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A Study on Modern Unconventional Machining Processes and Its Machining Parameters Characteristics

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Abstract -*The evolution of manufacturing process is due to the necessity of using new materials for the functional requirements and trimness. Both in the conventional and unconventional methods of manufacture, the developments take place. Some of the modern manufacturing processes are the high speed, hard, high accuracy machining. The aim of this paper is to elaborate the overview of modern manufacturing processes and capabilities of machining process currently under use in the manufacturing area.*

Key words - *Machining, Electro Chemical Machining, Laser beam machining, Material removal rate*

I. MECHANICAL METHODS OF UNCONVENTIONAL PROCESSES

1.1. Water Jet Machining (WJM)

Water Jet Machining (WJM) is a non-traditional machining process based on mechanical energy used for cutting and machining of soft and non-metallic materials. In this, high velocity water jet is used to smoothly cut a soft work piece. It is like Abrasive Jet Machining (AJM). In water jet machining, high velocity water jet is used to strike a given work piece. During the striking, its kinetic energy is converted in to pressure energy. This creates a stress on the work piece. When this stress is high enough, particles of the work piece are automatically removed.

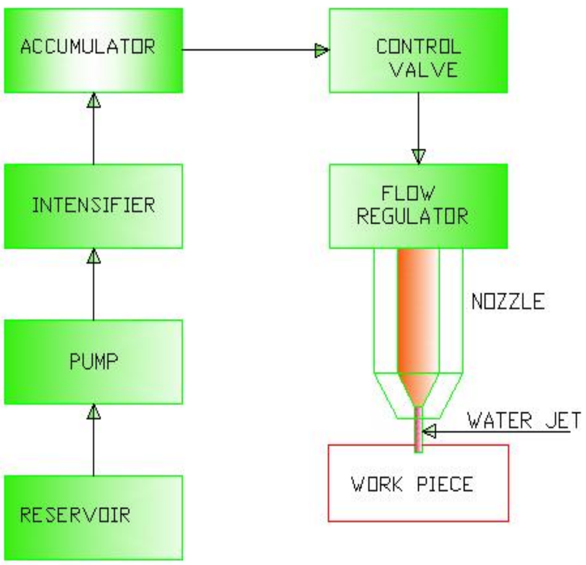

Figure 1. Water Jet Machining

1.2.Abrasive Jet Machining (AJM)

Abrasive Jet Machining (AJM), also called as micro-abrasive blasting , is a mechanical energy based unconventional machining process used to remove unwanted material from a given work piece. In this process an abrasive jet with high velocity is used to remove material and provide smooth surface finish to hard metallic work pieces. It is similar to Water Jet Machining.

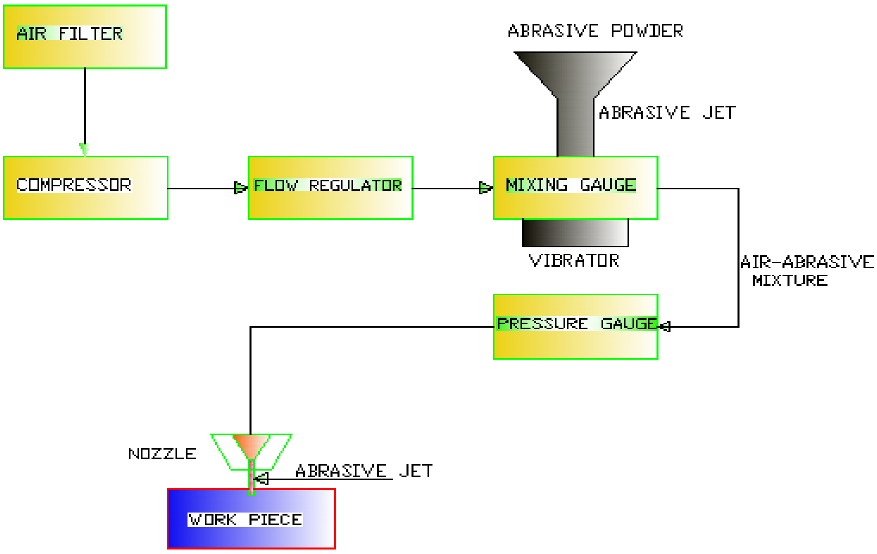

Figure 2. Abrasive Jet Machining

1.3.Ultrasonic Machining (USM)

Ultrasonic machining is used in the manufacturing industries to obtain a superlative performance. The main advantage of this machining process is it evolves less heat during the process. Ultrasonic machining processes are cost effective and best in results. Ultrasonic machining is an abrasive process which material in hard and brittle form with the help of its vibrating tool by the indirect passage of abrasive particles towards the work piece. It is a low material removal rate machining process. It is also known as Ultrasonic impact grinding an operation, that involves a vibrating tool fluctuating the ultrasonic frequencies in order to remove the material from the work piece. The process involves an abrasive slurry that runs between the tool and the work piece. Due to this, the tool and the work piece never interact with each other. The process rarely exceeds two pounds.

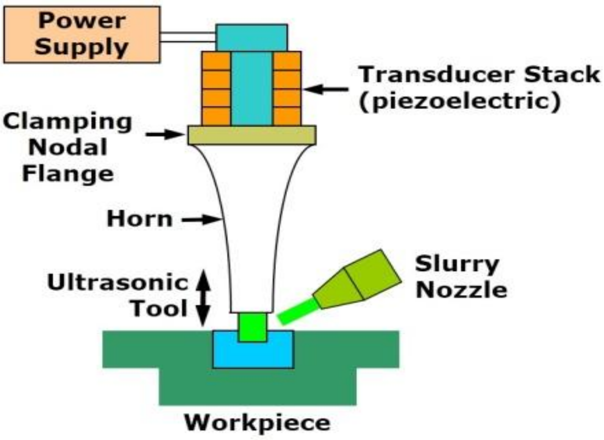

Figure 3. Ultrasonic Machining

II. THERMAL METHODS OF UNCONVENTIONAL PROCESSES

2.1. Electrical Discharge Machining (EDM)

EDM also known as spark machining, is well suited for creating fragile parts that can't withstand the stress produced due to machining. EDM is one of the most widely used machining processes where accuracy and surface speed is required. EDM works by eroding the metals caused by discharge that occurs between electrode and the work piece. EDM can be effectively used to machine electrically conductive metals and alloys regardless of their strength, toughness and hardness.

Another EDM technique is the electrical discharge grinding where the stationary electrode used in EDM is replaced by a rotating electrode and material is removed by melting and vaporization.

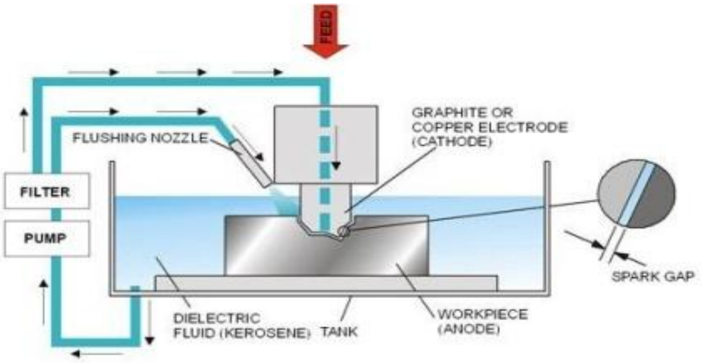

Figure 4. Electrical Discharge Machining

2.2.Micro EDM Process

Micro EDM is a newer technique to produce micro-parts in the range of 50 µm – 100 µm. It is a non-contact process in which micro-metal holes can be fabricated. Machining is carried out by the discharge through a dielectric in order to supply heat on the surface of work piece. Micro EDM works in the same way as the conventional EDM except for the usage of small electrode size & micro metal removal rate and micro axes movements. Micro EDM can be used as variant machining processes like Micro-ED milling, Micro-ED grinding, Micro-ED dressing etc...

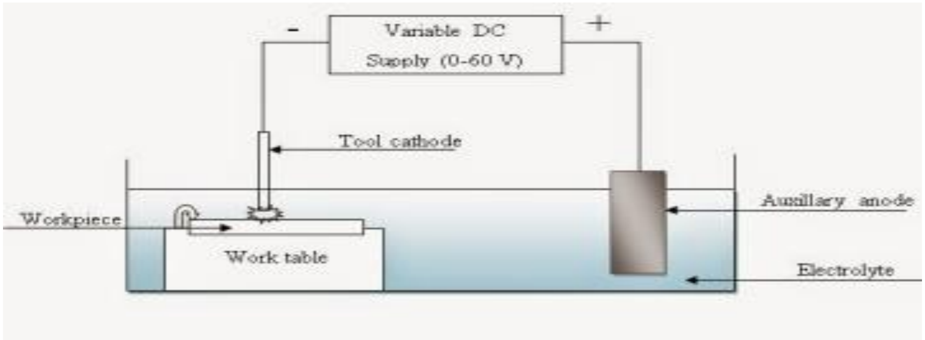

Figure 5. Micro EDM Process

2.3.Laser Beam Machining (LBM)

Laser, an acronym for light amplification by stimulated emission of radiation is one of the greatest innovations of 20th century. LBM or Broadly Laser Material Processing is carried out using the energy of coherent protons which is converted into thermal energy on interacting with materials. When the laser beam is focused on the surface of work piece, heat is generated and as a result, the material vaporizes instantly, producing Kerfs on the workpiece.

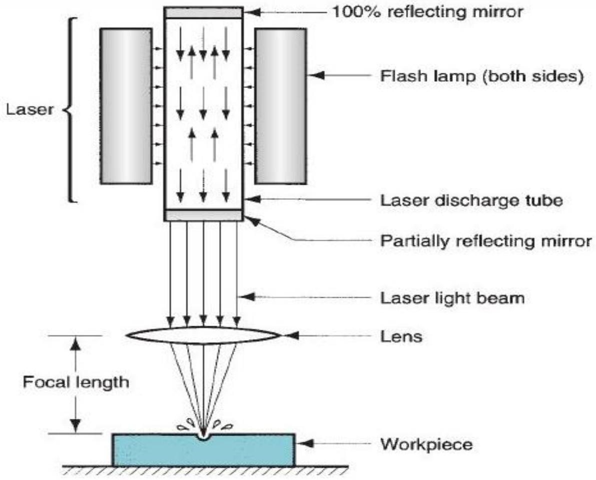

Figure 6. Laser Beam Machining

As there is no direct contact between the tool & work piece, no reactive forces are induced. LBM is used in machining of materials, such as metals, ceramics, composite and glasses etc… Micro LBM is an advanced machining process. It is capable of generating light pulses that last only a few femto seconds. These ultra fast pulses of light interact with materials on a different time scale. Miniature features (1 µm – 999 µm dimension) in sheet metals can be produced by micro LBM. Micro LBM finds its applications in several manufacturing industries like thin-film scribing, MEMS and inkjet printer head etc…

2.4.Electron Beam Machining (EBM)

EBM is a thermal process, where a steam of high speed electrons strikes the work surface producing intense heating and raises the temperature up to 5000˚C. This heating can melt and vaporize any material. During EBM, very high velocities (228,478 Km/Sec) can be obtained by using voltage of 1,50,000 V and the power density can go as far as 6500 billion W/Sq.mm which is sufficient enough to vaporize any material. Generally EBM is done in high Vacuum chamber but recent developments have made it possible to machine even outside the chamber. Another EBM technique is Electron Beam Melting which has the combined effect of simultaneously reducing the cost, weight and time. In Electron Beam Melting, fully dense parts with properties equal to wrought materials are built layer-by-layer. After melting & solidification of one layer, the process is repeated till the part is completed.

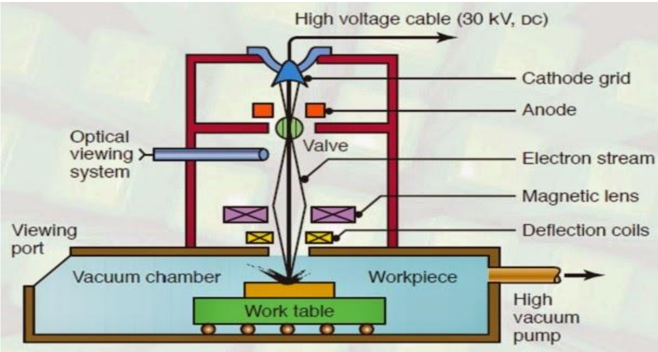

Figure 7. Electron Beam Machining

2.5. Plasma Arc Machining (PAM)

PAM is a thermal process that uses a jet of high temperature plasma gas to melt the work material. The plasma arc is produced by plasma torch. In this process, an inert gas is blown at high speed out of nozzle and an electric arc is generated in the gas from nozzle to the surface of workpiece. This plasma is sufficiently hot to melt the workpiece. Temperature in the plasma zone ranges from 11,000˚C – 28,000˚C. The variant PAM processes are plasma arc gouging, plasma arc cutting, plasma arc surfacing and plasma arc welding. The main advantage of Pam is that it uniformly affects the work material irrespective of its refractory nature.

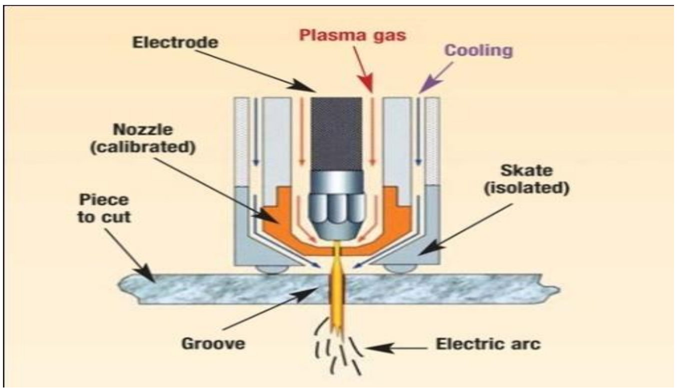

Figure 8. Plasma Arc Machining

2.6. Ion Beam Machining (IBM)

IBM also known as Ion etching or sputtering is carried out in vacuum using charged ions from a ion source directed towards the work piece by means of an accelerated voltage to remove or modify the atoms in the workpiece by means of an accelerated voltage. Metal removal rate depends on the binding energy of the atoms in work piece. For the removal of atoms, energy greater than binding energy (5-10 electron volt) is required. In IBM machining of small dimensions of order 10 – 100 nm is possible and a smooth surface finish of less than 1 µm can be obtained. IBM is used for texturing surface and for modifying the thickness of thin members.

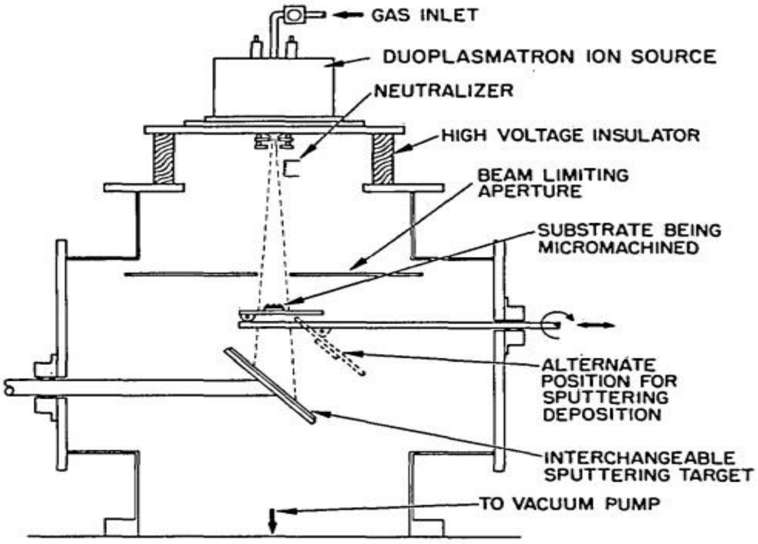

Figure 9. Ion Beam Machining

III. CHEMICAL METHODS OF UNCONVENTIONALPROCESSES

3.1.Electro Chemical Machining (ECM)

Electrochemical Machining (ECM) is an unconventional machining process is used to machine the material, which cannot be machined in conventional processes. Electrochemical Machining is the reverse processes of electrochemical coating. In ECM the work piece acts as the anode and tool act as cathode, both immersed into electrolyte and placed closely with a gap of about 0.5 mm. If potential difference is applied between the work piece and the tool, the positive ions move towards the tool and negative ions move towards the work piece. Fig.10 shows the schematic diagram of electrochemical machining Tool feed rate, electrolyte flow rate, and applied voltage are the important processes parameters in electrochemical machining. These parameters influences dimensional accuracy, tool life, material removal rate (MRR) and surface roughness (Ra)

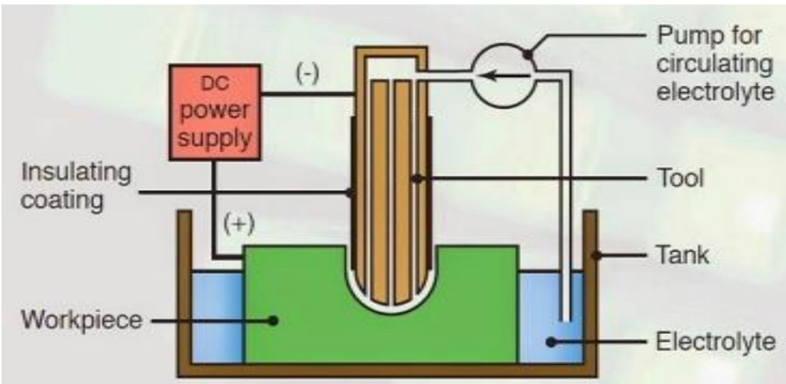

Figure 10. Electro Chemical Machining

IV. COMPARATIVE ANALYSIS OF UNCONVENTIONAL MANUFACTURING PROCESSES

An analysis of the various unconventional manufacturing processes are listed with compared each other, So that a guide-line may be drawn to find the suitability of application of different processes. One type of manufacturing process may be suitable under the given conditions and may not be under other conditions. Therefore, a careful selection of the process for a given manufacturing problem is essential. The analysis made from the point of ; Physical parameters of the processes, Machining capability ,Applicability of different processes to various types of material and Operational characteristics which are listed in the below tables

Table 1 Physical parameters of the Non-Conventional Processes

Parameters	USM	AJM	ECM	EDM	EBM	LBM	PAM
Potential(v)	220	220	10	45	150000	4500	100
Current (Amp)	12 (A.C)	1.0	1000 (D.C)	50 (Pulsed D.C)	0.001 (Pulsed D.C)	2 (Average 200 Peak)	500 (D.C)
Power(W)	2400	220	100000	2700	150	-	50000
Gap(m.m)	0.25	0.75	0.20	0.025	100	150	7.5
Medium	Abrasive in water	Abrasive in gas	Electrolyte	Liquid dielectric	Vacuum	Air	Argon or Hydrogen

Applicability to Materials- Materials applications of the various machining methods are summarized in the table 2 and table 3. For the machining of non conductive materials, both ECM and EDM are unsuitable. In this case mechanical methods can be used for the desired result.

Table 2 Applicability to materials

Metals Alloys					
Process	Aluminium	Steel	Super alloy	Titanium	Refractory Material
USM	Poor	Fair	Poor	Fair	Good
AJM	Fair	Fair	Good	Fair	Good
ECM	Fair	Good	Good	Fair	Fair
EDM	Fair	Good	Good	Good	Good
EBM	Fair	Fair	Fair	Fair	Good
LBM	Fair	Fair	Fair	Fair	Poor
PAM	Good	Good	Good	Fair	Poor

Refractory materials can be machined using Ultrasonic machining, while AJM are used for super alloy materials.

Table 3 Applicability to non - metals

Process	Non -Metals		
	Ceramics	Plastic	Glass
USM	Good	Fair	Good
AJM	Good	Fair	Good
ECM	-	-	-
EDM	-	-	-
EBM	Good	Fair	Fair
LBM	Good	Fair	Fair
PAM	-	Poor	-

Machining Characteristics of various unconventional machining processes are analyzed with respect to metal removal rate, tolerance, surface roughness, depth of surface damage and power required in machining

The process capabilities of non – conventional manufacturing process have been compared in the table 4. Power requirement of ECM and PAM is also very high when compared with other unconventional machining processes. This involves higher capital cost for those processes. Electro chemical machining has comparatively low tool wear rate, but in this process electrolyte creates the corrosion of machine parts. The surface roughness obtained by various processes are good, except Plasma Arc Machining.

Table 4 Machining Characteristics

Process	MRR mm^3/ min	Tolerance µ	Surface roughness µ	Depth of surface damage µ	Power watts
USM	300	7.5	0.2-0.5	25	2400
AJM	0.8	50	0.5-1.2	2.5	250
ECM	15000	50	0.1-2.5	5.0	100000
EDM	800	15	0.2-1.2	125	2700
EBM	1.6	25	0.5-2.5	250	1100
LBM	0.1	25	0.5-2.5	125	2
PAM	75000	125	Rough	500	50000

V. CONCLUSION

In this paper, the effective process parameters like MRR, surface roughness, type of dielectric are analyzed. These unconventional methods find vast application in aerospace, bio-medical, automobile & micro-electronic industries. It is concluded that the performance of the above discussed unconventional approaches has the potential for optimization of process parameters and proved to be an alternative to the conventional methods for a wide range of applications.

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