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A Review on Non- Conventional Machining Processes in present era

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Abstract: The present era required workpiece which are efficient in the quality and possesses a long functional values with durability. The conventional machining processes are often used in major machining areas but often finds their limitation in the areas where the machining up to the micro and nano machining is required. Also the problem of tool wear and tool holding is the prominent factor when we consider the non-traditional machining processes as there is physical contact between the workpiece and the tool. The present article highlights the prominent non-conventional energy resources along with their process parameters and their application in the manufacturing sector.

1. Introduction

Generally manufacturing processes is broadly divided into two main categories which includes primary manufacturing processes and the second is the secondary manufacturing processes. The secondary manufacturing processes are further divided into the conventional and non-conventional machining processes [1]. The primary manufacturing processes includes material adding concept which most specifically involves material addition like casting. Powder metallurgy and metal forming operations whereas the secondary manufacturing operation includes metal removal operation often term as machining [2]. The machining is one of the key requirement when it comes to the field of the manufacturing. The process generally terms as the removal of the material to get the requisite dimensions and the requisite tolerance. The machining is further divided into conventional and non-conventional machining processes based on the tool and workpiece interaction. In conventional machining process the tool used is harder than the workpiece and the shearing mechanism obtain due to the relative motion of the tool and the workpiece accelerate the material removal process [3] whereas there is no physical interaction between the tool and the workpiece and the material removal mechanism is specific based on the energy resources. Depending upon the interaction of the tool and workpiece the traditional machining tools are of various type which includes lathe, shaper, planer, milling and drilling. A large number of operation may be performed on these machine tool depending upon the requirement and the dimension of the workpiece. The various nontraditional process involves EDM, LBM, Ultrasonic machining, EBM etc. Figure 1 shows various finishing process. The various machining process are discussed in the subsequent sections.

2. Non-traditional finishing processes

2.1 Ultrasonic machining

Ultrasonic machining is a subtractive manufacturing process that removes material from the surface of a part through high frequency, low amplitude vibrations of a tool against the material surface in the presence of fine abrasive particles. The tool travels vertically or orthogonal to the surface of the part at amplitudes of 0.05 to 0.125 mm. The fine abrasive grains are mixed with water to form a slurry that is distributed across the part and the tip of the tool.

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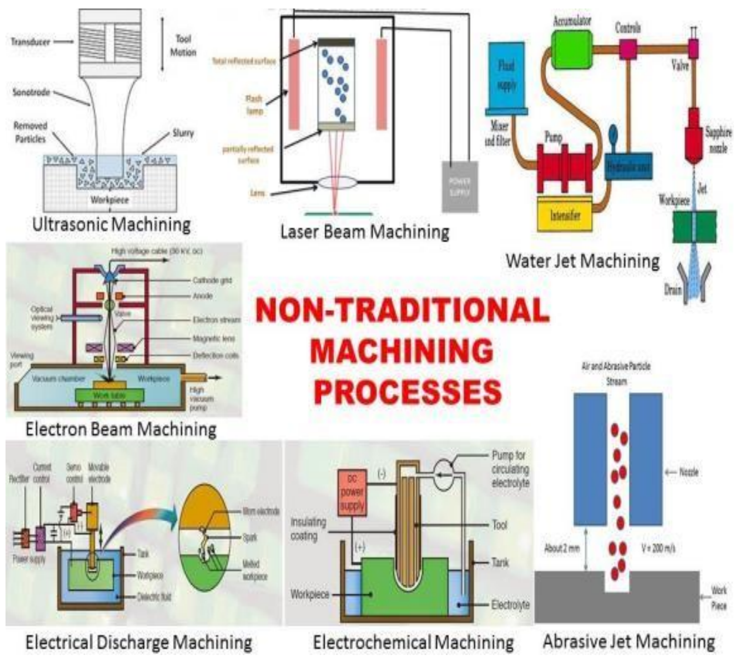

Fig. 1: Non-traditional finishing processes

Typical grain sizes of the abrasive material range from 100 to 1000, where smaller grains (higher grain number) produce smoother surface finishes [2]. Ultrasonic vibration machining is typically used on brittle materials as well as materials with a high hardness due to the micro cracking mechanics.

Ultrasonic Machining

2.2 Laser Beam Machining

Laser beam machining (LBM) is a form of machining that uses heat directed from a laser beam. This process uses thermal energy to remove material from metallic or non- metallic surfaces. The high frequency of monochromatic light will fall on the surface, thus heating, melting and vaporizing the material due to the impinge of photons. Laser beam machining is best suited for brittle materials with low conductivity, but can be used on most materials [3]. Laser beam machining can be done on glass without melting the surface. With photosensitive glass, the laser alters the chemical structure of the glass allowing it to be selectively etched. The glass is also referred to as photomachinable glass. The advantage of photomachinable glass is that it can produce precisely vertical walls and the native glass is suitable for many biological applications such as substrates for genetic analysis.

2.3 Water Jet Machining

A water jet cutter, also known as a water jet or waterjet, is an industrial tool capable of cutting a wide variety of materials using an extremely high-pressure jet of water, or a mixture of water and an abrasive substance. The term abrasive jet refers specifically to the use of a mixture of water and an abrasive to cut hard materials such as metal, stone or glass, while the terms pure waterjet and water-only cutting refer to waterjet cutting without the use of added abrasives, often used for softer materials such as wood or rubber [4]. Waterjet cutting is often used during the fabrication of machine parts. It is the preferred method when the materials being cut are sensitive to the high temperatures generated by other methods; examples of such materials include plastic and aluminium. Waterjet cutting is used in various industries, including mining and aerospace, for cutting, shaping, and reaming.

2.4 Electron Beam Machining

Electron-beam machining (EBM) is a process where high- velocity electrons concentrated into a narrow beam that are directed towards the work piece, creating heat and vaporizing the material. EBM can be used for very precise cutting or boring of a wide variety of metals. Surface finish is better and kerf width is narrower than those for other thermal cutting processes [5]. EBM process is best suitable for high melting point and high thermal conductivity materials. The EBM beam is operated in pulse mode. This is achieved by appropriately biasing the biased grid located just after the cathode. Switching pulses are given to the bias grid so as to achieve pulse duration of as low as 50 µs to as long as 15 ms. Beam current is directly related to the number of electrons emitted by the cathode or available in the beam. Beam current can be as low as 200 µamp to 1 amp. Increasing the beam current directly increases the energy per pulse. Similarly, increase in pulse duration also enhances energy per pulse. High-energy pulses (in excess of 100 J/pulse) can machine larger holes on thicker plates. The energy density and power density is governed by energy per pulse duration and spot size. Spot size, on the other hand is controlled by the degree of focusing achieved by the electromagnetic lenses. If a higher energy density is combined with a smaller spot size, the material removal would be faster though the size of the hole would be smaller. The plane of focusing would be on or just beneath the surface of the work piece. The electron beam is generated by the potential difference between the negatively-charged cathode and the positively-charged anode.

2.5 Electrical Discharge Machining

Electron-beam machining (EBM) is a process where high- velocity electrons concentrated into a narrow beam that are directed towards the work piece, creating heat and vaporizing the material. EBM can be used for very precise cutting or boring of a wide variety of metals. Surface finish is better and kerf width is narrower than those for other thermal cutting processes [5]. EBM process is best suitable for high melting point and high thermal conductivity materials. The EBM beam is operated in pulse mode. This is achieved by appropriately biasing the biased grid located just after the cathode. Switching pulses are given to the bias grid so as to achieve pulse duration of as low as 50 µs to as long as 15 ms. Beam current is directly related to the number of electrons emitted by the cathode or available in the beam. Beam current can be as low as 200 µamp to 1 amp. Increasing the beam current directly increases the energy per pulse. Similarly, increase in pulse duration also enhances energy per pulse. High-energy pulses (in excess of 100 J/pulse) can machine larger holes on thicker plates. The energy density and power density is governed by energy per pulse duration and spot size. Spot size, on the other hand is controlled by the degree of focusing achieved by the electromagnetic lenses. If a higher energy density is combined with a smaller spot size, the material removal would be faster though the size of the hole would be smaller. The plane of focusing would be on or just beneath the surface of the work piece. The electron beam is generated by the potential difference between the negatively-charged cathode and the positively-charged anode.

The process depends upon the tool and work piece not making physical contact. Extremely hard materials like carbides, ceramics, titanium alloys and heat treated tool steels that are very difficult to machine using conventional machining can be precisely machined by EDM. When the voltage between the two electrodes is increased, the intensity of the electric field in the volume between the electrodes becomes greater, causing dielectric break down of the liquid, and produces an electric arc. As a result, material is removed from the electrodes. Once the current stops (or is stopped, depending on the type of generator), new liquid dielectric is conveyed into the inter-electrode volume, enabling the solid particles (debris) to be carried away and the insulating properties of the dielectric to be restored. Adding new liquid dielectric in the inter-electrode volume is commonly referred to as flushing. After a current flow, the voltage between the electrodes is restored to what it was before the breakdown, so that a new liquid dielectric breakdown can occur to repeat the cycle. The formation of crater and the thermal recast layer on the surface of the workpiece is a major disadvantage with the EDM process. Also, the other major limitation of the EDM process is that it is applicable on the conductive material only.

2.6 Electrochemical Machining

Electrochemical machining (ECM) is a method of removing metal by an electrochemical process. It is normally used for mass production and for working extremely hard materials, or materials that are difficult to machine using conventional methods. Its use is limited to electrically conductive materials. ECM can cut small or odd-shaped angles, intricate contours or cavities in hard and exotic metals, such as titanium aluminides, Inconel, Waspaloy and high nickel, cobalt, and rhenium alloys. Both external and internal geometries can be machined [7]. In the ECM process, a positively-charged (cathode) cutting tool is advanced into a negatively-charged (anode) workpiece. Pressurized electrolyte is injected at a set temperature into the area being cut, at a feed rate equal to the rate of "liquefaction" of the anode material. The gap between the tool and the workpiece varies within 80–800 micrometres (0.003–0.030 in.). As electrons cross the gap between the tool and workpiece, material from the workpiece is dissolved, as the tool forms the desired shape in the workpiece. The electrolytic fluid carries away the metal hydroxide formed in the process.

2.7 Abrasive Jet Machining

Abrasive jet machining (AJM), also known as abrasive micro-blasting, pencil blasting and micro-abrasive blasting, is an abrasive blast machining process that uses abrasives propelled by a high velocity gas to erode material from the workpiece. Common uses include cutting heat-sensitive, brittle, thin, or hard materials. Specifically, it is used to cut intricate shapes or form specific edge shapes. Material is removed by fine abrasive particles, usually about

0.001 in (0.025 mm) in diameter, driven by a high velocity fluid stream; common gases are air or inert gases. Pressures for the gas range from 25 to 130 psig (170–900 kPa or 4 bars) and speeds can be as high as 300 m/s (1,000 km/h). The main advantages are its flexibility, low heat production, and ability to machine hard and brittle materials. Its flexibility owes from its ability to use hoses to transport the gas and abrasive to any part of the workpiece [8]. Normally inaccessible between the particle mixture and the workpiece surface result in material removal. Since MAF does not require direct contact with the tool, the particles can be introduced into areas which are hard to reach by conventional techniques [10]. Additionally, careful selection of magnetic particles and abrasive particles give rise to surface texture and roughness control that was previously impossible especially for hard to access area. The magnetic field source in MAF is typically an electromagnet or a rare earth permanent magnet. A permanent magnet offers high energy density, lack of overheating resulting in a constant flux density, low cost, ease of integration into existing CNC equipment, and simplicity. Some applications require adjustment of the flux density during finishing, or require a switching magnetic field, which is only attainable with an electromagnet since the magnetic field in a permanent magnet cannot simply be switched off. Relative motion between the magnetic/abrasive particle mixture and the workpiece is essential for material removal. There are several options for achieving the necessary motion. A common setup is the rotation of the magnetic pole tip. This is done by either rotating the entire permanent magnet setup or by rotating only the steel pole. Another method which is commonly utilized in internal finishing is the rotation of the workpiece, this is unfortunately limited to axial symmetric workpiece. In addition to rotational motion there is oscillatory and vibrational configurations that are applicable.

The table 1 shows the various non-conventional machining process along with their applications and their material removal process. The different processes are based on different energy sources as a result their material removal mechanism is different.

Table 1: Machining processes with application and mechanism of material removal

S. No	Machining Process	Mechanism of MR	Application
1	Ultrasonic Machining	Impact Erosion	• Machining very precise and intricately shaped articles. • Drilling the round holes of anyshape. • Grinding the brittle materials. • Profiling the holes. • Engraving. • Trepanning and coining. • Threading. • Slicing and broaching hard materials.
2	Laser Beam Machining	Melting and Evaporation	• Laser Beam Machining can be used for engraving of materials. • It can be used for drilling ofmicro holes. • It is used to drilling holes of jetengine. • It can be used for laser heattreatment. It can be used for surgery of medical.
3	Water jet Machinin	Impact Erosion	• Stones & Tiles Cutting. • Glass Cutting. • Metal Cutting. • Ceramics. • Plastics. • Foam and Rubber. • Textiles. • Composites
4.	Electron Beam Machining	Melting and Evaporation	• Thin hole and slots in metals, plastics and ceramics of any hardness. • Hole Drilling
5	Electrical Discharge Machining	Melting and Evaporation	• Mould and Die • Micro channels • Micro drilling
6	Electro Chemical Machining	Dissolution	• Automotive • Construction • Medical equipment • Micro-systems and power supplyindustries
7	Abrasive Jet Machining	Impact Erosion	• The process is best suited for machining brittle and heat sensitive materials like glass, quartz, sapphire, ceramics, etc. • It is used for drilling holes, cutting slots, cleaning hard substance deburring, polishing,etc.
8	Abrasive Flow Machinin	Abrasion	• It is used for producing high quality surface • Finishing surfaces
9	Magnetic Abrasive Finishing	Abrasion	• Micro Surface finishing

3. Abrasive Flow Machining

Abrasive flow machining (AFM), also known as abrasive flow deburring or extrude honing, is an interior surface finishing process characterized by flowing an abrasive-laden fluid through a workpiece. This fluid is typically very viscous, having the consistency of putty or dough. AFM smooths and finishes rough surfaces, and is specifically used to remove burrs, polish surfaces, form radii, and even remove material [9]. The nature of AFM makes it ideal for interior surfaces, slots, holes, cavities, and other areas that may be difficult to reach with other polishing or grinding processes. Due to its low material removal rate, AFM is not typically used for large stock-removal operations, although it can be. Abrasive flow machining was first patented by the Extrude Hone Corporation in 1970.

3.1 Magnetic Abrasive Finishing

Magnetic Assisted Finishing or MAF is essentially the manipulation of a homogeneous mixture of magnetic particles and abrasive particles with a magnetic field to impart a machining force on a workpiece.

4. Conclusions

The following points may be concluded that the conventional machining tool does not provide finish upto the micro level. Non-traditional machining operation provides finishing upto the nano level compared to conventional energy tool. The problem of tool wear and machining time is curbed with non-conventional machining operations. The classification and the mechanism of material removal of non-conventional machining process is based on their energy source. Specific operation may be achieved with the help of non-conventional machining processes.

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