INTRODUCTION TO NTM

Types of Manufacturing Processes:

Manufacturing processes can be broadly divided into two groups
- Primary manufacturing processes
- Secondary manufacturing processes.

The Primary manufacturing process provides basic shape and size to the material as per designer’s requirement. For example: Casting, forming, powder metallurgy processes provide the basic shape and size.

The Secondary manufacturing processes provide the final shape and size with tighter control on dimension, surface characteristics etc. Most of Material removal processes are mainly the secondary manufacturing processes.

Material removal processes can be further divided into mainly two groups
- Conventional Machining Processes
- Non-Traditional Manufacturing Processes

Examples of conventional machining processes are turning, boring, milling, shaping, broaching, slotting, grinding etc.

Examples of non conventional (or also called non traditional or unconventional)are Abrasive Jet Machining (AJM), Ultrasonic Machining (USM), Water Jet and Abrasive Water Jet Machining (WJM and AWJM), Electro-discharge Machining (EDM), Electro chemical machining.

Characteristics of Conventional Processes

Conventional machining processes mostly remove material in form of chips by applying forces on work material with a cutting tool which is harder than the work material. Such forces induce plastic deformation within the workpiece leading to shear deformation along the shear plane. Figure 1.0 shows chip formation by shear deformation in conventional machining.

Major characteristics of conventional machining are:
- Generally chips are macroscopic and are formed by shear deformation
- Material removal takes place due to application of cutting forces – energy domain can be classified as mechanical
- Cutting tool must be harder than work piece at room temperature as well as under machining conditions
- There is a direct physical contact between tool and work
- Material removal rate of the traditional processes is limited by the mechanical properties of the work material.
Non Traditional Machining (NTM) Processes are characterized as follows:

- Material removal may occur with chip formation or even no chip formation may take place. For example in AJM, chips are of microscopic size and in case of Electrochemical machining material removal occurs due to electrochemical dissolution at atomic level.
- In NTM, there may not be a physical tool present. For example in laser jet machining, machining is carried out by laser beam. However, in Electrochemical Machining there is a physical tool that is very much required for machining.
- In NTM, the tool need not be harder than the work piece material. For example, in EDM, copper is used as the tool material to machine hardened steels.
- Mostly NTM processes do not necessarily use mechanical energy to provide material removal. They use different energy domains to provide machining. For example, in USM, AJM, WJM mechanical energy is used to machine material, whereas in ECM electrochemical dissolution constitutes material removal.

Need for development of Non Conventional Processes

The strength of steel alloys has increased five folds due to continuous R and D effort. In aero-space requirement of High strength at elevated temperature with light weight led to development and use of hard titanium alloys, nimonic alloys, and other HSTR alloys. The ultimate tensile strength has been improved by as much as 20 times. Development of cutting tools which has hardness of 80 to 85 HRC which cannot be machined economically in conventional methods led to development of non –traditional machining methods.

1. Technologically advanced industries like aerospace, nuclear power, wafer fabrication, automobiles has ever increasing use of High –strength temperature resistant (HSTR) alloys (having high strength to weight ratio) and other difficult to machine materials like titanium, SST, nimonics, ceramics and semiconductors. It is no longer possible to use conventional process to machine these alloys.

2. Production and processing parts of complicated shapes (in HSTR and other hard to machine alloys) is difficult, time consuming an uneconomical by conventional methods of machining.

3. Innovative geometric design of products and components made of new exotic materials with desired tolerance, surface finish cannot be produced economically by conventional machining.

4. The following examples are provided where NTM processes are preferred over the conventional machining process:
   - Intricate shaped blind hole – e.g. square hole of 15 mmx15 mm with a depth of 30 mm with a tolerance of ± 100 microns
   - Difficult to machine material – e.g. Inconel, Ti-alloys or carbides, Ceramics, composites, HSTR alloys, satellites etc.,
   - Low Stress Grinding – Electrochemical Grinding is preferred as compared to conventional grinding
   - Deep hole with small hole diameter – e.g. φ 1.5 mm hole with l/d = 20
   - Machining of composites
## Differences between Conventional and Non conventional machining processes.

<table>
<thead>
<tr>
<th>Sl No.</th>
<th>Conventional Process</th>
<th>Non Conventional Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The cutting tool and work piece are always in physical contact with relative motion with each other, which results in friction and tool wear.</td>
<td>There is no physical contact between the tool and work piece, In some non traditional process tool wear exists.</td>
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<tr>
<td>2</td>
<td>Material removal rate is limited by mechanical properties of work material.</td>
<td>NTM can machine difficult to cut and hard to cut materials like titanium, ceramics, nimonics, SST, composites, semiconducting materials</td>
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<td>3</td>
<td>Relative motion between the tool and work is typically rotary or reciprocating. Thus the shape of work is limited to circular or flat shapes. In spite of CNC systems, production of 3D surfaces is still a difficult task.</td>
<td>Many NTM are capable of producing complex 3D shapes and cavities</td>
</tr>
<tr>
<td>4</td>
<td>Machining of small cavities, slits, blind holes or through holes are difficult</td>
<td>Machining of small cavities, slits and Production of non-circular, micro sized, large aspect ratio, shall entry angle holes are easy using NTM</td>
</tr>
<tr>
<td>5</td>
<td>Use relative simple and inexpensive machinery and readily available cutting tools</td>
<td>Non traditional processes requires expensive tools and equipment as well as skilled labour, which increase the production cost significantly</td>
</tr>
<tr>
<td>6</td>
<td>Capital cost and maintenance cost is low</td>
<td>Capital cost and maintenance cost is high</td>
</tr>
<tr>
<td>7</td>
<td>Traditional processes are well established and physics of process is well understood</td>
<td>Mechanics of Material removal of Some of NTM process are still under research</td>
</tr>
<tr>
<td>8</td>
<td>Conventional process mostly uses mechanical energy</td>
<td>Most NTM uses energy in direct form For example : laser, Electron beam in its direct forms are used in LBM and EBM respectively.</td>
</tr>
<tr>
<td>9</td>
<td>Surface finish and tolerances are limited by machining inaccuracies</td>
<td>High surface finish (up to 0.1 micron) and tolerances (25 Microns) can be achieved</td>
</tr>
<tr>
<td>10</td>
<td>High metal removal rate.</td>
<td>Low material removal rate.</td>
</tr>
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</table>
**Definition:**
A machining process is called *non-traditional* if its material removal mechanism is basically different than those in the traditional processes, i.e. a different form of energy (other than the excessive forces exercised by a tool, which is in physical contact with the work piece) is applied to remove the excess material from the work surface, or to separate the workpiece into smaller parts.

**Applications**
Some of the applications of NTM are given below:
Classification of Non Traditional processes:

Advanced machining process can be classified according to the fundamental energy employed.

### ABREVIATIONS USED:
1. AJM - Abrasive Jet Machining  
2. USM - Ultrasonic Machining  
3. WJM - Water Jet Machining  
4. AWJM - Abrasive Water Jet Machining  
5. ECM - Electro Chemical Machining  
6. ECG - Electro Chemical Grinding  
7. EJD - Electro Jet Drilling  
8. EDM - Electro Discharge Machining  
9. LJM - Laser Jet Machining  
10. EBM - Electron beam Machining  
11. PAM - Plasma Arc Machining  
12. CHM - Chemical Milling  
13. PCM - Photo Chemical Milling

History of Non Traditional processes:

Although, the non conventional machining processes have created a revolution in the field of machining technology by the development of idea of various processes were initiated as early as in nineteen- twenties in USSR.

1920 The initiation was first made by Gussev towards the end of 1920 in USSR. He suggested a method of machining by combination of Chemical and mechanical means. His work is basis for all Electro Chemical processes known today.
1941  Burgess, American Scientist had demonstrated the possibility of ECM process by drawing a sharp contrast between the mechanical and electrolyte methods in metal removal

1942  The idea of Ultrasonic machining was invented by Balamuth at the He invented at the time of investigation of dispersion of solids in Liquids with the help of a vibrating magneto-strictive nickel tube However, the origination of the process was made by Rosenberg

1943  DM was developed by B R Lazarenko and N I Lazarenko in USSR. They first developed the idea of spark erosion machining. In the early nineteen-sixties, the idea of Ultrasonic machining began to to develop widely in USSR and basis of this development was laid on extensive investigation that took place in the mechanism of ultrasonic machining and in the design of Magneto-strictive transducers, converters and wave guides.

1950  The basis of laser machining was established by the process which Which were developed by Basov, Prokhorov and Fabrikanth in USSR in 1950.

1950  Electro chemical Grinding has practically been developed in about 1950.

1960  The concept of whirling jet machining was innovated.

Many of these new techniques of machining have been developed in last few decades to meet the challenges put forward by rapid development of hard to machine and high strength temperature resistant (HSTR) alloys. It is anticipated that in near future, these new technologies will find an ever increasing application in all branches of mechanical engineering industry.

**SELECTION OF PROCESS:**
The correct selection of the non-traditional machining methods must be based on the following aspects.

i) Physical parameters of the process
ii) Shape to be machined
iii) Process capability
iv) Economics of the processes

**Physical parameter of the process:**
The physical parameters of the different NTM are given in the Table 1.0 which indicates that PAM and ECM require high power for fast machining. EBM and LBM require high voltages and require careful handling of equipment. EDM and USM require medium power. EBM can be used in vacuum and PAM uses oxygen and hydrogen gas.
Table 1.0 Physical parameter of the process:

<table>
<thead>
<tr>
<th>Parameters</th>
<th>USM</th>
<th>AJM</th>
<th>CHM</th>
<th>ECM</th>
<th>EDM</th>
<th>EBM</th>
<th>LBM</th>
<th>PAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential (Volts)</td>
<td>220</td>
<td>220</td>
<td>-</td>
<td>10-30</td>
<td>100-300</td>
<td>150 kV</td>
<td>4.5 kV</td>
<td>100</td>
</tr>
<tr>
<td>Current (amps)</td>
<td>12</td>
<td>1</td>
<td>-</td>
<td>10000</td>
<td>50</td>
<td>0.001</td>
<td>2</td>
<td>500</td>
</tr>
<tr>
<td>Power (kW)</td>
<td>2.4</td>
<td>0.22</td>
<td>-</td>
<td>100</td>
<td>2.70</td>
<td>0.15</td>
<td>-</td>
<td>50</td>
</tr>
<tr>
<td>Gap (mm)</td>
<td>0.25</td>
<td>0.75</td>
<td>-</td>
<td>0.20</td>
<td>0.025</td>
<td>100</td>
<td>150</td>
<td>7.5</td>
</tr>
<tr>
<td>Medium</td>
<td>Abrasives in water</td>
<td>Abrasive in gas</td>
<td>Liquid chemical</td>
<td>Electrolyte</td>
<td>Dielectric oil</td>
<td>Vacuum</td>
<td>Air</td>
<td>Argon H_2/O_2</td>
</tr>
</tbody>
</table>

**SHAPES CUTTING CAPABLITY**

The different shapes can be machined by NTM. EBM and LBM are used for micro drilling and cutting. USM and EDM are useful for cavity sinking and standard hole drilling. ECM is useful for fine hole drilling and contour machining. PAM can be used for cutting and AJM is useful for shallow pocketing.

**PROCESS CAPABILITY**

The process capability of NTM is given in Table 2.0 EDM which achieves higher accuracy has the lowest specific power requirement. ECM can machine faster and has a low thermal surface damage depth. USM and AJM have very material removal rates combined with high tool wear and are used non metal cutting. LBM and EBM are, due to their high penetration depth can be used for micro drilling, sheet cutting and welding. CHM is used for manufacture of PCM and other shallow components.