

# Advance Manufacturing Processes Review Part I

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**Abstract**– The paper presents aspects regarding an innovative manufacturing technology. Many research works have been done in the field of Manufacturing techniques and advancements. However, there is always a scope for research in any particular field. Many research works have been put forward on the basis of optimising and upgrading the basic process and the process parameter. Manufacturing activities and advancements indicate a country's wealth at many times. It is defined as the utilization of enabling technologies, incorporating design and business process innovation in order to deliver high value-added processes and products in ways that are novel, recognized and competitive. In our day to day life the clothes we wear, the hooks, buttons, belts, shoes, etc are processed or manufactured articles. These manufacturing processes when further developed and integrated bring valuable revenue to the country and people, may be through exports or by any other means. The need for advanced manufacturing can be ascribed to the following: Limitations in the conventional methods, Rapid improvements in the material properties, High tolerance requirements, product requirements. The advancements in AMP include reverse engineering (RE), rapid prototyping (RP) and virtual reality (VR) techniques and so on, in modern product design is developed.

**Keywords**— advance manufacturing processes, AMP, nonconventional, technological, construction, innovative, industry

## 1. INTRODUCTION:

In this paper the non-traditional (non-conventional) machining processes which are important to understand by mechanical engineer is explained. Machining process removes certain parts of the work piece to change them to final product. The traditional processes of machining are turning, milling, drilling, grinding, broaching, etc. Traditional, also termed as conventional, machining requires the presence of a tool that is harder than the work piece to be machined. This tool should be penetrated in the work piece to a certain depth. Moreover, a relative motion between the tool and workpiece is responsible for forming or generating the required shape. The end of second world war brought a new revolution in the engineering industry. Advanced Manufacturing is basically the use of innovative technologies, such as automation, computation, software, sensing and networking, to create existing and new products. Many new materials were developed to fulfil the need of aircraft industry, missile technology, space research equipment and nuclear industry. These

materials like carbide, tungsten, ceramics, tantalum, beryllium, uranium, nitro-alloy etc. Are extremely hard and sometimes unmachinable by traditional machining processes. The traditional processes are not suitable for the machining in following cases:

1. Workpiece materials of greater hardness
2. New materials with high strength, heat resistance such as titanium alloys, manganese alloys, etc.
3. Complex and intricate shapes with high accuracy.

Also, these materials mentioned above, possess high strength to weight ratio, hardness and heat resisting qualities making it sometimes impossible for machining. When conventional methods are tried, it is difficult, time consuming and economical to machine the workpiece material. This adds to the fact that during conventional machining processes an increase in hardness of workpiece material results in decrease in economic cutting speed. This needed the development of improved cutting tool material. For such conditions, in spite of recent developments, traditional methods of machining are uneconomical, time consuming and degree of accuracy and surface finish are poor. The newer machine processes, so developed are often called 'Modern Machining Methods' or non-traditional machining processes or unconventional machining processes. These are unconventional in the sense that conventional tool is not utilized for cutting the material. It employs some form of energy like mechanical, chemical, thermal, electro-chemical etc. for cutting the material. Also, the absence of tool-workpiece contact or relative motion, makes the processes a non-traditional one.

## 2. DEFINITION OF NON-TRADITIONAL MACHINING PROCESS:

It is defined as a group of processes that removes excess material by various techniques involving mechanical, thermal, electrical or chemical energy or combination of these energies without use of sharp cutting tools which are required in traditional machining processes.

## 3. ADVANTAGES OF NON-TRADITIONAL MACHINING OVER CONVENTIONAL MACHINING PROCESSES:

1. Applicable to all materials: these methods are not affected by hardness, toughness and brittleness of work materials.

2. Intricate shape machining: it can produce complex-intricate shape on any workpiece material.
3. Extreme hard material machining: hard to machine materials like tungsten, uranium, tantalum can be machined.
4. No mechanical contact: material is removed without mechanical contact with the workpiece and tool.
5. Easy compatible: it can be combined with CNC and minicomputer controls for automation.
6. High accuracy: high accuracy to close tolerance is easily obtained in these methods.
7. Any material can be machined irrespective of its hardness.
8. Any compatible shape can be produced on the workpiece.
9. Very fine holes can be easily drilled.
10. The parts produced are burr-free.
11. No mechanical force is exerted on the workpiece, so fragile work piece can be machined.
12. Drilling of tapered holes is possible.
13. Through cutting of any material.

**4. CLASSIFICATION OF NON-TRADITIONAL MACHINING PROCESSES:**

- Type of energy used to shape materials.
- The basic mechanism of material removal.
- The source of energy for material removal.
- Medium of transfer of these energies.

**5. MACHINING PROCESSES:**

1. Mechanical Processes
  - Abrasive Jet Machining (AJM)
  - Ultrasonic Machining (USM)
  - Water Jet Machining (WJM)
  - Abrasive Machining (AWJM)
2. Chemical Processes:
  - Chemical Milling (CHM)
  - Photochemical Milling (PCM)
3. Electrochemical Processes:
  - Electrochemical Machining (ECM)
  - Electrochemical Grinding (ECG)
  - Electro Jet Drilling (EJD)
4. Thermal/Electrothermal Processes:
  - Electro Discharge Machining (EDM)
  - Laser Beam (LBM)
  - Plasma Arc (PAM)
  - Electron-Beam (EBM)
  - Ion-Beam (IBM)

**6. COMPARISON OF TRADITIONAL AND NON-TRADITIONAL MACHINING:**

Table no.1: Comparison of Traditional and Non-traditional machining

Sr. No.	Parameters	Traditional Machining Process	Non-Traditional Machining Process
1.	Tool geometry	It uses a cutting tool of fixed geometry.	It uses some sort of energy along with tool which does not have a fixed geometry.
2.	Tool hardness	Tool material should be harder than the metal to be cut.	Hardness of tool is independent of the material hardness.
3.	Cutting ability	Hard metals are difficult to cut and sometimes impossible.	Almost any known hard material can be cut.
4.	Complex profile	Difficult to produce complex shapes.	Complex profiles can easily be obtained.
5.	Metal removal rate	Metal removal rate is comparatively high.	Metal removal rate is comparatively low.
6.	Metal removal method	Metal is removed in the form of chips.	Metal is removed by melting, vaporization, electrochemical reaction etc.
7.	Tool force	Higher tool forces are required to cut harder material.	Tool force is independent of the material hardness.
8.	Application	Very minute cannot be produced.	Very fine or minute holes can be easily drilled.
9.	Example	Turning, Milling, Shaping, Drilling etc.	EDM, LBM, USM, EBM, PAM, ECM, etc.

## 7. NEED OF NON-TRADITIONAL MACHINING PROCESSES:

As the world is advancing forth technically in the field of space research, missiles and nuclear industry, very complicated and precise components are demanded by the above fields.

## 8. PRINCIPAL OF AJM:

The fundamental principal of this process involves the use of high-speed stream of abrasive particles carried by a high-pressure air/gas on the work surface through a nozzle. It is a process that removes material from a workpiece with the help of abrasive particles. The metal removal occurs due to erosion caused by the abrasive particles impacting the work surface at high speed. With repeated impact of abrasive, small bits of material get loosened and a fresh surface is exposed to the jet. The process differs from sand blasting is that in AJM the abrasive particles have much smaller diameter of about 0.025 mm. The process consists of mixture of fine abrasive particles and gas at high pressure. The material removal takes place because of chipping action. As the particle impacts the surface, it causes a small fracture of the work surface which results in removal of material. The gas stream carries both the abrasive particles and the fractured particles away. The abrasive particles carried by high pressure gas/air at a velocity of 200 to 400 m/sec and standoff distance between nozzle tip and workpiece is kept about 0.7 to 1.0 mm.

## 9. WORKING OF AJM:

The gas is supplied under pressure (2 to 8 kg/cm<sup>2</sup>) and after filter and regulator, it is passed to a mixing chamber containing abrasive particles vibrating at 50 c/sec. From the mixing chamber, the gas along with the abrasive particles of size 10-50 μm passes on to a nozzle having its tip of tungsten carbide and diameter of 0.45 mm, with a velocity of 150-300 m/sec. The relative motion between nozzle and workpiece is obtained by cams, pantographs to control the size and shape of cut. The nozzle tip distance is of order of 0.81 mm. The high velocity jet of abrasives impacts on the workpiece surface. It removes the material due to sharp edges hitting a brittle and fragile material. The chipped out or wear particles are carried away by the air or gas.

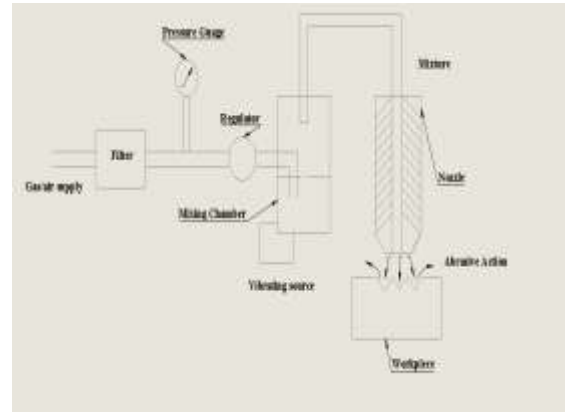


Figure 1: Setup for Abrasive Jet Machining

## 10. APPLICATIONS OF AJM:

1. Fine drilling and micro drilling.
2. Deburring, etching and cleaning of hard and brittle materials, alloys and non-metals.
3. Machining of semiconductor.

## 11. PRINCIPLE OF WATER JET MACHINING:

Water jet machining is based on a simple functional principle. Water hits the surface in a fine jet form of a workpiece at high speeds. Results in material removal and separates the material. To create the required high-pressure water jet, a pump which creates a high-pressure pump brings the water to pressure of up to several thousand bar and directs it to the cutting head. Depending on the material to be cut, the water can also be mixed with an abrasive. The jet diameter of 0.1 to 0.5 millimetres emerges from a fine nozzle opening at the cutting head. Depending on the nature of the water jet and hardness and thickness of the material, different cutting depths and speeds can be achieved.

## 12. WORKING OF WATER JET MACHINING:

1. Water from the reservoir is pumped to the intensifier using a hydraulic pump.
2. The intensifier increases the pressure of the water to the required level. Usually, the water is pressurized to 200 to 400 MPa.
3. Pressurized water is then sent to the accumulator. The accumulator temporarily stores the pressurized water.
4. Pressurized water then enters the nozzle by passing through the control valve and flow regulator.
5. Control valve controls the direction of water and limits the pressure of water under permissible limits.
6. Flow regulator regulates and controls the flow rate of water.

7. Pressurised water finally enters the nozzle. Here it expands with a tremendous increase in the kinetic energy. High velocity water jet is produced by the nozzle.
8. When this water jet strikes the workpiece, stresses are induced. These stresses are used to remove material from the workpiece.

The water used in the water jet machining may or may not be used with stabilizers. Stabilizers are substances that improve the quality of water jet by preventing its fragmentation.

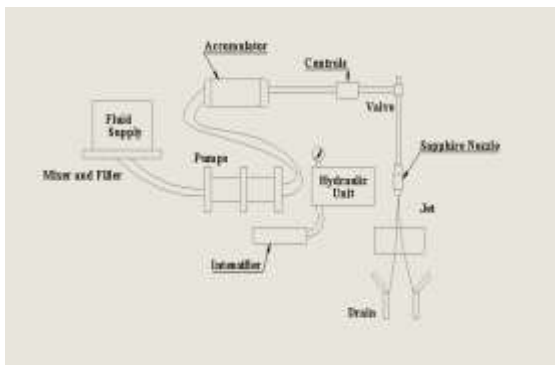


Figure 2: Setup for Water Jet Machining

### 13. APPLICATIONS OF WJM:

1. It is used for machining circuit boards.
2. It is used to cut rubber, wood, ceramics and many other soft materials.
3. Water jet machining is used to cut thin non-metallic sheets.

### 14. PRINCIPLE OF ELECTRO DISCHARGE MACHINING:

- EDM works on the principle that heat energy generated by a spark is used to remove material from the work piece.
- The tools and work piece are separated by a small gap called as spark gap. The gap varies from 0.01 mm to 0.5 mm. The tool and work piece both immersed in the dielectric fluid.
- When the supply is made 'ON', thousands of sparks are produced per second. The duration of each spark is very short.

When the spark comes in contact with the dielectric fluid in the spark gap, the fluid gets ionized. It allows current to flow between the tools and workpiece

### 15. WORKING OF EDM:

1. Tool Electrode and Workpiece:

The tool and work piece is kept in a reservoir and is connected to a DC power supply. The tool is connected to negative terminal, so that it becomes cathode, while work piece is connected to positive terminal and become

anode. Tool electrode has the shape basically same to that of the product desired with allowance for side clearance and over cut.

2. Dielectric fluid system:

The dielectric fluid is spark conductor, coolant and also flushing medium. The common dielectric fluids used are paraffin oil, transformer oil and kerosene. Dielectric fluid is stored in a tank and circulated through a pump with the help of nozzle at the gap between tool and workpiece. Dielectric is continuously flushed into the spark gap. The used dielectric is filtered and recirculated into the reservoir. The dielectric fluid is pumped at a pressure of 2 kg/cm<sup>2</sup> or less.

3. Electrical power supply and spark generator:

The D.C. power supply with current density in the range of 10,000 A/cm<sup>2</sup> and the power density of 500 mw/cm<sup>2</sup> is used. The voltage is about 40-450 volts is applied. Spark generator is the circuit consist of RC combination. The capacitor is continued to charge as long as the voltage in the capacitor reaches to the value of breakdown voltage. This circuit helps to produce spark between the gap of tool and workpiece. When the supply is made 'ON' the capacitor voltage starts rising continuously. When the capacitor voltage equals the breakdown voltage, (of dielectric fluid) a spark discharge will occur in the spark gap. The spark persists until the capacitor voltage falls below that which is required to maintain sparking. After the capacitor discharge, sparking ceases and the dielectric fluid in the spark gap gets deionized. The capacitor is then recharged and the cycle repeats itself. The time taken by the capacitor to recharge upto the breakdown voltage should be sufficient to allow the dielectric to ionize. Resistor R in the circuit prevents the charging of capacitor before the spark gap is ionized.

4. Tool feed mechanism/ Servo system:

A servo-controlled electrode feeding arrangement is provided which continuously senses the spark gap and moves the tool electrode to maintain the gap. The servo system advances the tool electrode according to the machining required. The tool feed control prevents.

- Too large gaps which may prevent the formation of spark.
- Short circuits which will damage both tool and the workpiece.

The servo system may work electromechanically or hydraulically (1). Since during operation both the tool and work piece are eroded, it is necessary to feed the tool continuously towards the workpiece so as maintain the spark gap. This can be achieved by a suitable tool feed control mechanism along with servo mechanism system (2).

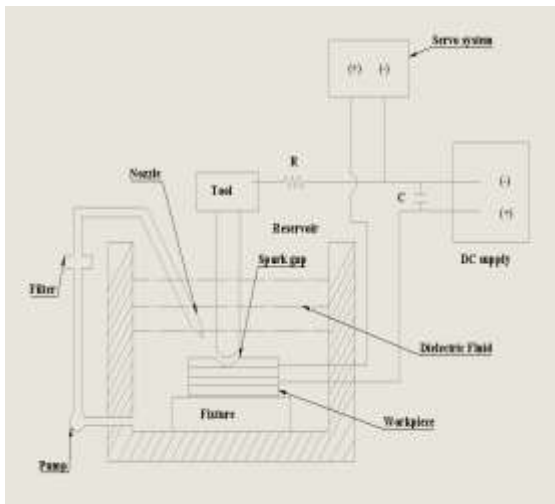


Figure 3: Setup for Electric Discharge Machining

### 16. APPLICATIONS OF EDM:

1. Machining dies for forging, blanking, extrusion etc.
2. Machining of hydraulic valve spools.
3. Internal threads, internal helical gears can be cut in hardened materials.

### 17. PRINCIPLE OF PLASMA ARC MACHINING:

When the high velocity jet of plasma is directed on the workpiece surface by means of a plasma arc cutting torch, the metal from the workpiece melts which results in to the machining of the workpiece. The continuous attack of electrons on the workpiece which transfer the heat energy of plasma on the workpiece causes the workpiece to melt. In this process, the material of the workpiece melts similar to gas flame cutting operation. The melting occurs due to :

- a. Convective heat transfer from high temperature plasma
- b. Direct electron bombardment of an electric arc

### 18. SET-UP AND WORKING OF THE PROCESS:

The setup of the process consists of:

- 1) Plasma cutting torch: a plasma cutting torch carries a tungsten electrode fitted in a small chamber. At other end of the torch is a small converging orifice called as nozzle. One side of the torch provides a passage for supply of gas into the torch.
- 2) Tool and workpiece: the electrode is connected to negative terminal of D.C. power supply and therefore acts as a cathode. The nozzle is made anode by connecting to the positive terminal of the power supply through a suitable resistor. This resistor limits the current through the nozzle to about 50 A. The workpiece to be machined is also

connected to the positive terminal of the supply. The anode and cathode are separated by an insulator.

3) Gas supply unit: it consists of gas cylinder, regulators and gas supply hoses. The commonly used gases are argon or nitrogen or the mixture of two. For certain useful purposes, a percentage of hydrogen may be added. The choice of the gas depends upon the material to be cut, economics and the quality of the cut edge desired. The flow rate of the gas varies directly with the thickness of the workpiece. Typical gas flow rate is 2 to 11 m<sup>3</sup>/hr.

4) Cooling system: a provision is made for circulating the water around the torch so that the electrodes and the nozzle both remains water cooled.

5) Power supply: a D.C. power supply of 400 V, 200 KW and upto 10000 A is supplied to the nozzle. When supply is made ON, a strong arc is struck between the electrode and the nozzle and then gas is forced into the chamber. When the gas molecules collide with the high velocity electrons of the arc, plasma is formed. This plasma is forced through the nozzle (anode) onto the workpiece. The heat produced from this jet of plasma is sufficient to raise the workpiece temperature above its melting point and high velocity gas stream effectively blows the molten metal away.

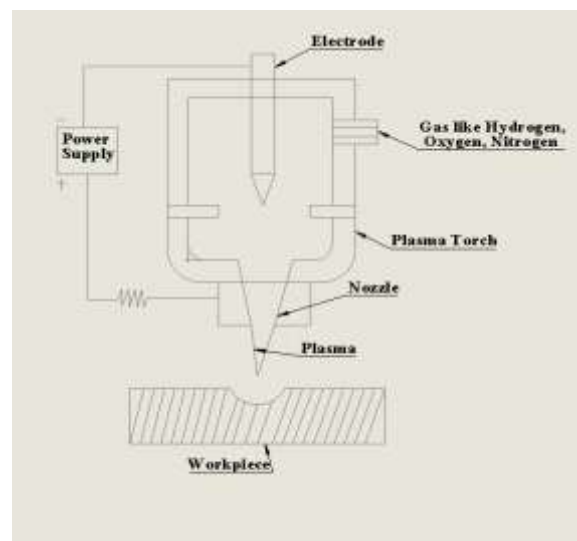


Figure 4: Setup for Plasma Arc Machining

### 19. APPLICATIONS OF PAM:

- 1) For stack cutting, plate bevelling, shape cutting and piercing.
- 2) In manufacturing of automotive and rail road components.
- 3) It can cut hot extrusion extrusions to desired length.

## 20. PRINCIPLE OF LASER BEAM MACHINING:

It works on the principle of conversion of electrical energy of flash lamp into heat energy to emit the laser beam by pumping the energy. Laser beam is then focused by a lens to give high energy in the concentrated form and helps to melt and vaporize the material of workpiece.

As laser interacts with the material, the energy of photon is absorbed by the work material leading to rapid rise in local temperature and results in melting and vaporization of the work material (1).

## 21. SETUP AND WORKING OF LASER BEAM MACHINING:

Laser beam machining utilizes the narrow beam of intense monochromatic light which melts and vaporize the material of the workpiece. The setup for this process is shown in the fig. It mainly consists of:

1. **Laser generation unit:** in this unit ruby rod, flash lamp, power supply, mirrors are used for production of laser beams. The solid-state laser i.e. ruby rod is used in the form of cylindrical crystal with 10 mm diameter and 150 mm long. The ends are finished to close optical tolerances. The flash lamp is wound around the ruby rod and it is connected to electric power supply. The inner surface of the container wall is made highly reflective all the light on the ruby rod. The electrical power supply is designed to give 250 to 1000 watts energy to the flash lamp.
2. **Cooling arrangement:** the ruby rod becomes less efficient at higher temperatures and gives maximum efficiency at when kept at a very low temperature. Hence cooling system is provided in which liquid nitrogen is used, sometimes air- or water-cooled provision is also made, but it has less effectiveness compared to liquid nitrogen.
3. **Collimating lens:** the highly amplified beam of laser light is focused on workpiece through a lens, it gives high energy density which melts and vaporizes the metal.
4. **Workpiece tables:** the workpiece to be cut is placed on the aluminium work table which is resistant to the laser beam. The laser head is transverse over the workpiece and table can be moved as per requirement.

Characteristics of laser: a laser beam has the following properties:

- 1) A laser beam is highly monochromatic.
- 2) Laser ray is highly pure beam of light.
- 3) It is an intense beam of light.
- 4) Highly directional.
- 5) Highly collimated.
- 6) The light produced by laser is coherent.

These properties allow laser light to be focused, using optical lens, onto a very small spot with resulting high-power densities.

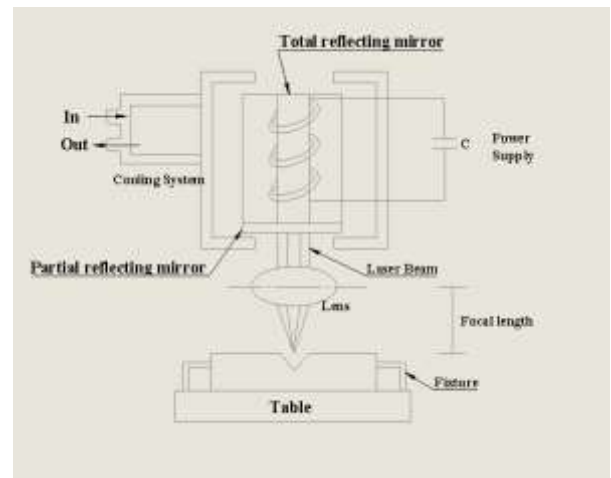


Figure 5: Setup for Laser Beam Machining

## 22. FUTURE SCOPE

Over the past few decades, tremendous progress in science and technology transformed the way a product is manufactured. Digital manufacturing is a novel technology that creates designs and manufactures sustainable products at speeds beyond imagination! The more complex a product and its manufacturing operations are the more valuable is the digital manufacturing.

There's significant development in the process and the technology, it still requires more advancements and research for microscopic and macroscopic related aspects of manufacturing processes as well as systems. Novel advance manufacturing systems and standard processes need to be developed with focus on the design of complex materials with multifunctionality, multimaterial structures, electrically conductive materials, bio-applications, nanoengineering, energy and sustainability implications in order to elevate it as a middle-of-road technology. The potential of the technology to revolutionize manufacturing has been recognized by the private sector, governments, and university researchers. Overcoming the limitations of the advance manufacturing technology in order for it to be used for high volume manufacturing remains a challenge for all interested stakeholders. Addressing the challenge will require collaboration across different sectors to maximize the revenue and optimization of the processes. The range of business impacts of the developments Additive manufacturing will become clearer over the next few years. This paper is an initial exploration of these developments in advance manufacturing technology.

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