Abrasive Jet Machining (AJM)

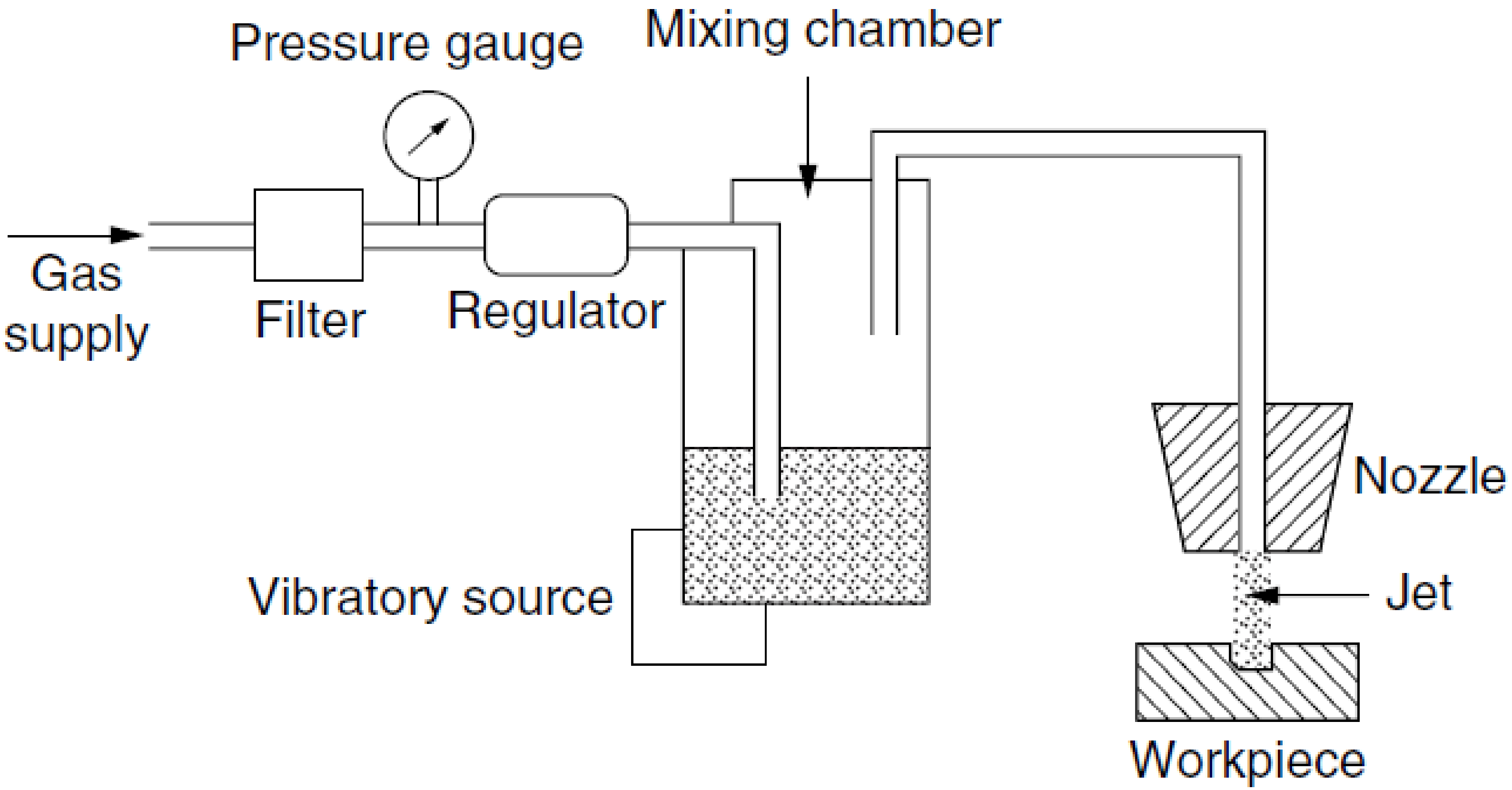
Introduction

- A stream of abrasive grains (Al_2O_3 or SiC) is carried by high pressure gas or air (compressed).
- Impinges on the work surface at very high velocity through a nozzle of 0.3 to 0.5 mm diameter.
- Sand Blasting (SB) - a similar process
- The major differences between are SB and AJM

  (i) smaller diameter abrasives

  (ii) a more finely controlled delivery system
- Material removal – by mechanical abrasion action of the high velocity abrasive particles.
- Best suited for hole drilling in superhard materials.
- Typically used to cut, clean, peen, deburr, deflash and etch glass, ceramics and other hard materials.

Machining System



Machining System – Contd.

- A gas (Nitrogen, CO_2 or air) is supplied at 2 – 8 kg/cm^2
- Oxygen should never be used. (because, it causes violent chemical action with the workpiece chips or abrasive particles).
- Gas passes through a mixing chamber after filtration and regulation.
- In the mixing chamber, abrasive particles (10 – 40 μm) are present and vibrated at 50 Hz.
- Amplitude of vibration – to control the feed rate of abrasives.
- (Gas + abrasives) - passed through a 0.45 mm diameter tungsten carbide nozzle at a speed of 150 – 300 m/s.
- The nozzle is directed over the area to be machined.

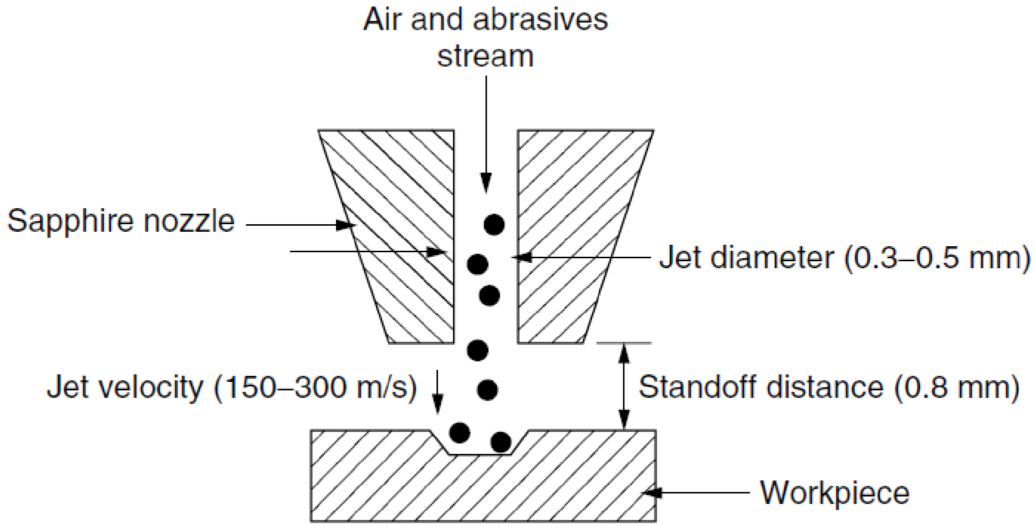
Machining System – Contd.

- Aluminium oxide (Al_2O_3) and silicon carbide (SiC) powders are used for heavy cleaning, cutting and deburring.
- Magnesium carbonate is recommended for use in light cleaning and etching.
- Sodium bicorbonate – fine cleaning and cutting of soft materials.
- Commercial grade powders are not suitable – b’cos their sizes are not well classified. Also, they may contain silica which can cause a health hazard.
- Abrasive powders are not reused. B’cos, contaminations and worn grits will reduce the machining rate (MRR).
- The nozzle stand off distance is 0.81 mm.

Machining System – Contd.

- Relative motion between nozzle and workpiece – can be manual
- Or automatically controlled using cam drives, tracer mechanisms or using computer controlled according to the cut geometry required.
- Masks of copper, glass or rubber – can be used to concentrate the jet stream of abrasives to a confined area on the workpiece.
- Intricate and precise shapes can be produced using masks with corresponding contours.
- Dust removal or collecting equipment must be incorporated to protect the environment.

Material Removal



- **The abrasive particles from the nozzle follow parallel paths for a short distance**
- **Then the abrasive jet flares outward like a narrow cone.**
- **When the sharp-edged abrasive particles of Al_2O_3 or SiC hit a brittle and fragile material at high speed, tiny brittle fractures are created from which small particles dislodge.**
- **The dislodged particles are carried away by the air or gas.**

Material Removal Rate

- **Material or Volumetric Removal Rate (MRR or VRR) is given by the formula**

$$= KN{d_a}^3 v^{3/2} \left(\frac{\rho_a}{12 H_w} \right)^{3/4}$$

where K = constant
N = number of abrasive particles impacting/unit area
d_a = mean diameter of abrasive particles, μm
ρ_a = density of abrasive particles, kg/mm^3
H_w = hardness number of the work material
v = speed of abrasive particles, m/s

Process Parameters

- **MRR, machining accuracy, surface roughness and nozzle wear are influenced by**
  - **Size and distance of the nozzle.**
  - **Composition, strength, size, and shape of abrasives**
  - **Flow rate**
  - **Composition, pressure, and velocity of the carrier gas.**
- **MRR is mainly dependent on the flow rate and size of abrasives.**
- **Larger grain sizes produce greater removal rates.**
- **At a particular pressure, the VRR increases with the abrasive flow rate up to an optimum value and then decreases with any further increase in flow rate. (Why?)**
- **The mass flow rate of the gas decreases with an increase in the abrasive flow rate**
- **Hence the mixing ratio increases and causes a decrease in the removal rate because of the decreasing energy available for material removal.**

Process Parameters – Contd.

- **Typical MRR is 16.4 mm^3/min when cutting glass.**
- **Cutting rates for metals vary from 1.6 to 4.1 mm^3/min.**
- **For harder ceramics, cutting rates are about 50 percent higher than those for glass – 24.6 mm^3/min.**
- **The minimum width of cut can be 0.13 mm.**
- **Tolerances are typically within ± 0.05 mm by using good fixation and motion control.**
- **Finished surface has a random or matte texture.**
- **Attainable surface roughness - 0.2 to 1.5 µm using 10 and 50 µm particles, respectively.**
- **Taper is present in deep cuts.**
- **High nozzle pressures result in a greater removal rate, but the nozzle life is decreased.**

Process Characteristics

Abrasives	
Type	Al_2O_3 or SiC (used once)
Size	Around 25 μm
Flow rate	3–20 g/min
Medium	
Type	Air or CO_2
Velocity	150–300 m/s
Pressure	2–8 kg/cm^2
Flow rate	28 L/min
Nozzle	
Material	Tungsten carbide or sapphire
Shape	Circular, 0.3–0.5 mm diameter Rectangular (0.08 × 0.51 mm to 6.61 × 0.51 mm)
Tip distance	0.25–15 mm
Life	WC (12–30 h), sapphire (300 h)
Operating angle	Vertical to 60° off vertical
Area	0.05–0.2 mm^2
Tolerance	±0.05 mm
Surface roughness	0.15–0.2 μm (10-μm particles) 0.4–0.8 μm (25-μm particles) 1.0–1.5 μm (20-μm particles)

Applications

- **Drilling holes, cutting slots, cleaning hard surfaces, deburring, polishing, and radiusing.**
- **Deburring of cross holes, slots, and threads in small precision parts that require a burr-free finish, such as hydraulic valves, aircraft fuel systems, and medical appliances.**
- **Machining intricate shapes or holes in sensitive, brittle, thin, or difficult-to-machine materials.**
- **Insulation stripping and wire cleaning without affecting the conductor.**
- **Micro-deburring of hypodermic needles.**
- **Frosting glass and trimming of circuit boards, hybrid circuit resistors, capacitors, silicon, and gallium.**
- **Removal of films and delicate cleaning of irregular surfaces because the abrasive stream is able to follow contours.**

Advantages

- **Because AJM is a cool machining process, it is best suited for machining brittle and heat-sensitive materials like glass, quartz, sapphire, and ceramics.**
- **The process is used for machining superalloys and refractory materials.**
- **It is not reactive with any workpiece material.**
- **No tool changes are required.**
- **Intricate parts of sharp corners can be machined.**
- **The machined materials do not experience hardening.**
- **No initial hole is required for starting the operation as required by wire EDM.**
- **Material utilization is high.**
- **It can machine thin materials.**

Limitations

- **The removal rate is slow.**
- **Stray cutting can’t be avoided (low accuracy of ± 0.1 mm).**
- **The tapering effect may occur especially when drilling in metals.**
- **The abrasive may get impeded in the work surface.**
- **Suitable dust-collecting systems should be provided.**
- **Soft materials can’t be machined by the process.**
- **Silica dust may be a health hazard.**
- **Ordinary shop air should be filtered to remove moisture and oil.**