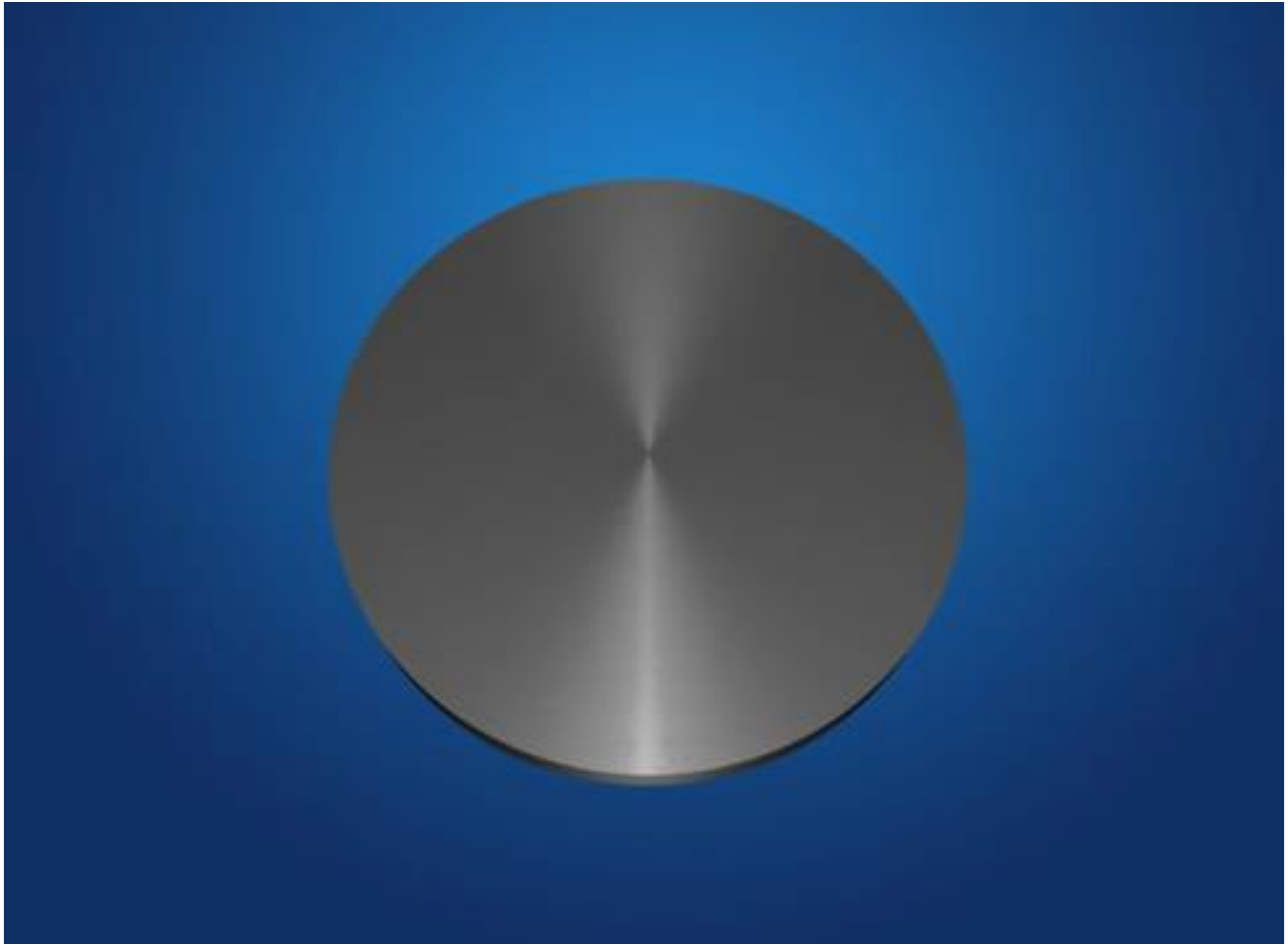
USM



Abrasive-Jet Machining (AJM)

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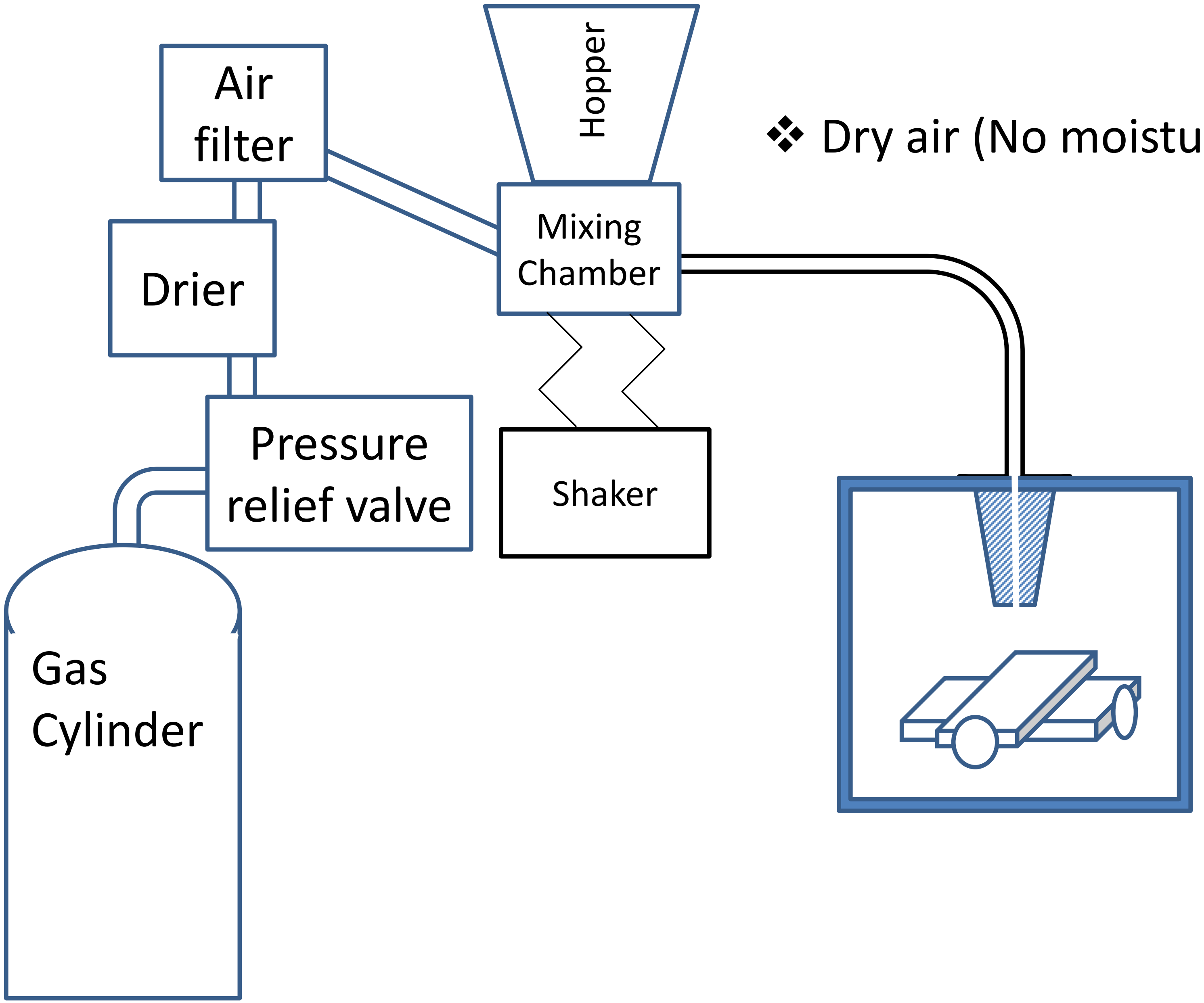


❖ Dry air (No moisture): To prevent agglomeration

Abrasive-Jet Machining (AJM)

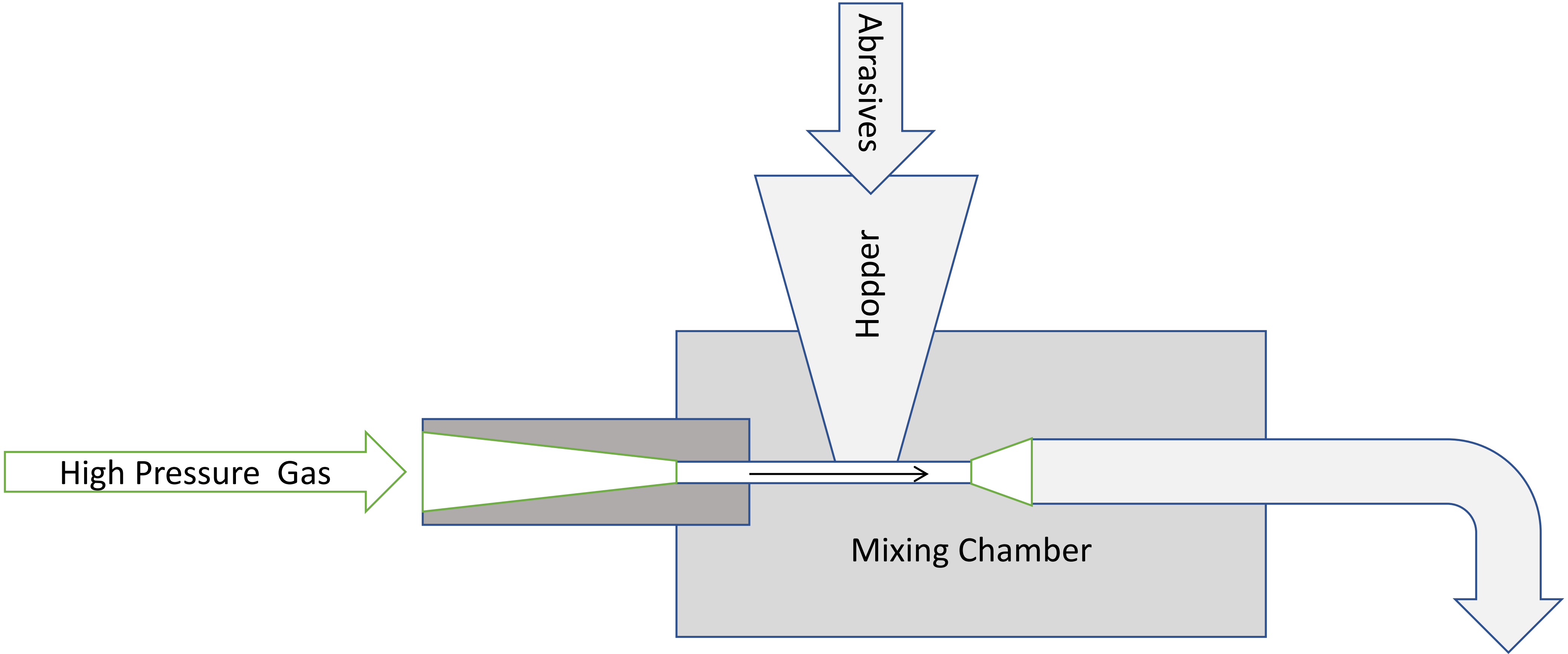
- AJM is a refined and controlled process.
- Abrasives are carefully selected and controlled. Used for finishing work as well as machining operations like cutting, grooving etc.
- Advantages : Inherent cooling mechanism in the system and the ability to machine fragile, heat sensitive components and the ability to cut out intricate patterns out of brittle, sheet-like materials.
- Finishing operations : Deburring, trimming, cleaning of internal passageways, forming radii on rough edges, removing rough surfaces on castings

Abrasive-Jet Machining (AJM)

- Gas supplied from cylinder or compressor.
- Gases : Air / Argon / N_2/ CO_2
- Pressure : 5 kgf/cm^2 (approx.)
- Air/gas needs to be dried : Moisture can cause agglomeration and clogging
- The air / gas needs to be free from dust particles
- To introduce the abrasive particles into the gas stream, there is a mixing chamber. Here, abrasives are pre-loaded and may be entrained by the air jet which is let in from high pressure through a thin inlet.

Abrasive-Jet Machining (AJM)

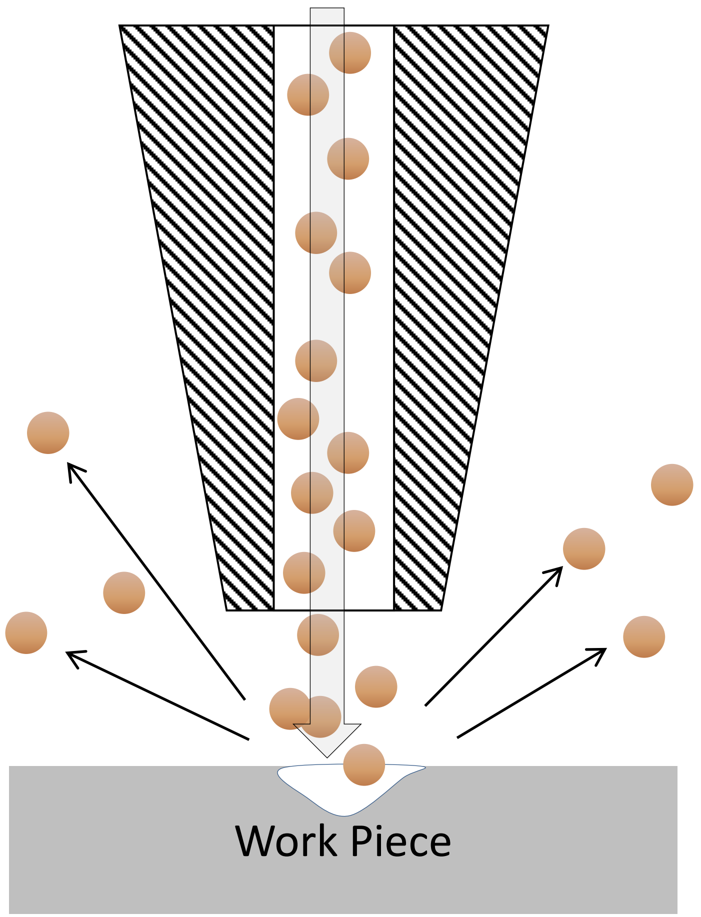
- In the mixing chamber, the abrasives get entrained by the high velocity jet of carrier gas (Venturi effect). The abrasives might also be fed by back pressure applied on the hopper
- **Nozzle** : Generally made of hard wear resistant materials like WC or Sapphire. The inner diameter may be around 0.2 - 0.8 mm.



Applications of AJM

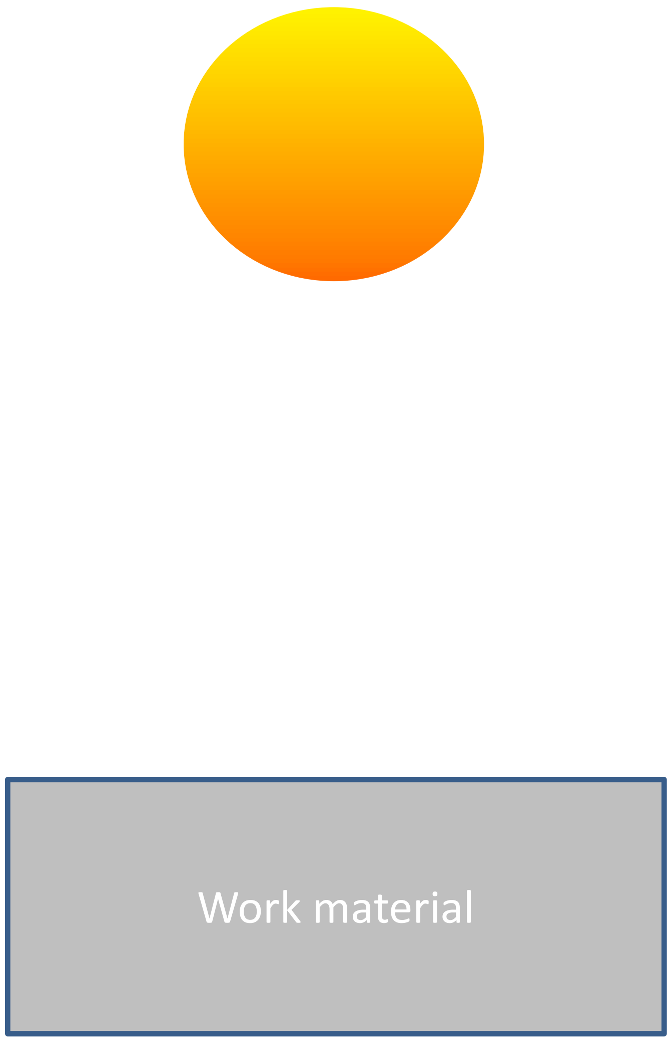
1. Abrading and frosting glass, ceramics and refractories
2. Cleaning of smears, oxides, resistive coatings
3. Manufacture of electronic devices
4. De-flashing, trimming of parting lines
5. Engraving on toughened glass
6. Micro fabrication
7. Cutting, drilling, grooving materials like glass, quartz, sapphire, mica, ceramics, germanium, silicon and gallium.
8. Deburring milled parts and small holes.

Abrasive-Jet Machining (AJM)



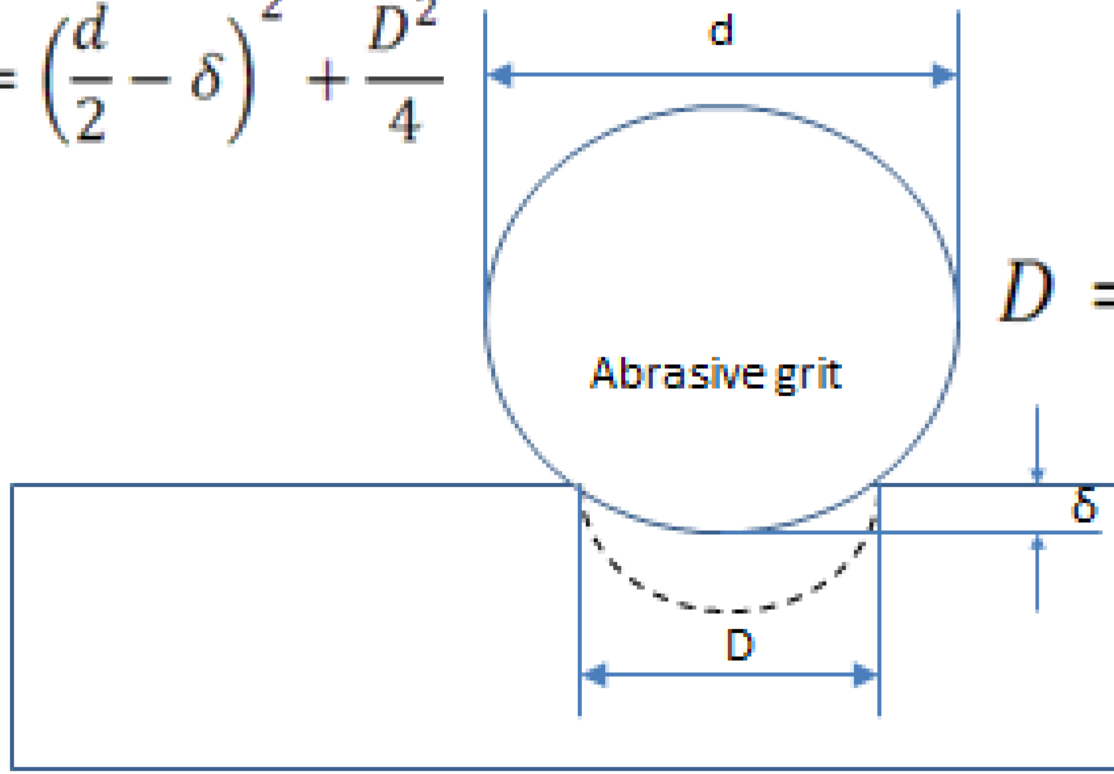
- **Material Removal:** By impact erosion of work material with abrasive grits at speeds of 150 – 300 m/s
- ***Abrasive acceleration*** *:* By a gaseous medium at high speed
- ***Abrasives*** *:* Al_2O_3, SiC.
- ***Typical size range*** *:* 10 - 50 microns
- ***Applications*** *:* Cutting small holes or slots, drilling, deburring and micro-machining of brittle non-conducting materials like glass, ceramics, semi-conductors, composites and heat-sensitive, fragile materials

How is material removed ?



Abrasive grit, indentation depth and material removal

$$\frac{d^2}{4} = \left(\frac{d}{2} - \delta\right)^2 + \frac{D^2}{4}$$



$$D = 2\sqrt{(d \times \delta)}$$

Material removal rate (MRR)

- **<u>Assumption (Energy Balance)</u> : Kinetic energy of the grit is completely converted into the plastic strain energy of the material or plastically straining the work material**

$$\frac{1}{2} * m * V^2 = \boxed{\frac{1}{2}} * \boxed{F * \delta}$$

Force x Displacement = Work Done

½ F - Mean Force

- **m** – Mass of the abrasive grit ; **V** – Velocity of the grit; **F** – Force for plastic deformation; $\boldsymbol{\delta}$ – Indentation (depth) due to plastic deformation.

Energy Balance

$$\frac{\mathbf{1}}{\mathbf{2}} * \boldsymbol{m} * \boldsymbol{V}^{\mathbf{2}} = \frac{\mathbf{1}}{\mathbf{2}} * \boldsymbol{F} * \boldsymbol{\delta}$$

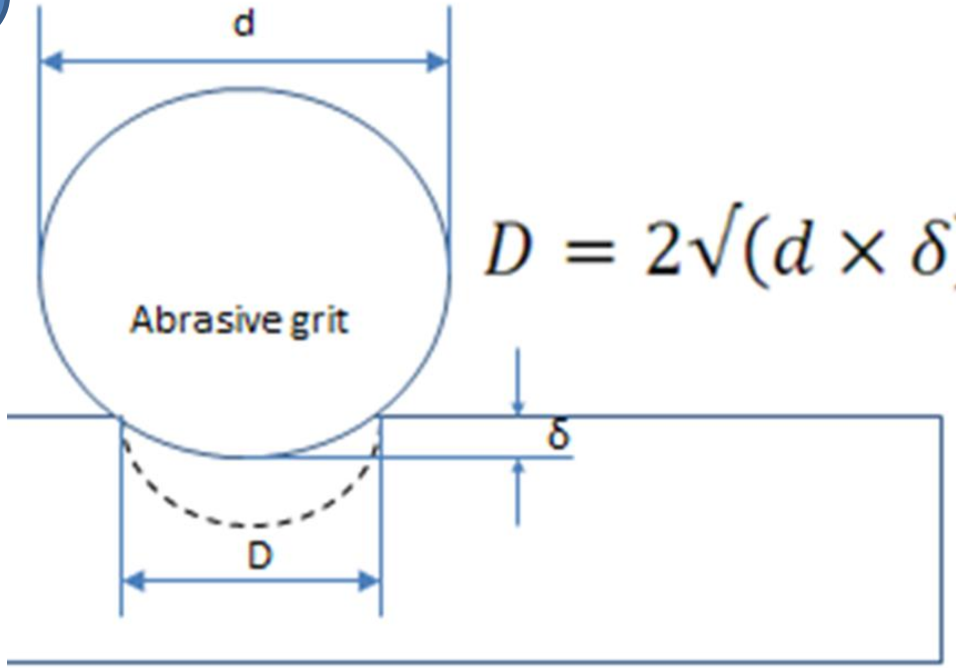
Projected Area

$$\frac{1}{2} \times \rho \times \frac{\pi d^3}{6} \times V^2 = \frac{1}{2} \times \boxed{\frac{\pi D^2}{4}} \times \boxed{\sigma_w} \times \delta$$

Flow Stress

$$\sigma_w \approx H$$

$$\delta = \sqrt{\frac{\rho}{6H}} \times d \times V$$



$$D = 2\sqrt{(d \times \delta)}$$

- **H** – Hardness of the material

Material removal rate (MRR)

MRR = Material removed due to single impact * Number of impacts per unit time (or per second)

Number of impacts per unit time = Mass flow rate of the abrasives / Mass of one abrasive particle

Number of impacts per unit time = Mass flow rate of the abrasives/ (Volume of one abrasive * density of the abrasive)

Number of impacts per unit time $= \dot{M} \Big/ \left(\frac{\pi}{6} d^3 \times \rho\right)$

MRR = Material removed due to single impact * Number of impacts per unit time

$$M.R.R. = \frac{{}^{\pi}/_{12} * D^3 * \dot{M}}{{}^{\pi}/_{6} * d^3 * \rho}$$

But $D = 2\sqrt{(d \times \delta)}$ and $\delta = \sqrt{\frac{\rho}{6H}} \times d \times V$

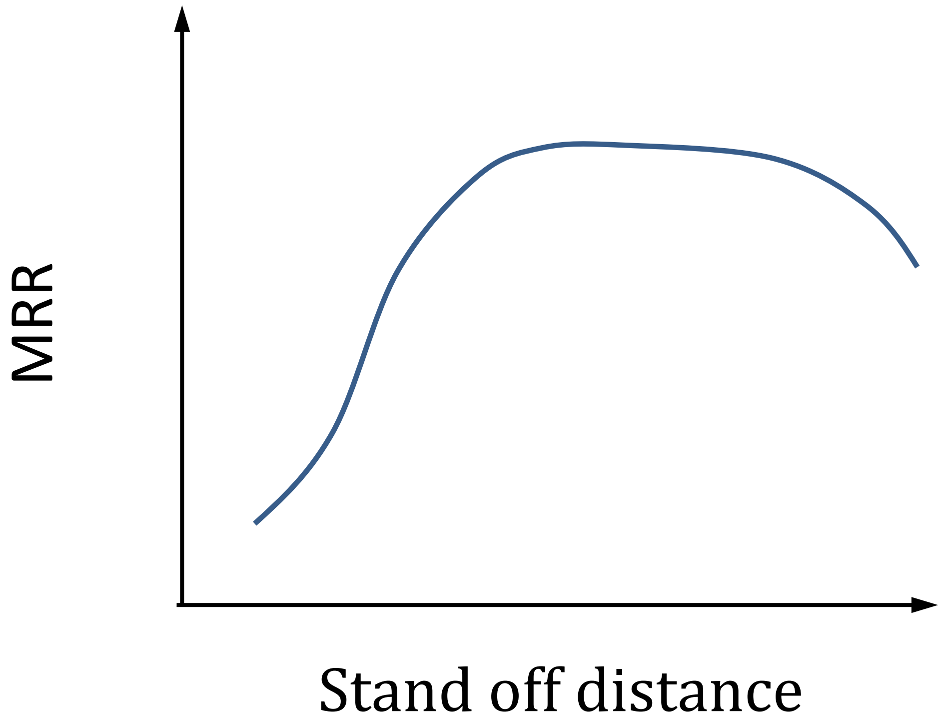
$$\text{M.R.R} = 1.04 \times \frac{\dot{M}.V^{3/2}}{\rho^{1/4}.H^{3/4}}$$

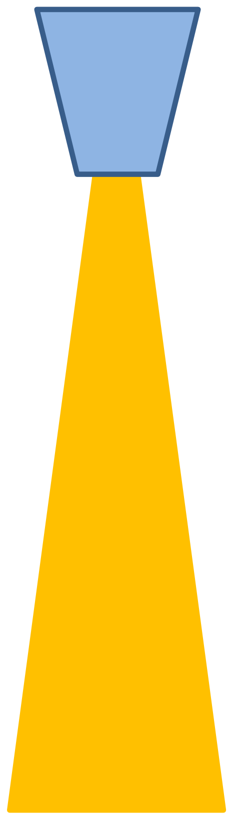
- A student in a laboratory is determining the ratio of δ/d_g, where δ is the depth of indentation caused by a single abrasive SiC grit in AJM. The density of the grit is 3.2 g/cc, diameter is 50 µm. The workpiece material is glass of hardness = 2660 N/mm^2 . The abrasive grit velocity is 200 m/s and jet diameter d=2 mm. The student plans to scaled-up and simulate the experiment using a tungsten carbide (density 15.8 g/cc) ball of diameter 5 mm diameter, and glass with Hardness 2500 N/mm^2 as work piece material. For proper simulation of the actual situation, what should be the velocity imparted to the tungsten carbide ball impacting the glass surface.

ANS : V = 87.5 m/s

Effect of Process Parameters

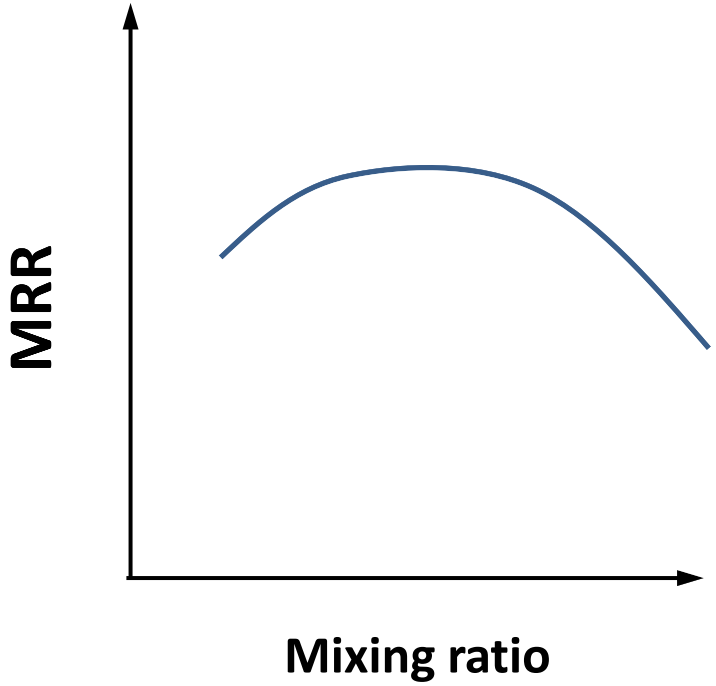
Stand off Distance : Distance between the tip of the nozzle and the work piece

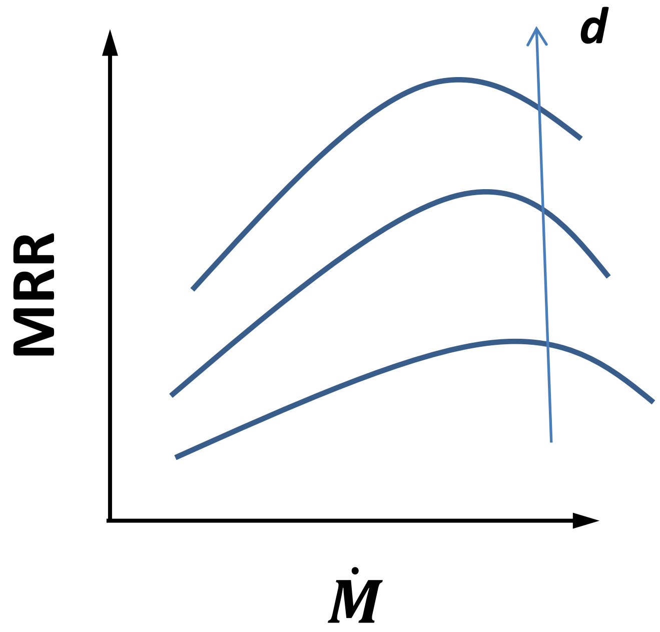




As the stand off distance increases, the MRR first increases, flattens out and ultimately falls off.
Range : 0.75 mm to 15.0 mm

Effect of Process Parameters





$$\text{MRR} = 1.04 \times \frac{\dot{M}.V^{3/2}}{\rho^{1/4}.H^{3/4}}$$

As mixing ratio increases, the MRR rises, as $\dot{M}$ increases , but the jet speed starts getting reduced, so that the MRR ultimately drops

If the abrasive mass flow rate increases, the MRR increases, but the jet velocity gets reduced and thus the MRR ultimately drops

Hybrid Machining Systems

- Abrasive machining and Electrodischarge Machining
- Abrasive Machining and Electrochemical Machining

Thank you