2: Hybrid Machining's Components

A. ASSISTED HYBRID MACHINING

In aided hybrid machining, the primary machining process is supplemented by input from one or more energy sources, such as a laser, fluid, magnetic field, or ultrasonic vibration, in order to enhance the constituent machining process.

Machining with mechano-chemical reactions

A specific machine tool design and machine tool were necessary for the procedure. Combining mechanical and electrochemical methods of material removal, the mechanic-electro chemical machining process reaps two benefits. A cutting-edge, specialised electrochemical machine tool is designed to analyse the process. When cutting hard, modern metals like Ti-6Al-4V, which experience surface roughness throughout the ECM process, the method is particularly extremely helpful.

The mechanical procedure makes it easier.

a cutting edge is used to remove the top layer, enhancing the process's existence and surface quality.

Processes for electro discharge grinding and abrasive-EDM

The removal of fabric is aided in electro discharge grinding and abrasive-EDM procedures by a combination of spark ignition and abrasive action. The necessary concept of the hybrid machining techniques used in abrasive-wire EDM and EDM grinding is shown in Fig. 3. When using a metal-bonded diamond grinding wheel to manufacture electrically conductive cemented carbides, the combination of EDM and grinding is very helpful. Depending on the process variables, material is removed owing to abrasive action and spark ignition. The material in the grinding zone is thermally softened as a result of the electric discharge machining technique' spark. As a result, the process gains from decreased cutting forces as well as the low spindle power need. Because this method produced machined surfaces, it is particularly suitable to the aerospace sector.

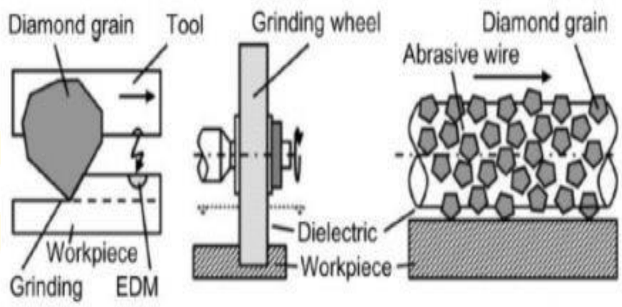

Figure 3: Electro discharge grinding and abrasive-EDM processes

Vibration-Assisted Machining

The term "vibration-assisted machining" refers to the use of vibrations to facilitate material removal and improve efficiency. A very slight vibration is added to the tool or work piece movement during this operation. Even more than one direction could be affected by the vibrations. In the case of older or conventional machining, a small-amplitude high-frequency tool displacement is supplied to the cutting motion of the tool, but in the case of nonconventional machining processes, it is delivered to the tool-electrode, work piece, and working fluid. Fig. 4 depicts an ultrasonic-assisted ECM system whereby the tool is subjected to ultrasonic vibrations in order to improve or increase the electrolyte flushing and by-product removal. The tool's ultrasonic vibration also has the potential to lessen electrode polarisation. Most systems exhibit vibrations with amplitudes between 1 and 16 mm, frequencies between 20 and 26 kHz, and origins in the piezoelectric components of the spindle, tool holder, and work piece holding mechanism. Ultrasonic vibrations are being produced.

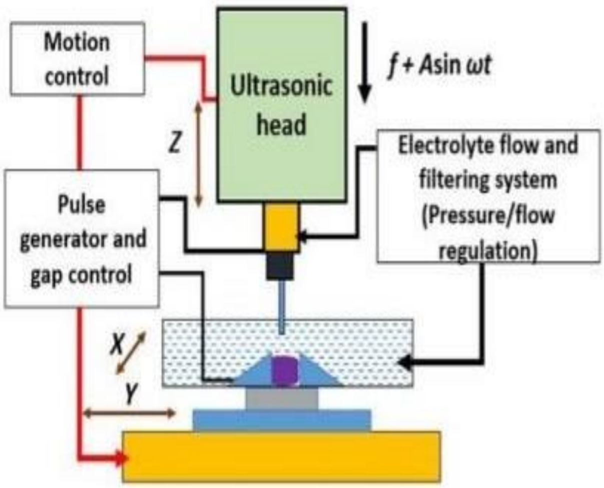

Figure 4: Vibration-assisted machining

The following are the key benefits of vibration-assisted machining:

- Improved machining of fragile materials like ceramic and glass
- Improvement in surface quality and machining speed.

Water-jet abrasive milling

Modern, hard, and low machinability materials including titanium alloys, ceramics, metal matrix composites, concrete, rocks, etc. are commonly cut using abrasive-water jet machining (AWJM). The technique uses both the impact of an abrasive and a water jet to improve the machinability of particular materials. A configuration for AWJM is shown in Fig. 5. The reciprocating pump, which is used to pump pure water at extremely high pressures, is one of the primary components of an abrasive-water jet arrangement. From a hopper in the mixing chamber, the abrasive particles are fed into the water jet. When cutting composite materials, hardened steels, and some ceramic materials, the combined impact of water jet and abrasives is tremendously helpful. Controlling the depth of cut during abrasive-water jet machining is crucial.

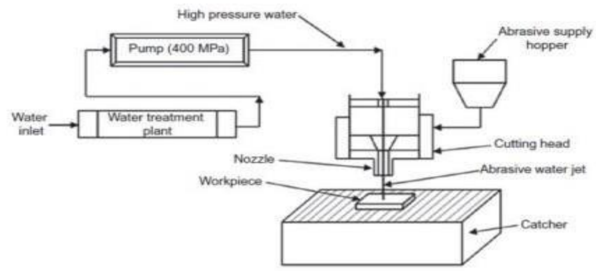

Figure 5: Abrasive-Water jet Milling

The following are some benefits of abrasive-waterjet machining over traditional machining techniques:

The AWJM technique may be used to cut thin parts with the least amount of bending and is capable of cutting intricate curves on a variety of materials. The process creates extremely modest stresses and negligible heat, making it appropriate for heat-sensitive materials like plastics.

Electrochemical Grinding

For challenging-to-cut aerospace alloys and other materials made of cemented carbides, combined electrochemical machining and grinding was developed. Due to negligible residual stresses, significant depths of cut, and prolonged wheel life, ECM and grinding are more advantageous than traditional grinding. Because combined grinding and ECM may achieve higher material removal rates, the combined process also outperforms the ECM technique. A spinning grinding wheel is used as the cathode in ECG. A gap forms between the workpiece and the wheel when the wheel approaches the workpiece and its abrasive particles make contact with the surface of the workpiece.

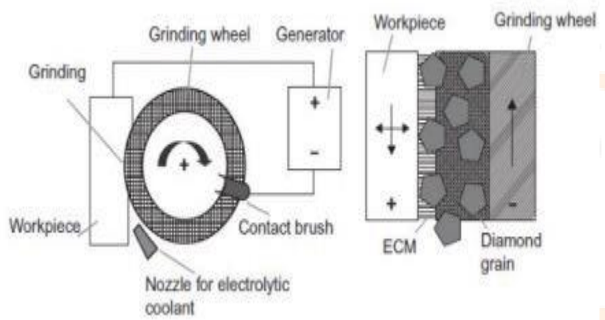

Figure 6: Electrochemical Grinding

Conclusion and future prospects

Advanced materials including ceramics, sintered carbides, titanium alloys, nickel alloys, etc. are required by the aerospace, aviation, medical, and military industries. These materials are challenging to shape, and it is challenging to get efficiency levels that are desirable and part surface qualities that are appropriate for real-world applications. When using EDG and ECG in finishing procedures, positive outcomes are frequently attained. Electrochemical grinding is widely used to achieve lower levels of surface roughness. Combining abrasive grinding with allowance removal by discharge or electrochemical dissolving enables:

1. A rise in machining efficiency compared to traditional mechanical grinding and EDM.
2. Achieving good surface layer characteristics and surface geometrical structure.
3. Improving wheel lifespan and reducing abrasive grain wear
4. The phenomena of self-sharpening wheels.

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