

Comparative Analysis of Non-Traditional Machining Processes

A particular Non-Traditional Machining Process (NTMP) found suitable under the given conditions may not be equally efficient under other conditions. Therefore, a careful selection of the process for a given machining problem is essential. The analysis of NTMPs can be made from the point of view of the following (Singh 2007):

- a) Physical parameters involved in the processes.
- b) Capability of machining different shapes of work material.
- c) Applicability of different processes to various types of materials, e.g. metals, alloys, and non-metals.
- d) Operational characteristics of NTMPs, and Economics involved in the various processes.

Physical Parameters

The physical parameters of NTMPs have a direct impact on the metal removal as well as on the energy consumed in different processes and it is shown in Table

Capability to Shape

The capability of different processes can be analysed on the basis of various machining operation point of view such as micro-drilling, drilling, cavity sinking, pocketing (shallow and deep), contouring a surface, and through cutting (shallow and deep). The shape application of various NTMPs is shown in Table.

For micro-drilling operation, the only process which has good capability to drill is LBM, whereas for drilling shapes having slenderness ratio, $L/D < 20$, the process USM, ECM, and EDM will be most suitable. EDM and ECM processes have good capacity to make pocketing operation (shallow and deep). For surface contouring operation, ECM is most suitable but other processes except EDM have no application for this operation.

Table Classification of NTMPs (Singh 2007)

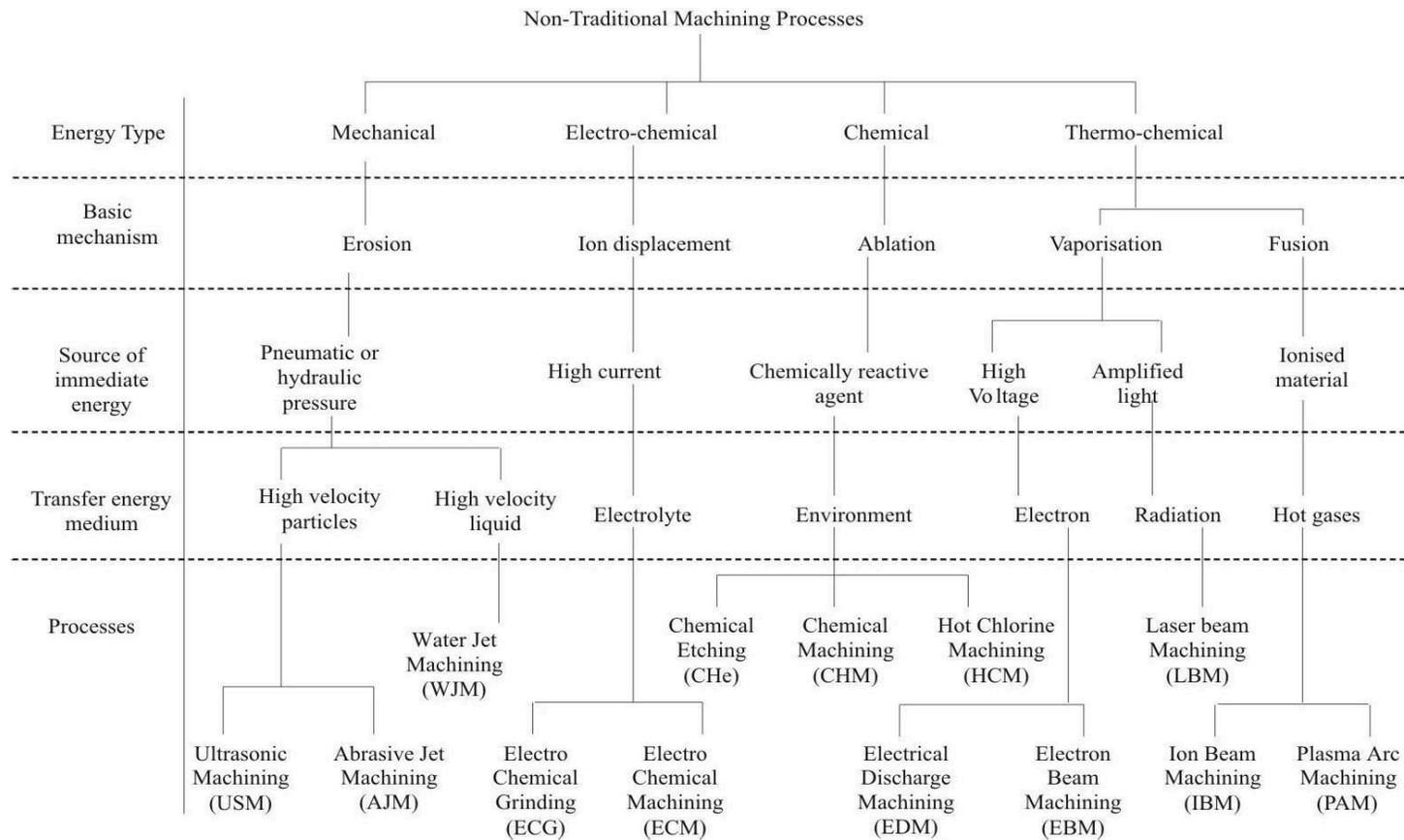


Table Physical parameters of NTMPs (Singh 2007)

Parameters	USM	AJM	ECM	CHM	EDM	EBM	LBM	PAM
Potential (V)	220	220	10	-	45	1,50,000	4,500	100
Current (Amp)	12 (AC)	1.0	10,000 (D.C)	-	50 (Pulsed D.C)	0.001 (Pulsed D.C)	2 (Average) 200 (Peak)	500 (D.C)
Power (W)	2,400	220	1,00,000	-	2,700	150	-	50,000
Gap (mm)	0.25	0.75	0.20	-	0.025	100	150	7.5
Medium	Abrasive in water	Abrasive in gas	Electrolyte	Liquid chemical	Liquid dielectric	Vacuum	Air	Argon or Hydrogen

Table Shape Application of NTMPs (Mishra 1997)

Process	Holes				Through cavities		Surfacing		Through cutting	
	Precision small holes		Standard		Precision	Standard	Double contouring	Surface of revolution	Shallow	Deep
	Dia <.025 mm	Dia >.025 mm	L/D <20	L/D >20						
USM	-	-	good	poor	good	good	poor	-	poor	-
AJM	-	-	fair	poor	poor	fair	-	-	good	-
ECM	-	-	good	good	fair	good	good	fair	good	good
CHM	fair	fair	-	-	poor	fair	-	-	good	-
EDM	-	-	good	fair	good	good	fair	-	poor	-
EBM	good	good	fair	poor	poor	poor	-	-	-	-
LBM	good	good	fair	poor	poor	poor	-	-	good	fair
PAM	-	-	fair	-	poor	poor	-	poor	good	good

Table Material Applications for Metals and Alloys (Cogun 1994)

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
CHM	good	good	fair	fair	poor
EDM	fair	good	good	good	good
EBM	fair	fair	fair	fair	good
LBM	fair	fair	fair	fair	poor
PAM	good	good	good	fair	poor

Table Material Applications for Non-metals (Cogun 1994)

Process	Ceramics	Plastic	Glass
USM	good	fair	good
AJM	good	fair	good
ECM	NA	NA	NA
CHM	poor	poor	fair
EDM	NA	NA	NA
EBM	good	fair	fair
LBM	good	fair	fair
PAM	NA	NA	NA

NA – Not Applicable

Machining Characteristics

The machining characteristics of different NTMPs can be analysed with respect to:

- a) Metal removal rate(MRR),
- b) Tolerance maintained,
- c) Surface finish obtained,
- d) Depth of surface damage, and
- e) Power required for machining.

The metal removal rates by ECM and PAM are respectively one- fourth and 1.25 times that of conventional rates whereas others are only a small fraction of it. Power requirement of ECM and PAM is also very high when compared with other NTMPs. The surface finish and tolerance obtained by various NTMPs except that of PAM is satisfactory. The process capabilities of various NTMPs are summarized in Table (ElHofy 2005).

Table Process Capabilities of NTMPs (El Hofy 2005)

Process	MRR (mm³/min)	Tolerance (μm)	Surface finish (μm)	Depth of surface damage (μm)	Power (watts)
USM	300	7.5	0.2 – 0.5	25	2,400
AJM	0.8	50	0.5 – 1.2	2.5	250
ECM	15,000	50	0.1 – 2.5	5.0	1,00,000
CHM	15	50	0.5 – 2.5	50	-
EDM	800	15	0.2 – 1.2	125	2,700
EBM	1.6	25	0.5 – 2.5	250	150(average) 2,000 (peak)
LBM	0.1	25	0.5 – 1.2	125	2 (average)
PAM	75,000	125	Rough	500	50,000

Economics of the Non-Traditional Machining Processes

The economics of the various NTMPs are analyzed on the basis of the following factors and is given in Table 2.7:

- a) Capital cost,
- b) Tooling cost,
- c) Power consumption cost,
- d) Material removal rate efficiency, and
- e) Tool wear.

Table Economics of the various NTMPs (Yurdakul et al 2003)

Process	Capital cost	Tooling cost	Power consumption cost	Material removal rate efficiency	Tool wear
USM	low	low	low	high	medium
AJM	very low	low	low	high	low
ECM	very high	medium	medium	low	very low
CHM	medium	low	high*	medium	very low
EDM	medium	high	low	high	high
EBM	high	low	low	very high	very low
LBM	low	low	very low	very high	very low
PAM	very low	low	very low	very low	very low

* indicates cost of chemicals

The capital cost of ECM is very high, whereas capital costs for AJM and PAM are comparatively low. EDM has got higher tooling cost than other machining processes. Power consumption is very low for PAM and LBM processes, whereas it is greater in the case of ECM. The material removal rate efficiency is very high for EBM and LBM than for other processes. In conclusion, the suitability of application of any of the processes is dependent on various factors and must be considered, all or some of

them, before selecting any NTMPs.

Overview Of Non-Traditional And Hybrid Non-Traditional Machining Processes

Non-Traditional Machining Processes (NTMPs) are defined as a group of processes that remove excess material by various techniques involving mechanical, thermal, electrical or chemical energy, or combinations of these energies but do not use sharp cutting tools as it needs to be used for traditional machining processes (Bhattacharya 1973). Extremely hard and brittle materials are difficult to machine by traditional machining processes such as turning, drilling, shaping, and milling. NTMPs are employed where traditional machining processes are not feasible, satisfactory, or economical due to special reasons as outlined below (Kalpakjian et al 2006):

- a) Machinability of work piece material,
- b) Workpiece shape complexity,
- c) Automation of data communication,
- d) Surface integrity and precision requirements, and
- e) Miniaturization requirements.

The various techniques may be conveniently classified according to the appearance of the applied energy, as shown in Figure 2.1 (Snoeys et al 1986).

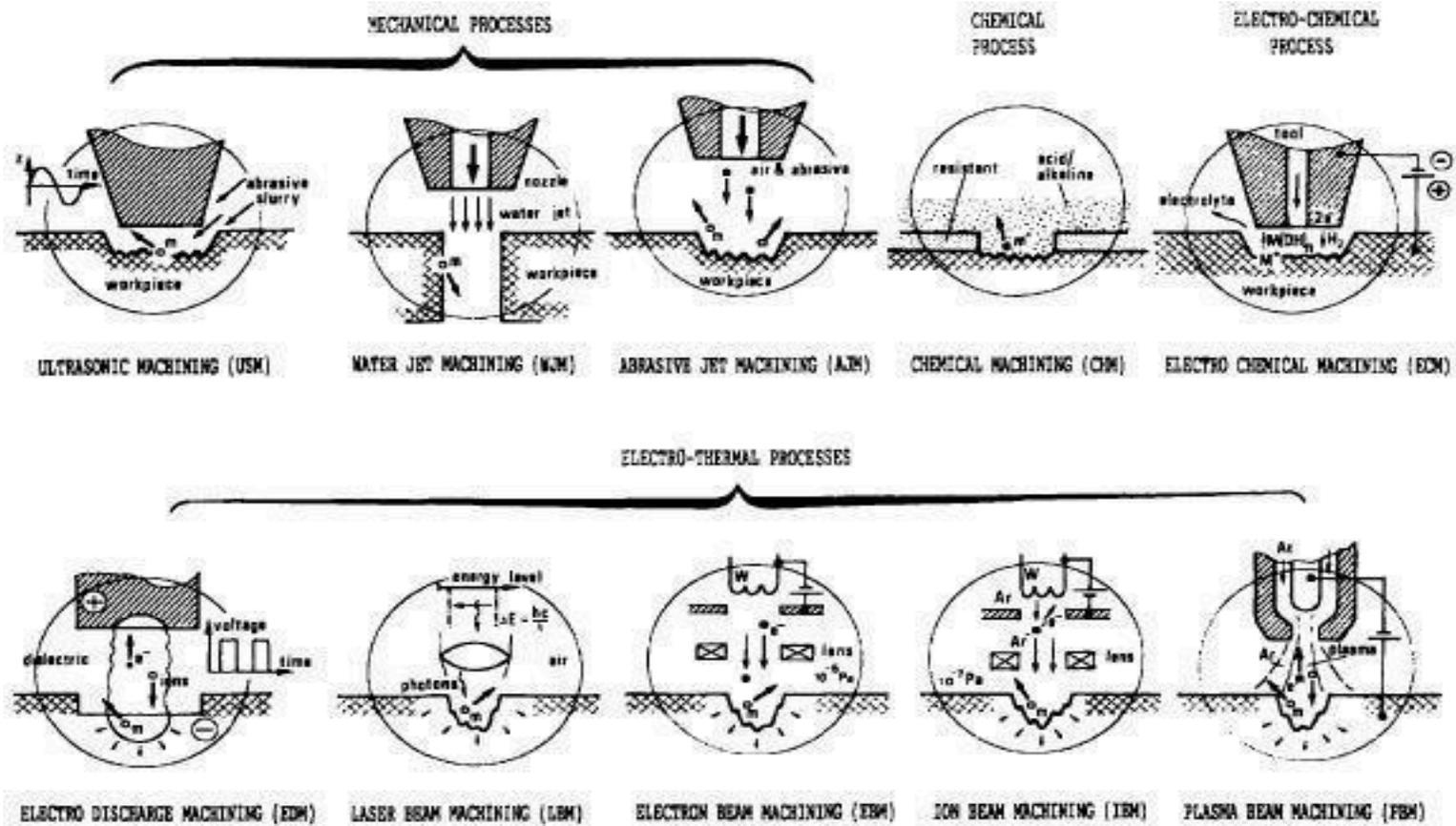


Figure Models of various NTMPs (Snoeys et al 1986)

Machinability

In modern manufacturing practice a more frequent use of harder, tougher or stronger workpiece materials is noticed: Materials, in other words, which are much more difficult to machine with traditional methods. Reference is made to all kinds of high strength thermal resistant alloys, to various kinds of carbides; fiber reinforced composite materials, stellites, ceramic materials, various modern composite tool materials etc. The introduction of new ways of machining is stimulated because of the high force levels observed. In some particular cases, those levels may simply not be sustained by the workpiece. Therefore, more attention is directed towards machining processes in which mechanical properties of the workpiece (mechanical strength, hardness, toughness etc.) are not imposing any limits. In electro-physical processes the „cutability“ limits are indeed more associated with material properties such as thermal conductivity, melting temperature, electrical resistivity, and atomic valence (Snoeys et al1986).

Shape Complexity

Geometrical restrictions, design requirements, problems related to accessibility during machining or what could be conveniently defined as 'shape complexity', states another group of reasons for an increased interest in using one of the more recent material removal processes. To give a rather simple example: it is quite easy to drill a circular hole with conventional techniques, however, to drill a square hole or just any other shape would be impossible. For EDM or ECM on the contrary, the cross sectional shape of the hole is of little concern. To cut some pattern of grooves with a depth of a few microns would be a difficult task in conventional machining. A CHM operation using some kind of masking procedure could yield a simple solution (Snoeys et al1986).

Automated Data Transmission

In mechanical production, the automation of communication is crucial. If the information flow is more automated, a considerable reduction of the throughput time can be achieved, yielding decreased production cost, reduced inventory etc. This aspect has been one of the reasons of the considerable success of the introduction of Numerically Controlled (NC) machines and later of Computer Aided Design (CAD), Computer Aided Manufacturing (CAM), and Computer Integrated Manufacturing (CIM). Those techniques may in some cases be integrated much easier with some NTMPs. EDM and Wire Electric Discharge Machining (WEDM) are obvious examples. Also NC Laser or electron beam cutting are applied partially because of the improved automation in data transmission. There are many other types of applications in which the use of NTMPs drastically reduced the number of successive elementary machine jobs. A die plate made of carbides for example, could be machined out of one piece using spark erosion; the classical way would require at least two pieces fitted together and produced separately on a profile grinder (Snoeys et al1986).

Precision Requirements

The trend of precision requirement as indicated by Taniguchi (1983) refers to nano-machining in tomorrow's ultra-high precision machining. This kind of precision may be obtained by removing atoms or molecules, rather than chips. Machining operations like sputtering IBM etc. would be possible candidates. The distortion of the surface layer due to mechanical or thermal action may be another reason to call upon some of the same NTMPs.

Miniaturisation

Trends toward reducing the workpiece dimensions already exist for some time. Ultra small diameter holes (10 – 100 μm) would not be possible to drill with conventional techniques. EDM, LBM, EBM or even Micro Electro chemical Machining (Micro-ECM) techniques are now frequently applied for such purposes. Micromachining has recently become an important issue, further reducing possible attainable workpiece dimensions. Various techniques developed for the production of micro electronic circuitry may be used for manufacturing extremely small items. Especially in the area of sensors, an integration of mechanical parts with the electronic circuitry may become a new possibility bringing the design and production of various sensors on the verge of drastic cost reductions. Several types of NTMPs have been developed to meet a wide range of machining requirements. When these processes are employed properly, they offer many advantages over traditional machining processes. The most common NTMPs and selected Hybrid NTMPs (HNTMPs) are described in this section (Snoeys et al 1986). The Surface Roughness and Tolerance of various machining processes are shown in Fig respectively.

