# 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)

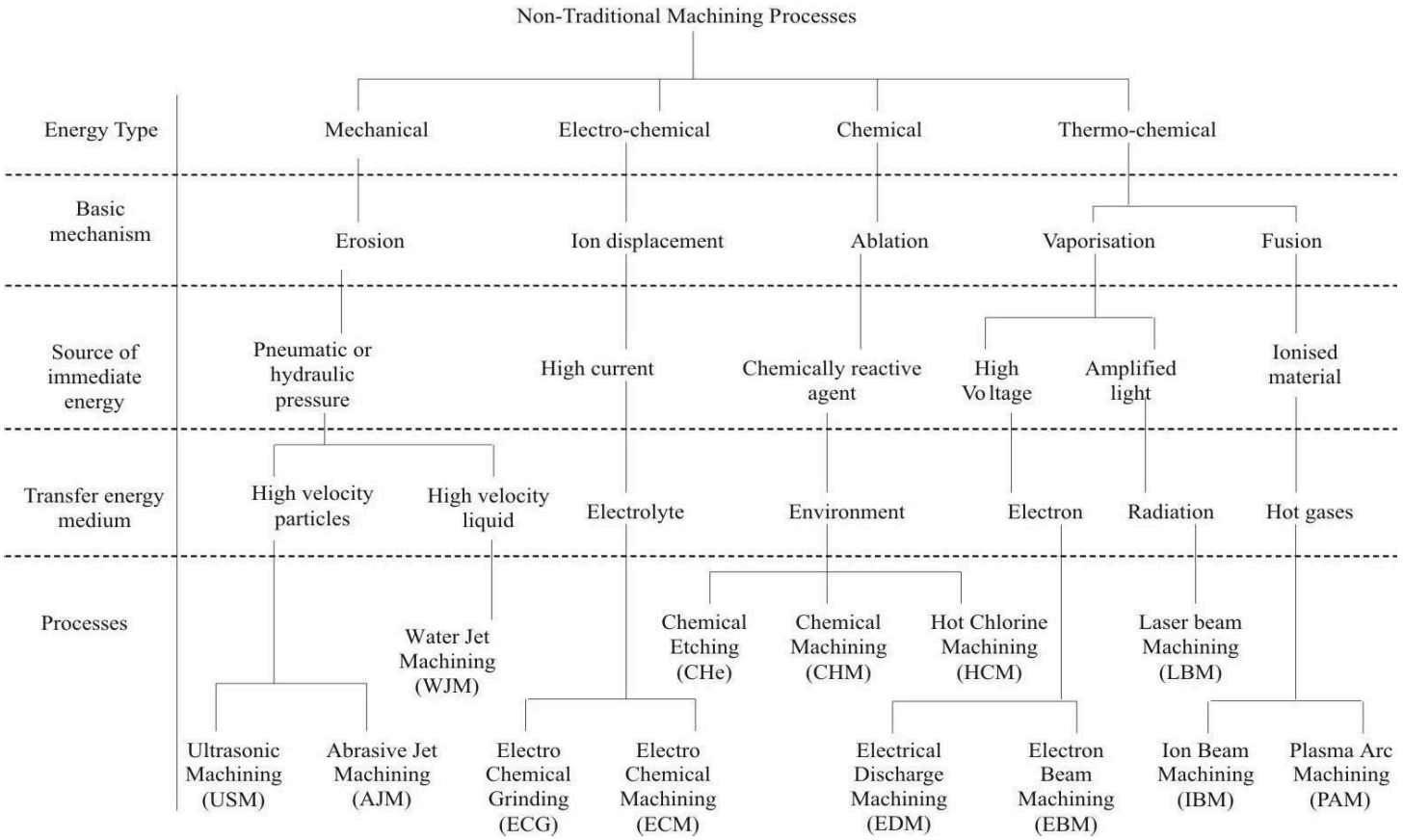


**Table Physical parameters of NTMPs (Singh 2007)**

| 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)**

| | Holes | | | | Through cavities | | Surfacing | | Through cutting | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Process** | **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 ($mm^3$/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 al2006):

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).

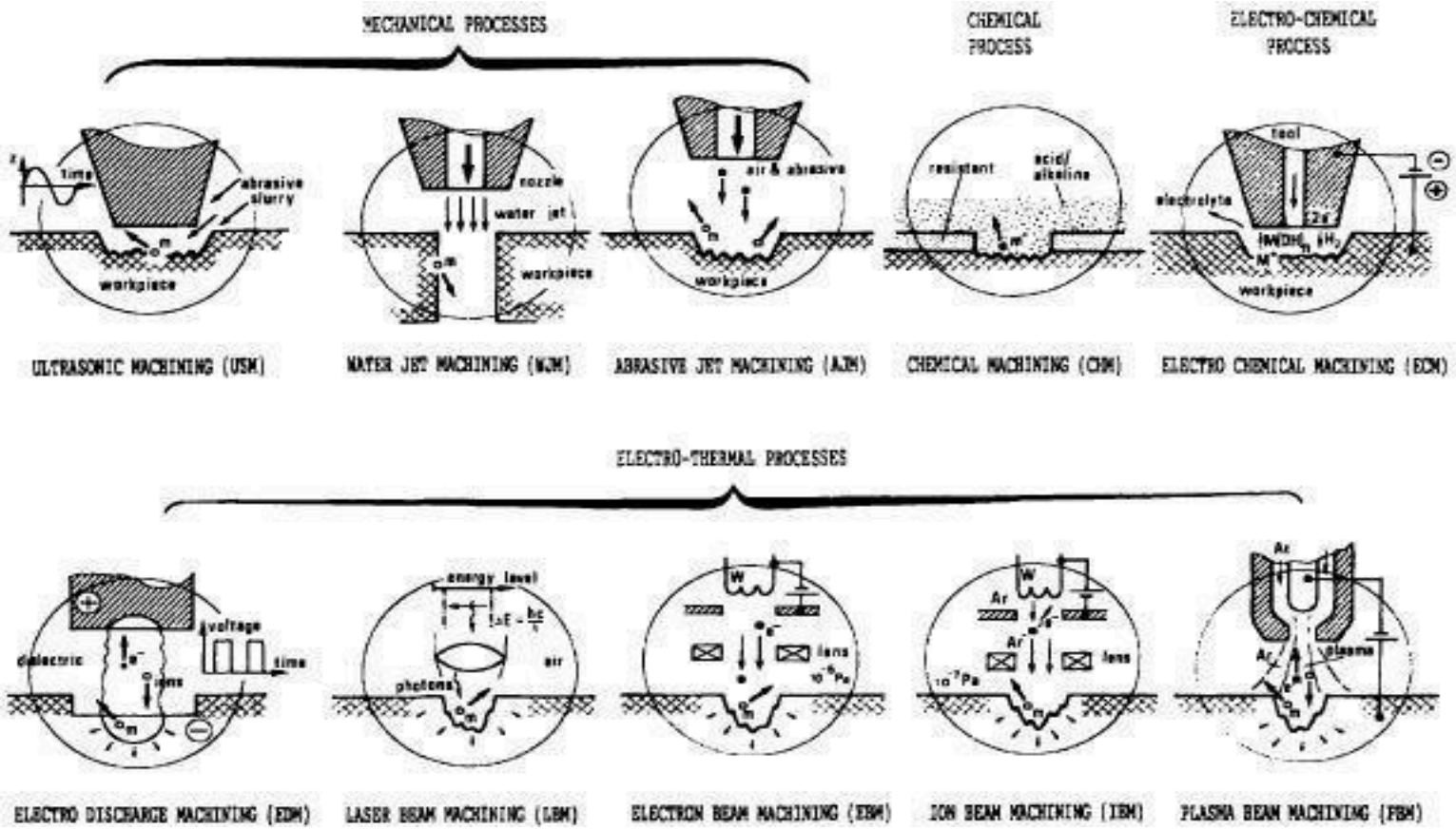



Figure Models of various NTMPs (Snoeys et al 1986)

## 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.