Non-Traditional Manufacturing Processes

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- Quantity methods for non-traditional processes
- Quantity production by non-traditional manufacturing processes
- Methods and systems of quantity production of various ceramic and polymer products of common use.
- Classification of NTM processes

INTRODUCTION

- Manufacturing processes can be broadly divided into two groups and they are primary manufacturing processes and secondary manufacturing processes.
- Secondary manufacturing process provide the final shape and size with tighter control on dimension, surface characteristics etc.
- Material removal processes are mainly the secondary manufacturing processes. Material removal processes once again can be divided into mainly two groups and they are “Conventional Machining Processes” and “Non-Traditional Manufacturing Processes”.
- Non-traditional machining covers a broad range of technologies, including some that are used on a large scale, and others that are only used in unique or proprietary applications.
- These machining methods generally have higher energy requirements and slower throughputs than traditional machining, but have been developed for applications where traditional machining methods were impractical, incapable, or uneconomical.

Non-Traditional Manufacturing Processes

- Non-traditional manufacturing processes is 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 a sharp cutting tools as it needs to be used for traditional manufacturing processes.
- In this process there is no direct contact between tool and work piece.
- Extremely hard and brittle materials are difficult to machine by traditional machining processes such as turning, drilling, shaping and milling.
- Non-traditional machining processes, also called advanced manufacturing processes, are employed where traditional machining processes are not feasible, satisfactory or economical.

NON-TRADITIONAL MANUFACTURING PROCESSES

Traditional machining processes are not feasible, satisfactory or economical due to following reasons:

- Material removal may occur with chip formation or even no chip formation may take place.
- Mostly NTM processes do not necessarily use mechanical energy to provide material removal.
- In NTM, the tool need not be harder than the work piece material.
- Very hard fragile materials difficult to clamp for traditional machining.
- When the work piece is too flexible or slender.
- When the shape of the part is too complex.

WHY NON-TRADITIONAL MANUFACTURING PROCESSES?

- In several industries, hard and brittle materials like tungsten carbide, high speed steels, stainless steels, ceramics etc.
- For example, tungsten carbide is used for making cutting tools while high speed steel is used for making gear cutters, drills, taps, milling cutters etc.
- If such materials are machined with the help of conventional machining processes, either the tool undergoes extreme wear (while machining hard work piece) or the work piece material is damaged (while machining brittle work piece).
- This is because, in conventional machining, there is a direct contact between the tool and the work piece.
- Large cutting forces are involved and material is removed in the form of chips.

WHY NON-TRADITIONAL MANUFACTURING PROCESSES?

- A huge amount of heat is produced in the work piece.
- This induces residual stresses, which degrades the life and quality of the work piece material.
- Hence, conventional machining produces poor quality work piece with poor surface finish (if the work piece is made of hard and brittle material).
- To overcome all these drawbacks, we use unconventional machining processes to machine hard and brittle materials.
- We also use unconventional machining processes to machine soft materials, in order to get better dimensional accuracy.

MAJOR CHARACTERISTICS OF NON-TRADITIONAL MACHINING

- 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.
- Non-traditional processes easily deal with such difficult-to-cut materials like ceramics and ceramic based tool materials, fire reinforced materials,

MAJOR CHARACTERISTICS OF NON-CONVENTIONAL 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.
- Machining of small cavities, slits, blind or through holes is difficult with traditional processes, whereas it is a simple work for some non-traditional processes
- 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.

Classification of NTM Processes

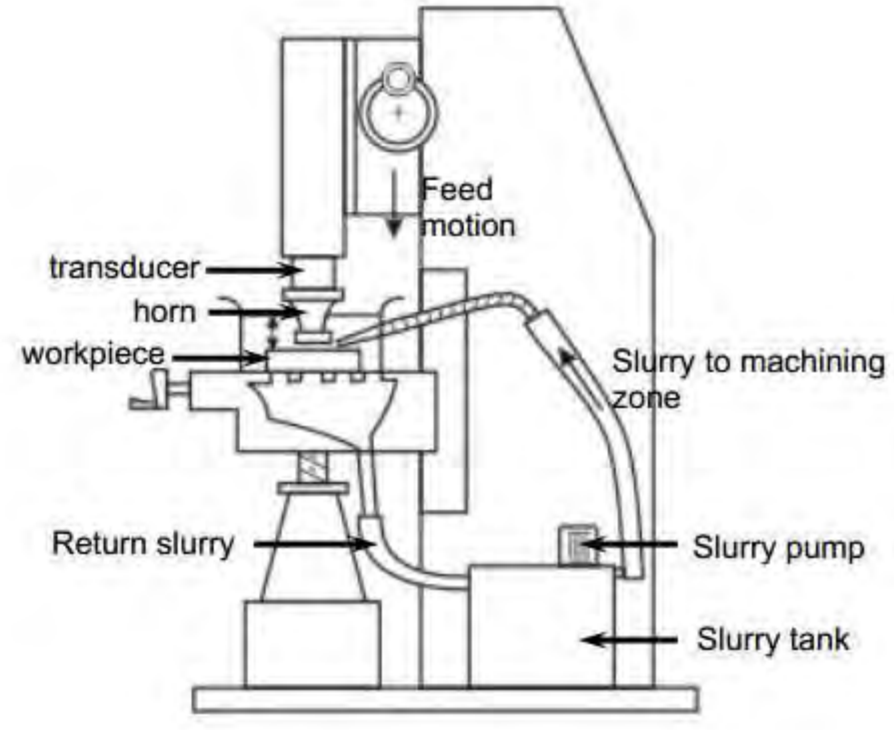
Classification of NTM processes is carried out depending on the nature of energy used for material removal.

1. Mechanical Processes
   - Ultrasonic Machining (USM)
   - Water Jet Machining (WJM)
   - Abrasive Jet Machining (AJM)
   - Abrasive Water Jet Machining (AWJM)
2. Chemical Processes
   - Chemical Milling (CHM)
3. Electrochemical Processes
   - Electro Chemical Grinding (ECG)
   - Electro Jet Drilling (EJD)
4. Electro-Thermal Processes
   - Laser Beam Machining (LBM)
   - Electron Beam Machining (EBM)

Mechanical Processes

Ultrasonic Machining (USM)

Ultrasonic machining is a non-traditional manufacturing process. Ultrasonic machining is a machining operation in which a vibrating tool oscillating at ultrasonic frequencies is used to remove material from the work piece, aided by abrasive slurry that flows freely between the work piece and the tool.

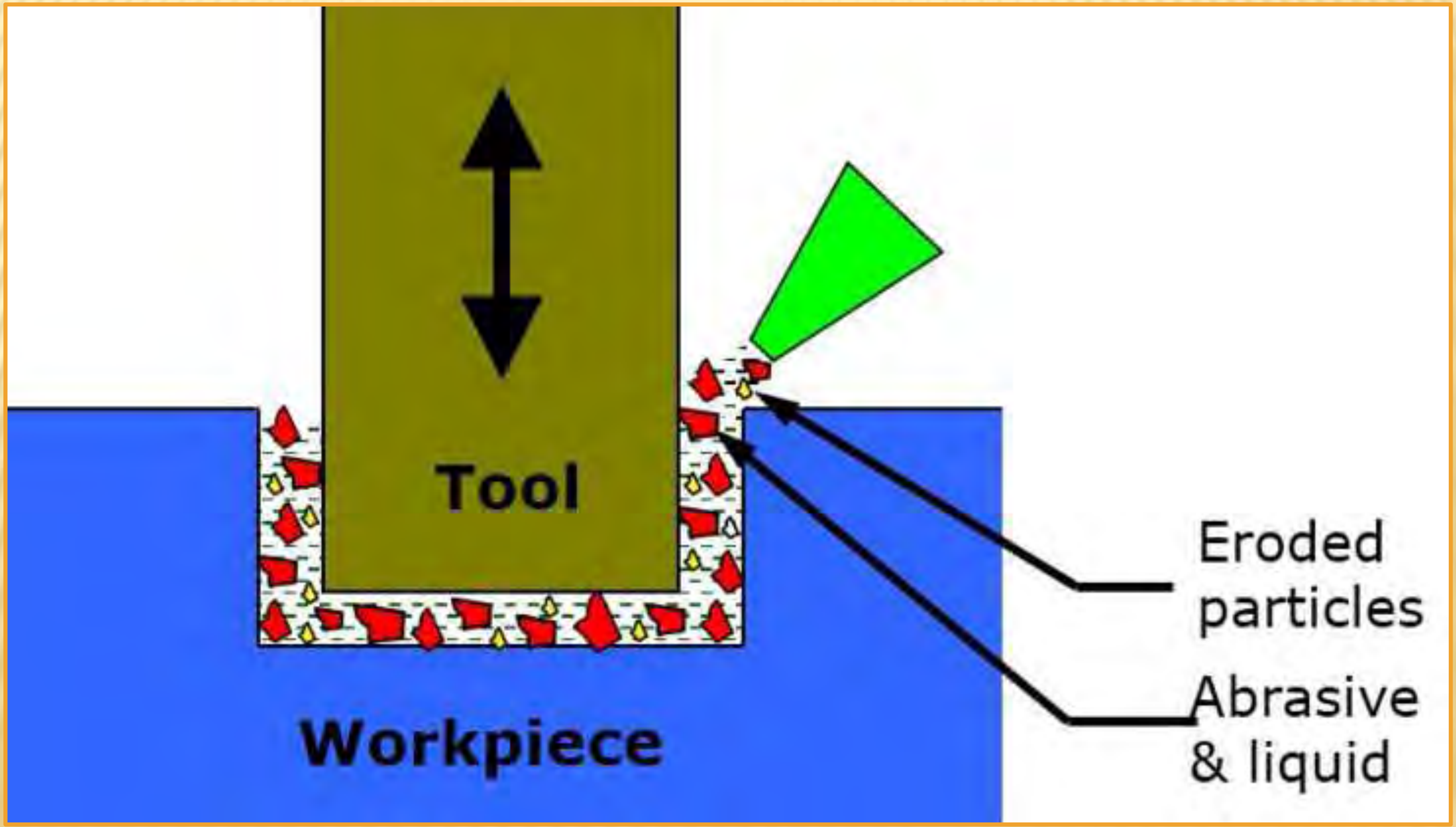


Schematic view of an Ultrasonic Machine

ULTRASONIC MACHINING (USM)

It differs from most other machining operations because very little heat is produced. The tool never contacts the work piece and as a result the grinding pressure is rarely more than 2 pounds which makes this operation perfect for machining extremely hard and brittle materials, such as glass, quartz, sapphire, ferrite, aluminium oxide, silicon, silicon carbide, silicon nitride, ruby, diamond, fibre optics and ceramics. The tool that does the cutting is made of a harder material than the work piece. Commonly used tool materials are nickel and soft steels. As the tool vibrates, it pushes down on the abrasive slurry, a liquid containing abrasive grains, until the grains impact the work piece. Because of the brittleness of the work piece, under the impact of the abrasive particles its surface abrades, while the softer tool material simply deforms slightly.

ULTRASONIC MACHINING (USM)



ULTRASONIC MACHINING (USM)

Applications

- It can make non round shapes in hard and brittle materials
- Used for machining hard and brittle metallic alloys, semiconductors, glass, ceramics, carbides etc.
- Used for machining round, square, irregular shaped holes and surface impressions.
- Machining, wire drawing, punching or small blanking dies.

limitations

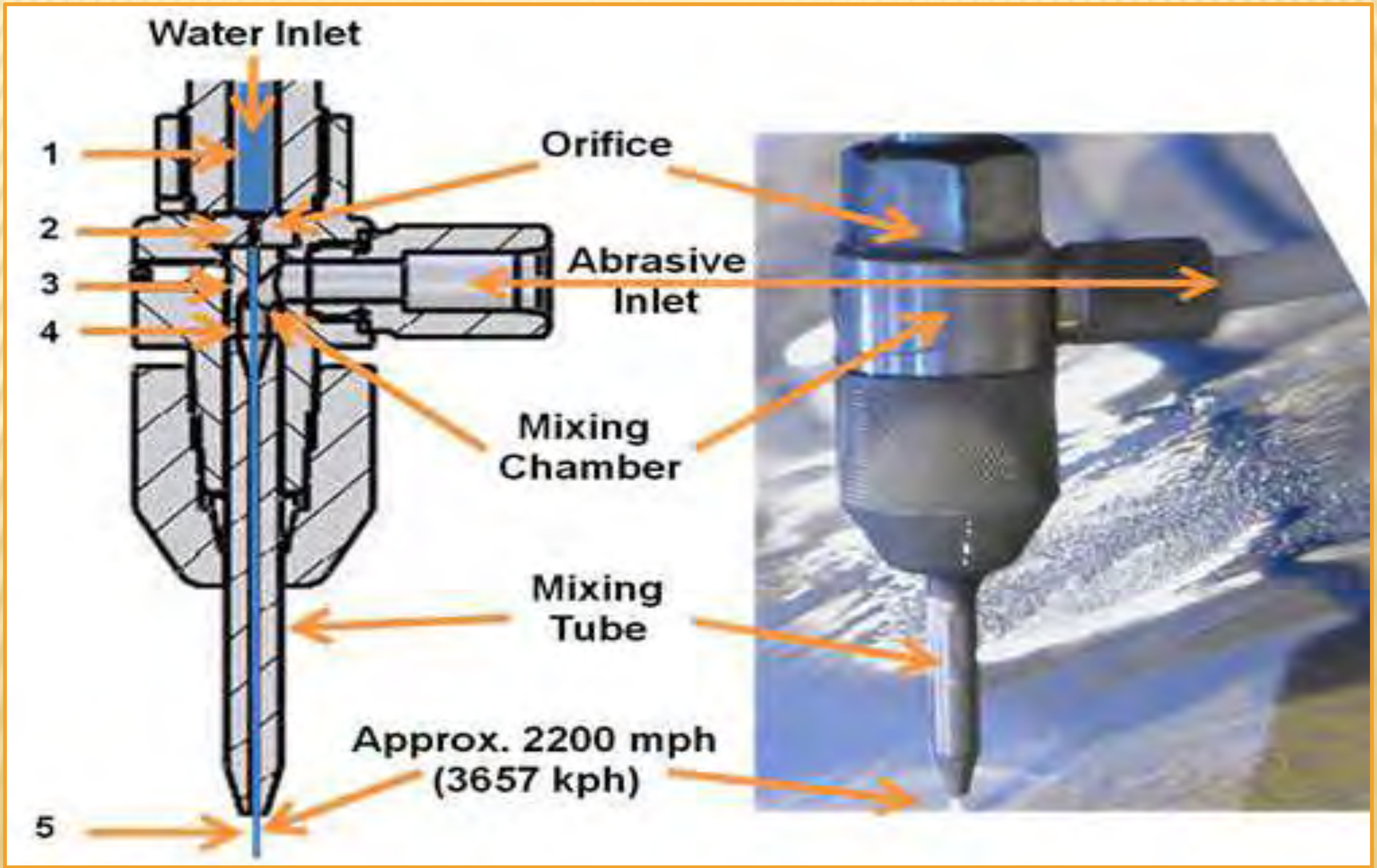
- USM has higher power consumption and lower material removal rates than traditional fabrication processes.
- Tool wear fast in USM.
- Machining area and depth is restraint in USM.
- Low depth of hole.

WATER JET MACHINING (WJM)

Water Jet Machining (WJM) and Abrasive Water Jet Machining (AWJM) are two non-traditional or non-conventional machining processes. Water jet cutting can reduce the costs and speed up the processes by eliminating or reducing expensive secondary machining process. Problems such as cracked edge defects, crystallization, hardening, reduced wealdability and machinability are reduced in this process. The cutting ability of water jet machining can be improved drastically by adding hard and sharp abrasive particles into the water jet.

Water jet technology uses the principle of pressurizing water to extremely high pressures, and allowing the water to escape through a very small opening called “orifice” or “jewel”. Water jet cutting uses the beam of water exiting the orifice to cut soft materials. This method is not suitable for cutting hard materials. The inlet water is typically pressurized between 1300 – 4000 bars. This high pressure is forced through a tiny hole in the jewel, which is typically o.18 to 0.4 mm in diameter.

WATER JET MACHINING (WJM)



WATER JET MACHINING (WJM)

Applications

- Water jet cutting is mostly used to cut lower strength materials such as wood, plastics and aluminum. Paint removal.
- Cleaning cutting soft materials, Cutting frozen meat.
- Textile, Leather industry
- Mass Immunization, Surgery, Peening.
- Pocket Milling, Drilling, Turning, Nuclear Plant Dismantling.

limitations

- One of the main limitations of water jet cutting is that a limited number of materials can be cut economically.
- Thick parts cannot be cut by this process economically and accurately.

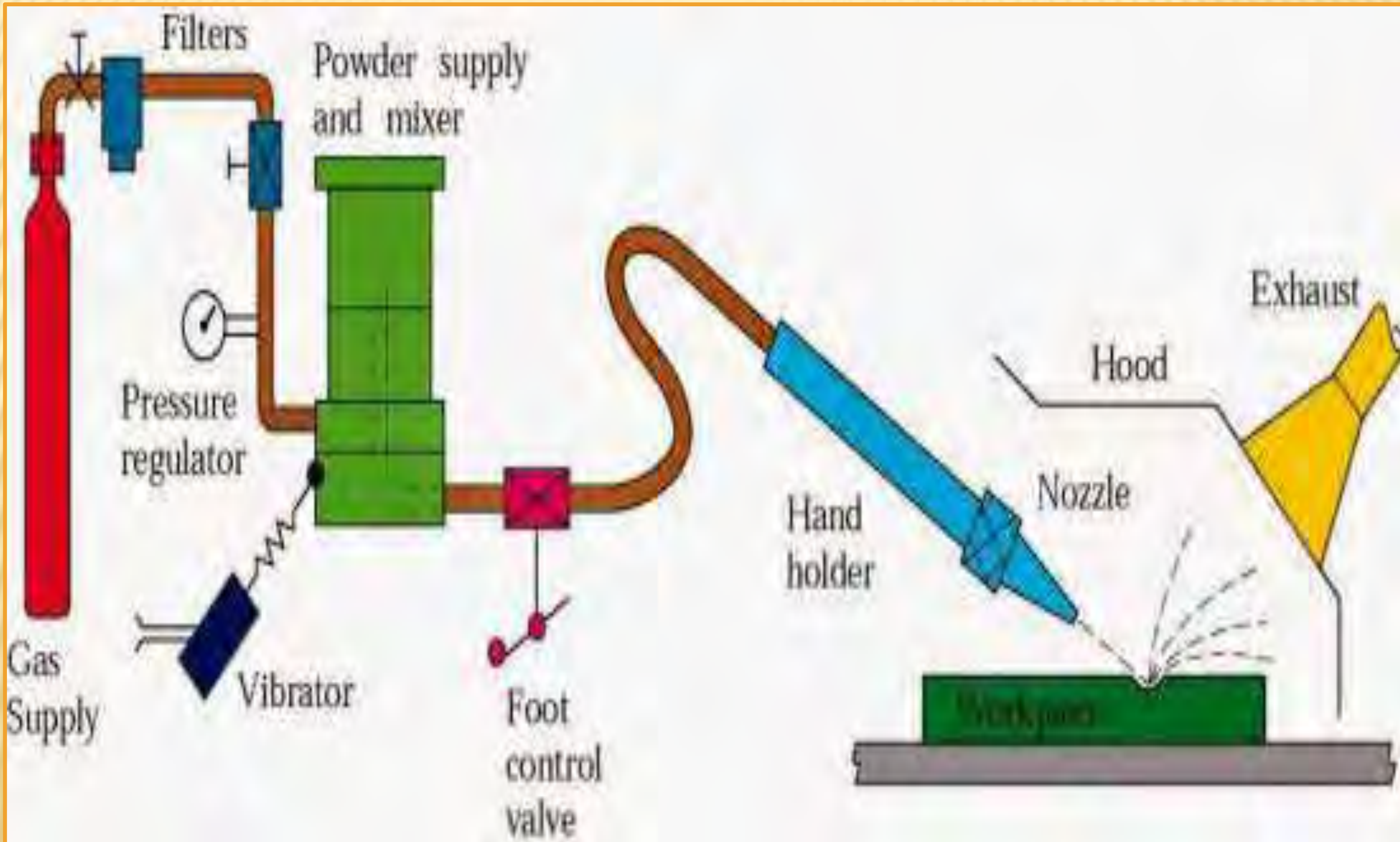
Abrasive Jet Machining (AJM)

In abrasive jet machining (AJM) a focused stream of abrasive grains of Al2O3 or Sic carried by high-pressure gas or air at a high velocity is made to impinge on the work surface through a nozzle of 0.3- to 0.5-mm diameter. The work piece material is removed by the mechanical abrasion (MA) action of the high-velocity abrasive particles.

Process:

In Abrasive jet machining abrasive particles are made to impinge on work material at high velocity. Jet of abrasive particles is carried by carrier gas or air. The high velocity stream of abrasives is generated by converting pressure energy of carrier gas or air to its Kinetic energy and hence high velocity jet. Nozzles direct abrasive jet in a controlled manner onto work material. The high velocity abrasive particles remove the material by micro-cutting action as well as brittle fracture of the work material.

ABRASIVE JET MACHINING (AJM)



ABRASIVE JET MACHINING (AJM)

Applications

- This is used for abrading and frosting glass more economically as compared to etching or grinding
- Cleaning of metallic smears on ceramics, oxides on metals, resistive coating etc.
- AJM is useful in manufacture of electronic devices, drilling of glass wafers, de burring of
- plastics, making of nylon and Teflon parts permanent marking on rubber stencils, cutting titanium foils.

Abrasive Jet Machining (AJM)

Advantages

- High surface finish can be obtained depending upon the grain sizes
- Depth of damage is low (around2.5 microns)
- It provides cool cutting action, so it can machine delicate and heat sensitive material
- Capital cost is low and it is easy to operate and maintain AJM.
- It has the capability of cutting holes of intricate shape in hard materials.

limitations

- The removal rate is slow.
- Nozzle life is limited (300 hours)
- Stray cutting can't be avoided (low accuracy of ±0.1 mm).
- The abrasive may get impeded in the work surface. Depth of damage is low (around2.5 microns)

ABRASIVE WATER JET MACHINING (AWJM)

Abrasive water jet machining (AWJM) is a relatively new machining technique. Abrasive Water Jet Machining is extensively used in many industrial applications. AWJM is a nonconventional machining process where material is removed by impact erosion of high pressure high velocity of water and entrained high velocity of grit abrasives on a work piece.

There are so many process parameter affect quality of machined surface cut by AWJM. Important process parameters which mainly affect the quality of cutting are traverse speed, hydraulic pressure, stand of distance, abrasive flow rate and types of abrasive. Important quality parameters in AWJM are Material Removal Rate (MRR), Surface Roughness (SR), kerf width, tapering of kerf. This paper reviews the research work carried out so far in the area AWJM.

ABRASIVE WATER JET MACHINING (AWJM)

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CHEMICAL PROCESSES

CHEMICAL MACHINING/MILLING (CM)

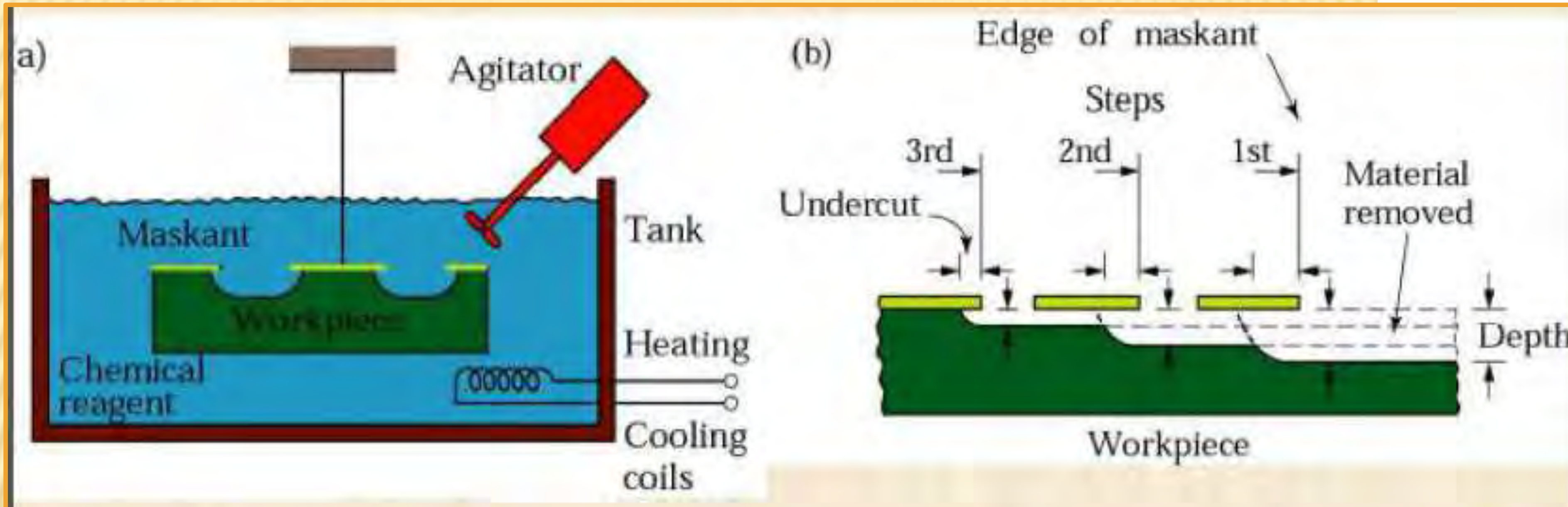
Purpose:

Non-traditional machining processes are widely used to manufacture geometrically complex and precision parts for aerospace, electronics and automotive industries. There are different geometrically designed parts, such as deep internal cavities, miniaturized microelectronics and fine quality components may only be produced by non-traditional machining processes. This paper is aiming to give details of chemical machining process, industrial applications, applied chemical etchants and machined materials. Advantages and limitations of the chemical machining are mentioned.

CHEMICAL MACHINING/MILLING (CM)

Chemical machining/milling (CM) is the controlled dissolution of work piece material (etching) by means of a strong chemical reagent (etchant). The two key materials used in CM process are etchant and maskant. Etchants are acid or alkaline solutions maintained within controlled ranges of chemical composition and temperature. Maskants are specially designed elastomeric products that are hand strippable and chemically resistant to the harsh etchants. In CM material is removed from selected areas of work piece by immersing it in a chemical reagents or etchants. Material is removed by microscopic electrochemical cell action, as occurs in corrosion or chemical dissolution of a metal. This controlled chemical dissolution will simultaneously etch all exposed surfaces even though the penetration rates of the material removal may be only 0.0025–0.1 mm/min.

CHEMICAL MACHINING/MILLING (CM)

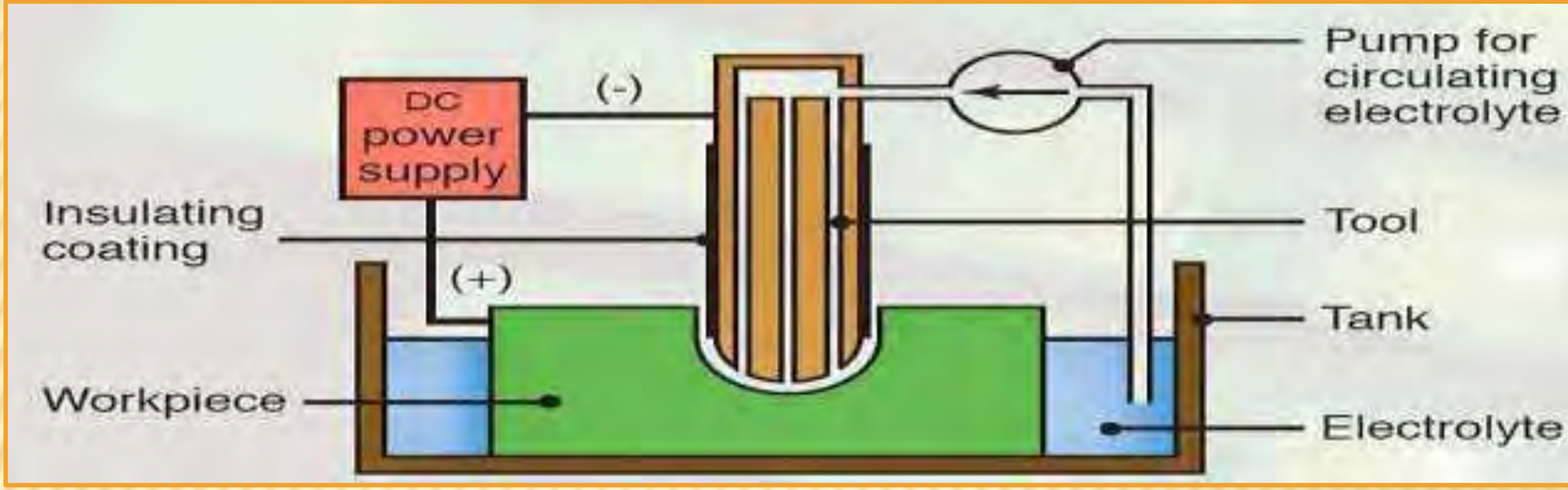


In chemical milling, shallow cavities are produced on plates, sheets, forgings and extrusions. The two key materials used in chemical milling process are etchant and maskant. Etchants are acid or alkaline solutions maintained within controlled ranges of chemical composition and temperature. Maskants are specially designed elastomeric products that are hand strippable and chemically resistant to the harsh etchants.

STEPS IN CHEMICAL MILLING

- Residual stress relieving: If the part to be machined has residual stresses from the previous processing, these stresses first should be relieved in order to prevent warping after chemical milling.
- Preparing: The surfaces are degreased and cleaned thoroughly to ensure both good adhesion of the masking material and the uniform material removal.
- Masking: Masking material is applied (coating or protecting areas not to be etched).
- Etching: The exposed surfaces are machined chemically with etchants.
- Damasking: After machining, the parts should be washed thoroughly to prevent further reactions with or exposure to any etchant residues. Then the rest of the masking material is removed and the part is cleaned and inspected.

CHEMICAL MACHINING/MILLING (CM)



Advantages

- Chemical milling is used in the aerospace industry to remove shallow layers of material from large aircraft components, missile skin panels, and extruded parts for airframes.

ELECTROCHEMICAL PROCESSES

ELECTROCHEMICAL GRINDING (ECG)

Electrochemical grinding is a process that removes electrically conductive material by grinding with a negatively charged abrasive grinding wheel, an electrolyte fluid, and a positively charged work piece. Materials removed from the work piece stay in the electrolyte fluid. Electrochemical Grinding (ECG) can produce burr free and stress free parts without heat or other metallurgical damage caused by mechanical grinding, eliminating the need for secondary machining operations.

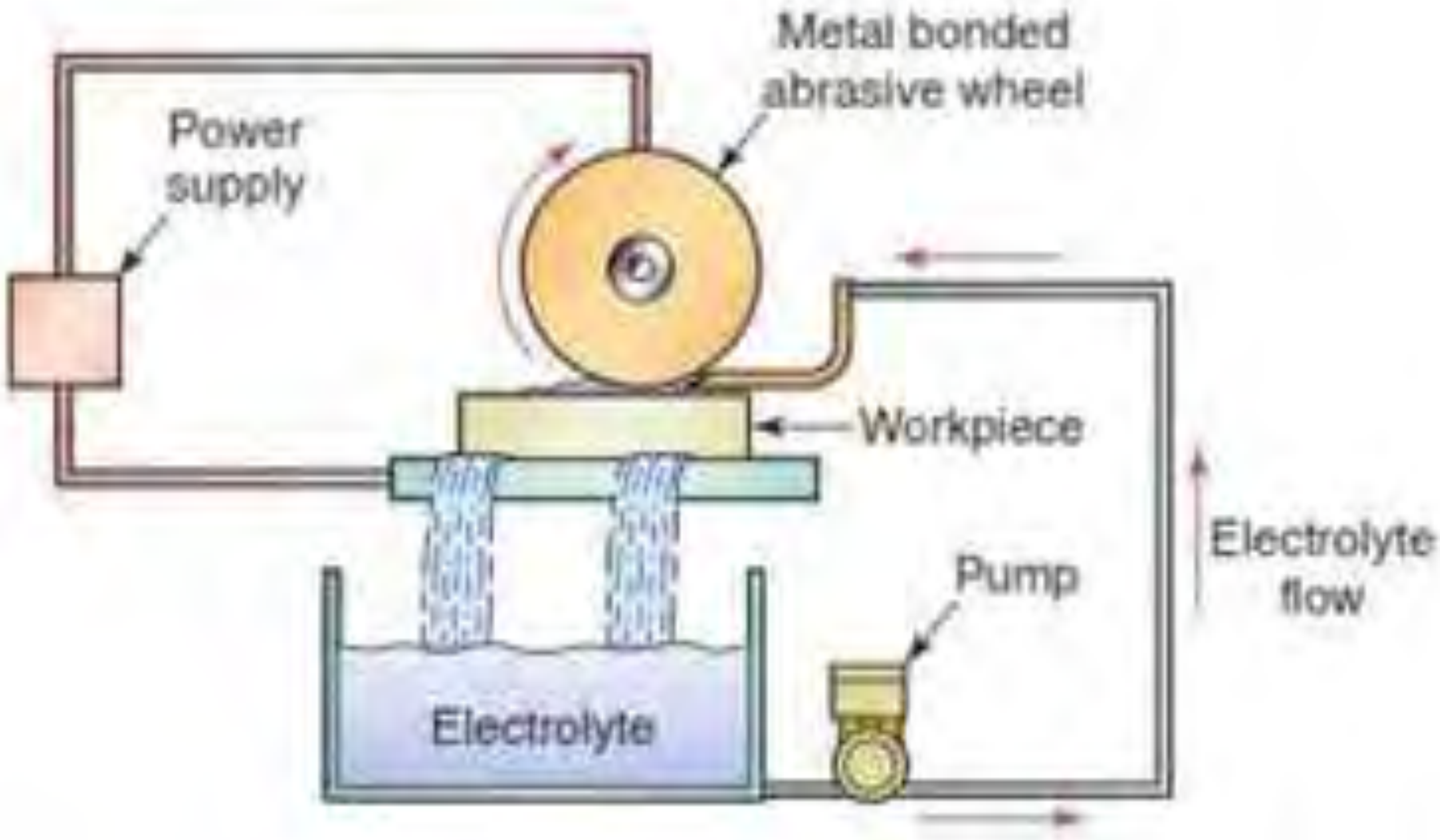
The wheels are metal disks with abrasive particles embedded. Copper, brass , and nickel are the most commonly used materials; aluminum oxide is typically used as an abrasive when grinding steel. A thin layer of diamond particles will be used when grinding carbides or steels harder than 65 Rc.

Electrochemical Grinding (ECG)

An electrolytic spindle with carbon brushes, acting as a commutator, holds the wheel. The spindle receives a negative charge from the DC power supply, which gives the work piece a positive charge. The electrolytic fluid is applied where the work contacts the tool by a nozzle similar to that which supplies coolant in conventional grinding. The fluid works with the wheel to form electrochemical cells that oxidize the surface of the work piece. As the wheel carries away the oxide, fresh metal is exposed. Removing the oxidized fluid may only require a pressure of 20 psi or less, causing much less distortion than mechanical grinding. The wheel is subject to little wear, reducing the need for truing and dressing.

Typically 90% of the metal is removed by electrolysis and 10% from the abrasive grinding wheel. The most common electrolytes are sodium chloride and sodium nitrate at concentrations of 2 lbs.

ELECTROCHEMICAL GRINDING (ECG)



ELECTROCHEMICAL GRINDING (ECG)

Applications

- Production of tungsten carbide cutting tools.
- Grinding of super alloy turbine blades.
- Removal of fatigue cracks from underwater steel structures It has the capability of cutting holes of intricate shape in hard materials.

limitations

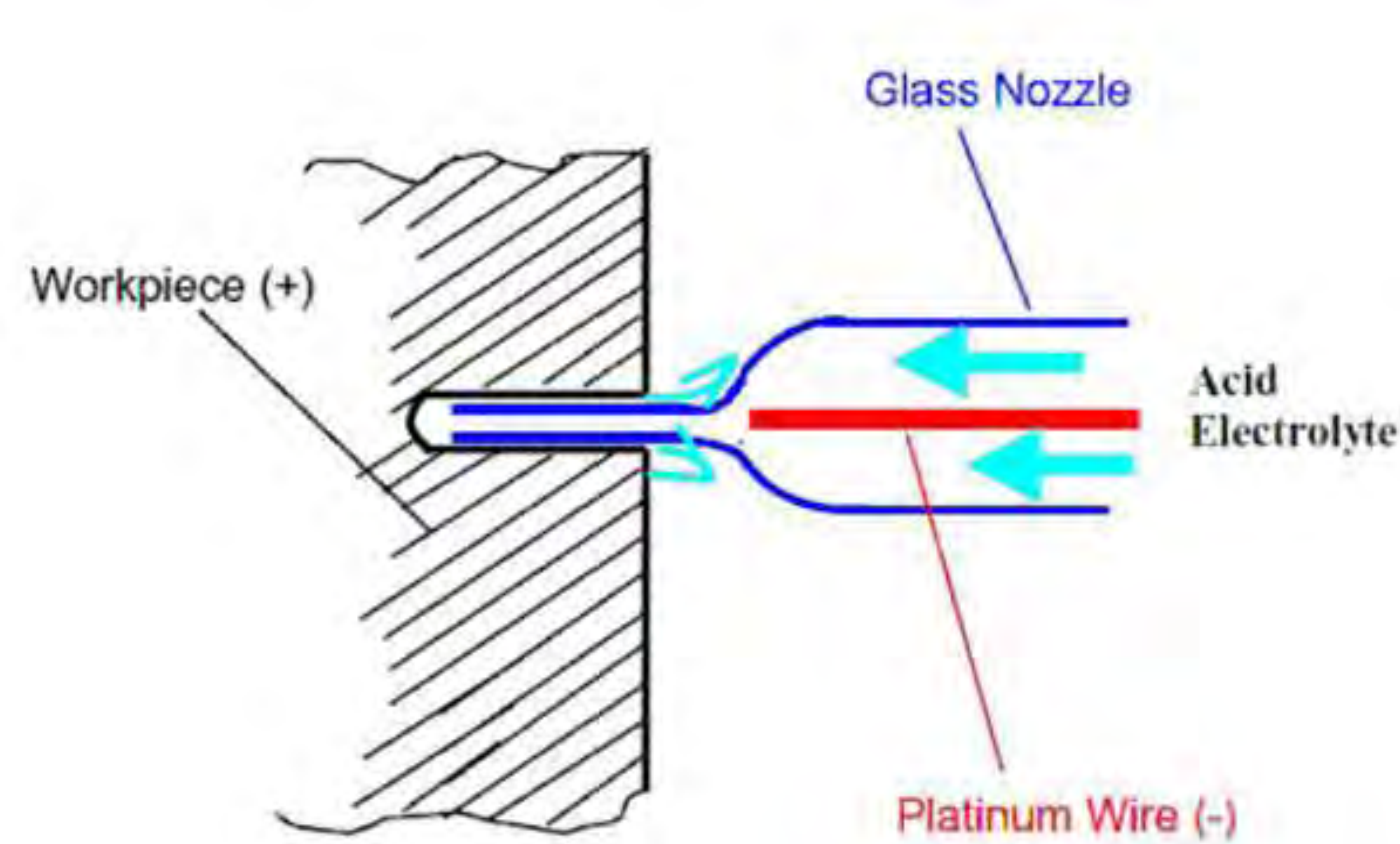
- Electrochemical grinding loses accuracy when grinding inside corners, due to the effects of the electric field. Nozzle life is limited (300 hours)

ELECTRO JET DRILLING (EJD)

It is micro level hole drilling used in cooling holes in jet turbine blades, printed circuit board, inkjet printer head, surgical implants.

A negatively charged stream of acid electrolyte is impinged on the work piece to form a hole. The acid electrolyte (10–25% concentration) is passed under pressure (0.3–1.0 MPa) through a finely drawn glass tube nozzle. The electrolyte jet acts as a cathode when a platinum wire, inserted into the glass tube well above the fine capillary is connected to the negative terminal of a DC power supply. The work piece acts as an anode. When a suitable electric potential is applied across the two electrodes, the material removal takes place through electrolytic dissolution as the electrolyte stream strikes the work piece. The metal ions thus removed are carried away with the flow of the electrolyte. A much longer and thinner electrolyte flow path requires much higher voltage (150–750 V) so as to affect sufficient current flow.

ELECTRO JET DRILLING (EJD)



ELECTRO JET DRILLING (EJD)

Advantages

- Micro-level holes can be made.
- Applied on hard and brittle material
- Material are removed easily
- Less costly than traditional drilling

limitations

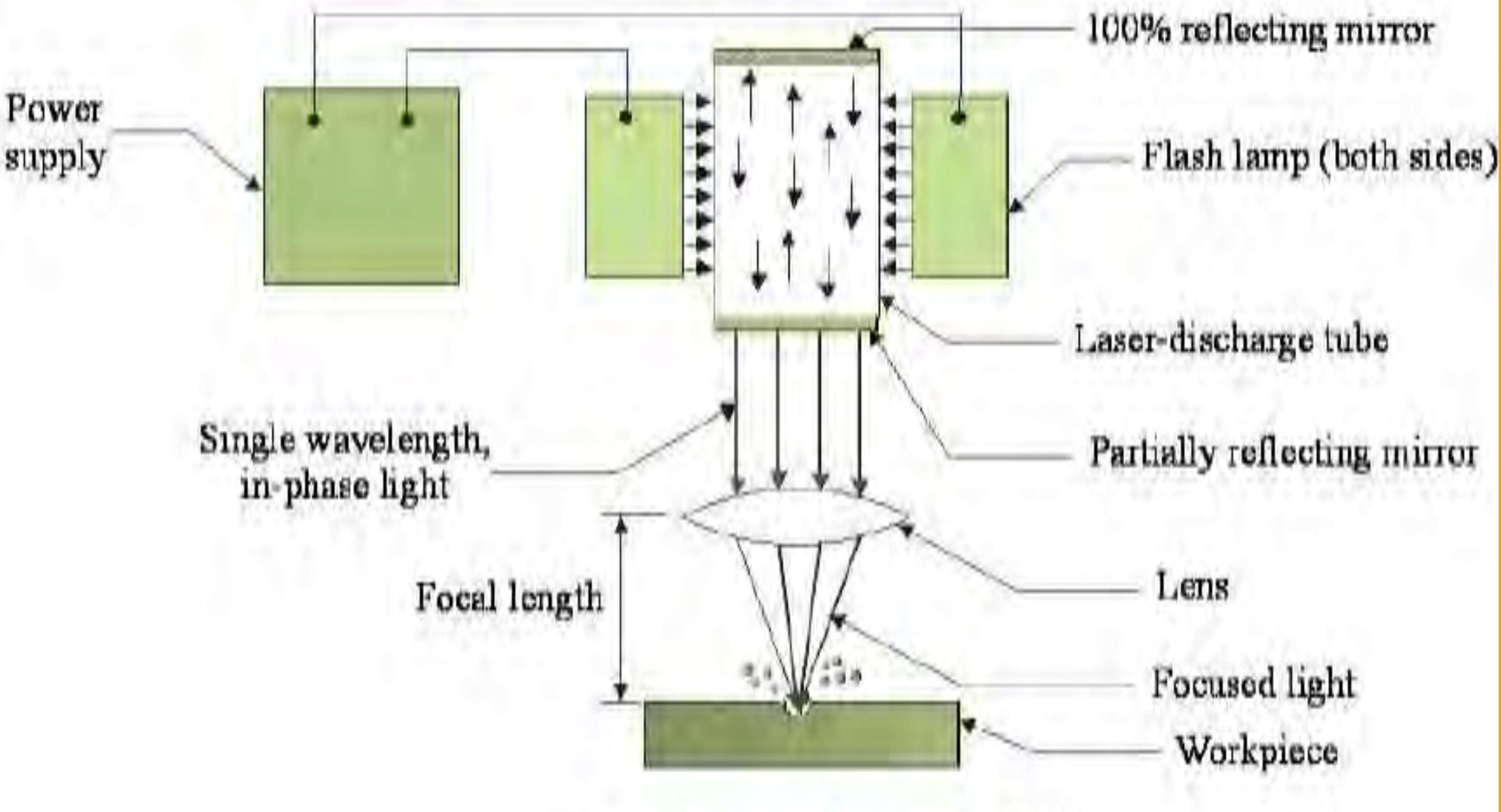
- Set up should not vibrate otherwise hole will get large or deform.
- More maintenance

ELECTRO-THERMAL PROCESSES

LASER BEAM MACHINING (LBM)

- Laser-beam machining is a thermal material-removal process that utilizes a high-energy, coherent light beam to melt and vaporize particles on the surface of metallic and non-metallic work pieces. Lasers can be used to cut, drill, weld and mark. LBM is particularly suitable for making accurately placed holes.
- Different types of lasers are available for manufacturing operations which are as follows:
- CO2 (pulsed or continuous wave): It is a gas laser that emits light in the infrared region. It can provide up to 25 kW in continuous-wave mode.
- ND: YAG: Neodymium-doped Yttrium-Aluminum-Garnet (Y3Al5O12) laser is a solid state laser which can deliver light through a fiber-optic cable. It can provide up to 50 kW power in pulsed mode and 1 kW in continuous-wave mode.

LASER BEAM MACHINING (LBM)



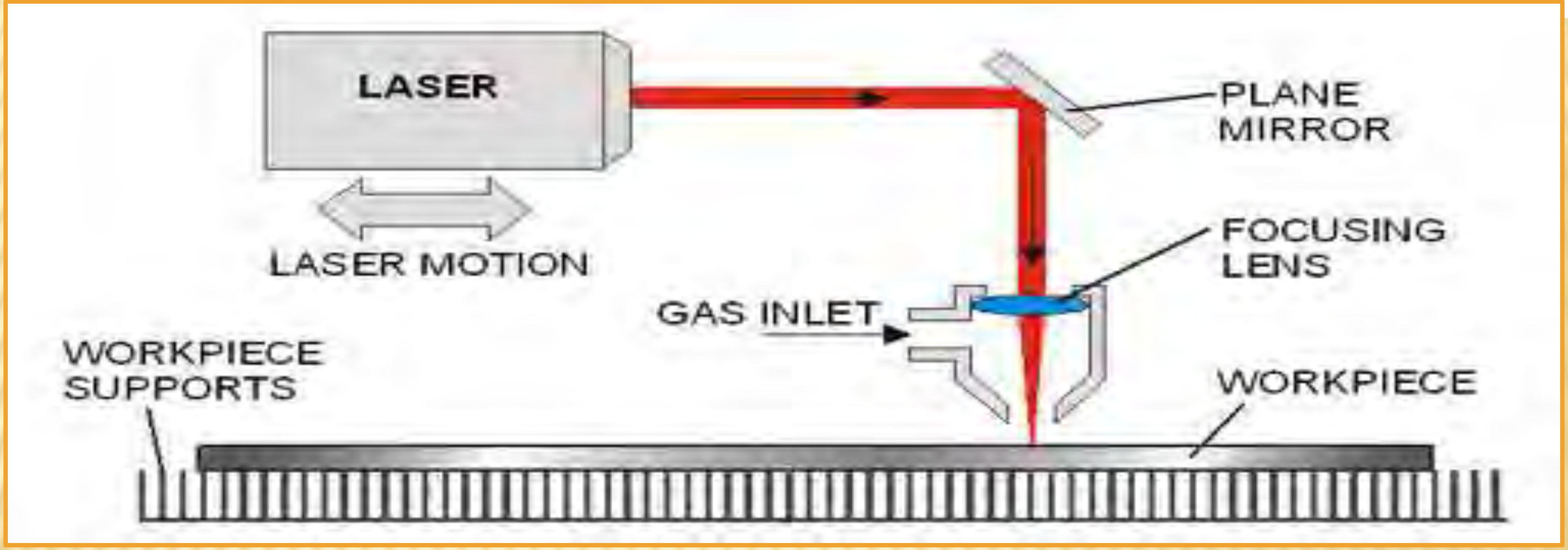
Laser beam machining schematic

LASER BEAM MACHINING (LBM)

Laser beam cutting (drilling)

- In drilling, energy transferred into the work piece melts the material at the point of contact, which subsequently changes into a plasma and leaves the region.
- A gas jet (typically, oxygen) can further facilitate this phase transformation and departure of material removed.
- Laser drilling should be targeted for hard materials and hole geometries that are difficult to achieve with other methods.

LASER BEAM MACHINING (LBM)



Laser beam cutting (milling)

- A laser spot reflected onto the surface of a work piece travels along a prescribed trajectory and cuts into the material.
- Continuous-wave mode (CO_2) gas lasers are very suitable for laser cutting providing high-average power, yielding high material-removal rates, and smooth cutting surfaces.

LASER BEAM MACHINING (LBM)

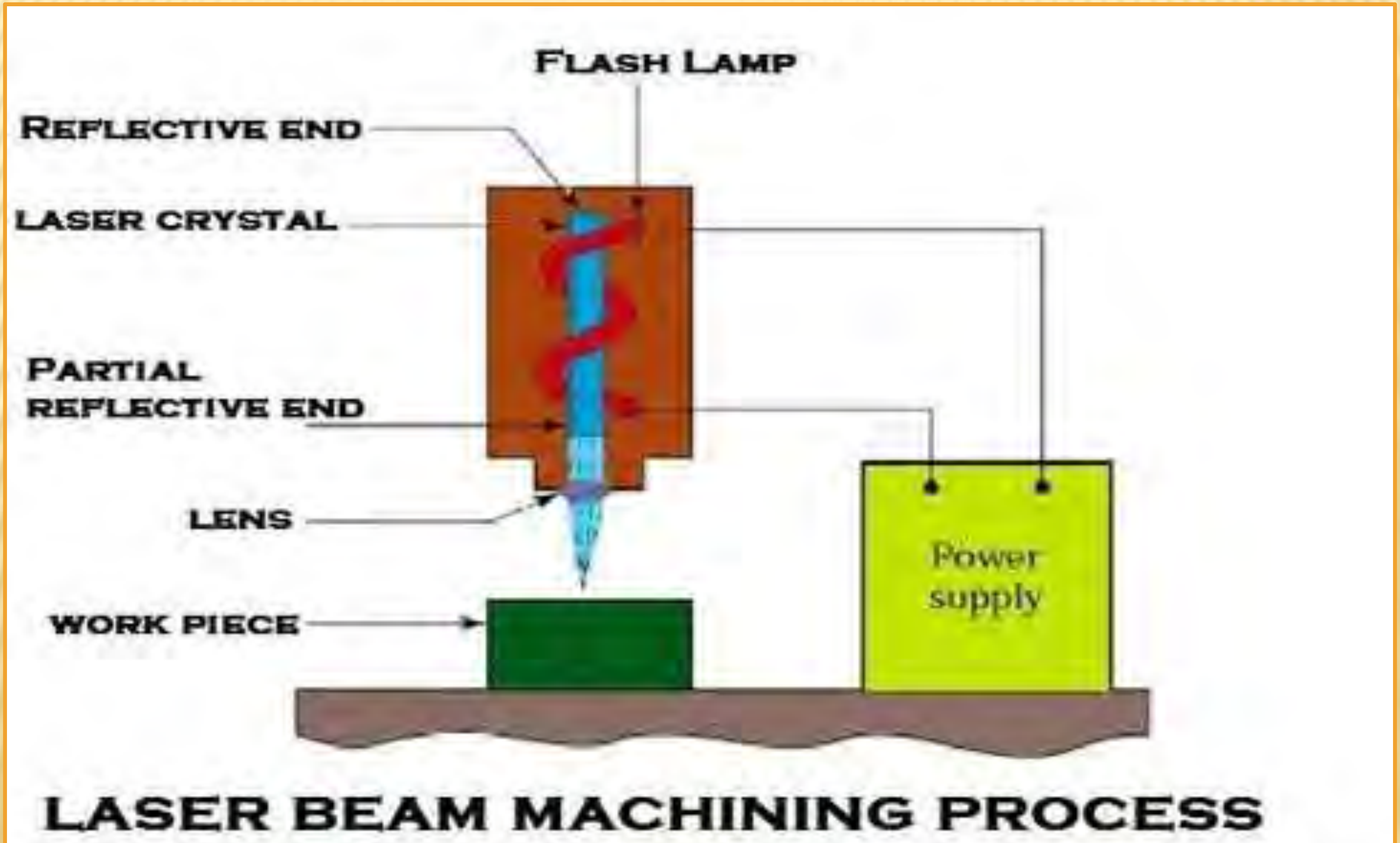
Applications of LBM

LBM can make very accurate holes as small as 0.005 mm in refractory metals ceramics, and composite material without warping the work pieces. This process is used widely for drilling and cutting of metallic and non-metallic materials. Laser beam machining is being used extensively in the electronic and automotive industries.Material are removed easily Less costly than traditional drilling

Limitations of LBM

- High capital cost
- High maintenance cost
- Assist or cover gas required

LASER BEAM MACHINING (LBM)

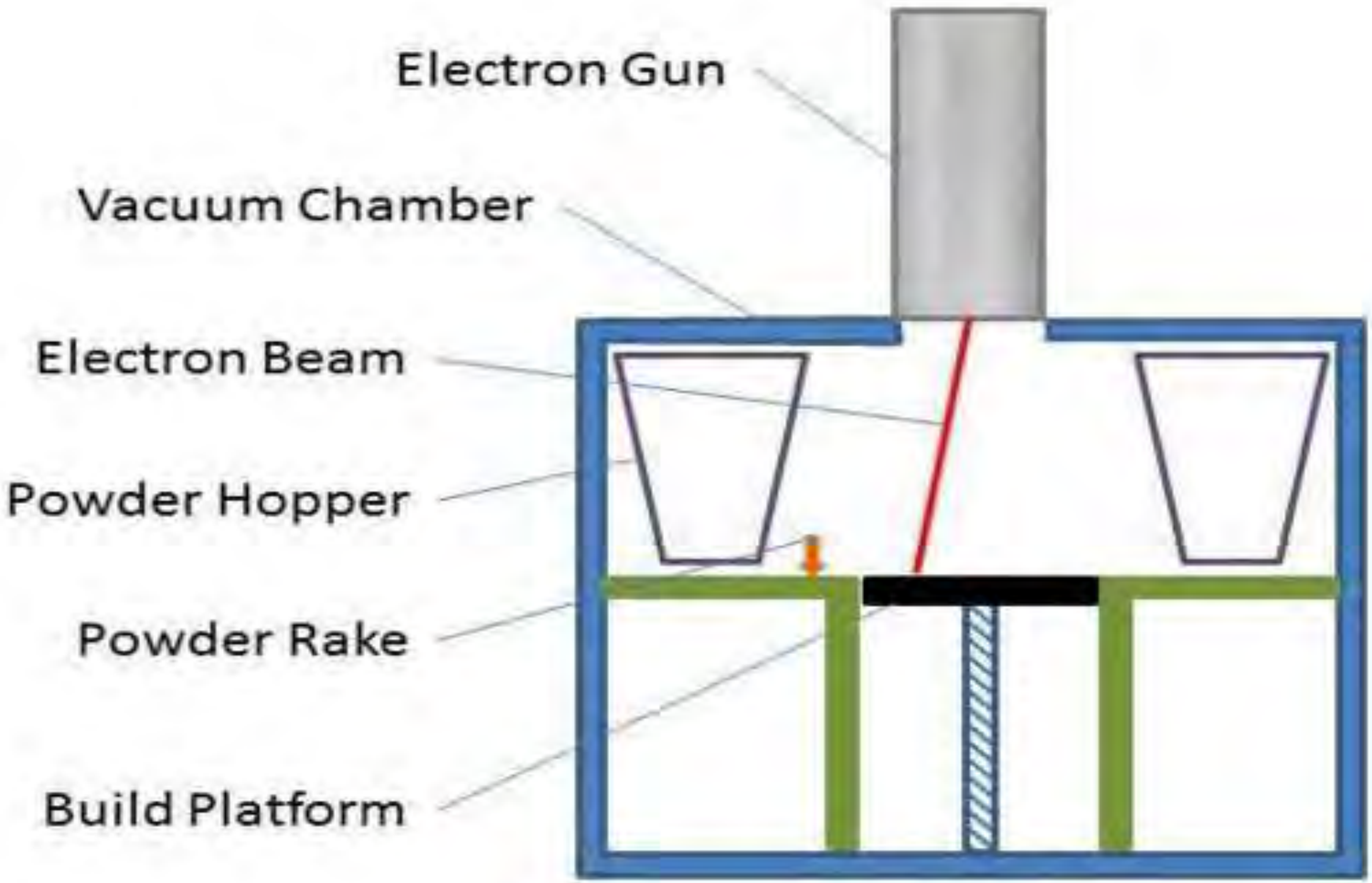


ELECTRON BEAM MACHINING (EBM)

Electron beam machining (EBM) is one of several industrial processes that use electron beams. Electron beam machining uses a high-velocity stream of electrons focused on the work piece surface to remove material by melting and vaporization.

An electron beam gun generates a continuous stream of electrons that are focused through an electromagnetic lens on the work surface. The electrons are accelerated with voltages of approx. 150,000 V to create velocities over 200,000 km/s. The lens is capable of reducing the area of the beam to a diameter as small as 0.025 mm. On impinging the surface, the kinetic energy of the electrons is converted into thermal energy of extremely high density, which vaporizes the material in a much localized area. EBM must be carried out in a vacuum chamber to eliminate collision of the electrons with gas molecules.

ELECTRO JET DRILLING (EJD)



ELECTRO JET DRILLING (EJD)

Applications of LBM

Electron beam machining is used for a variety of high-precision cutting applications on any known material. Applications include drilling of extremely small diameter holes, down to 0.05 mm diameter, drilling of holes with very high depth-to-diameter ratios, more than 100:1, and cutting of slots that are only about 0.025 mm wide. Besides machining, other applications of the technology include heat treating and welding.

Limitations of LBM

The process is generally limited to thin parts in the range from 0.2 to 6 mm thick. Other limitations of EBM are the need to perform the process in a vacuum, the high energy required, and the expensive equipment.

Thank You