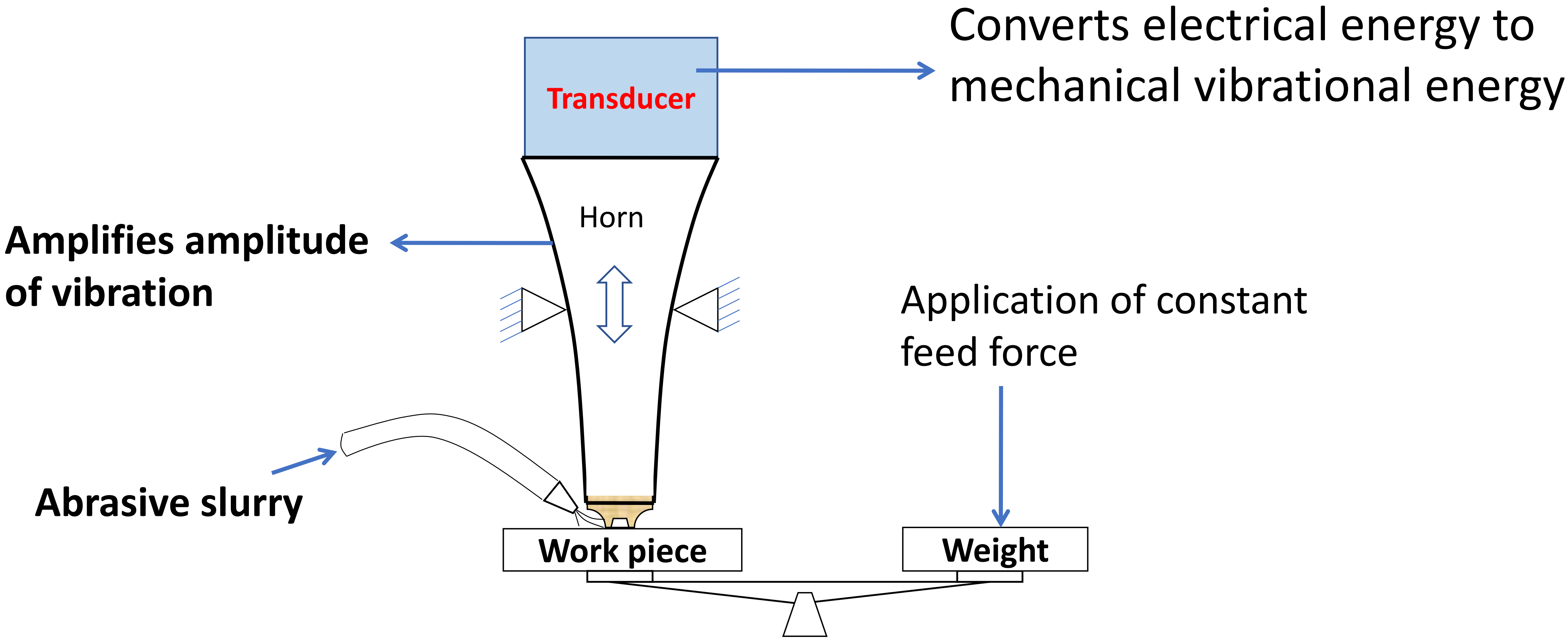
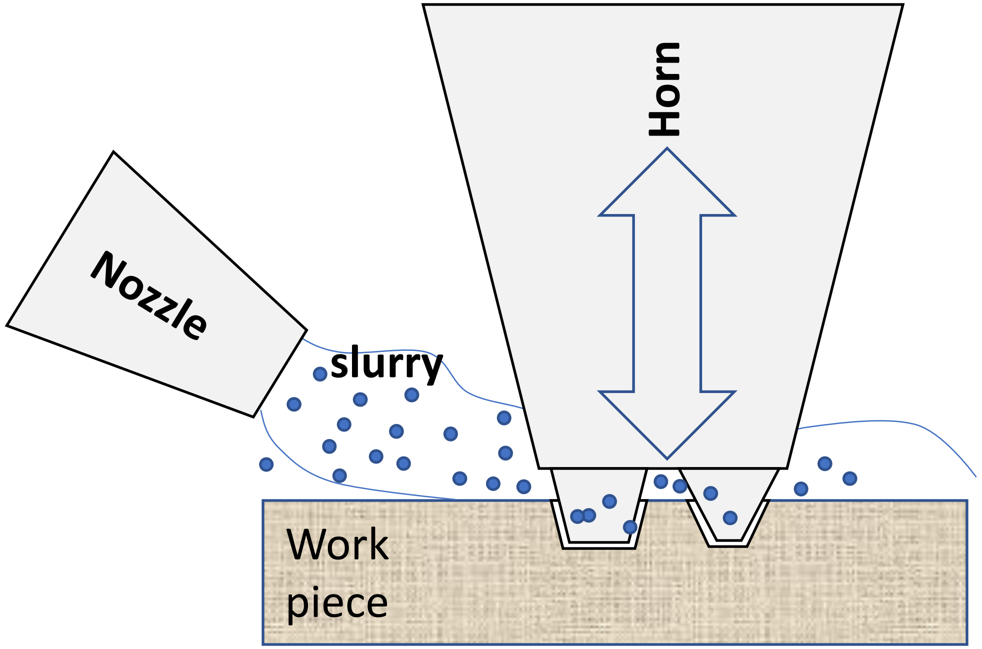
Ultrasonic machining

Ultrasonic machining : Support systems

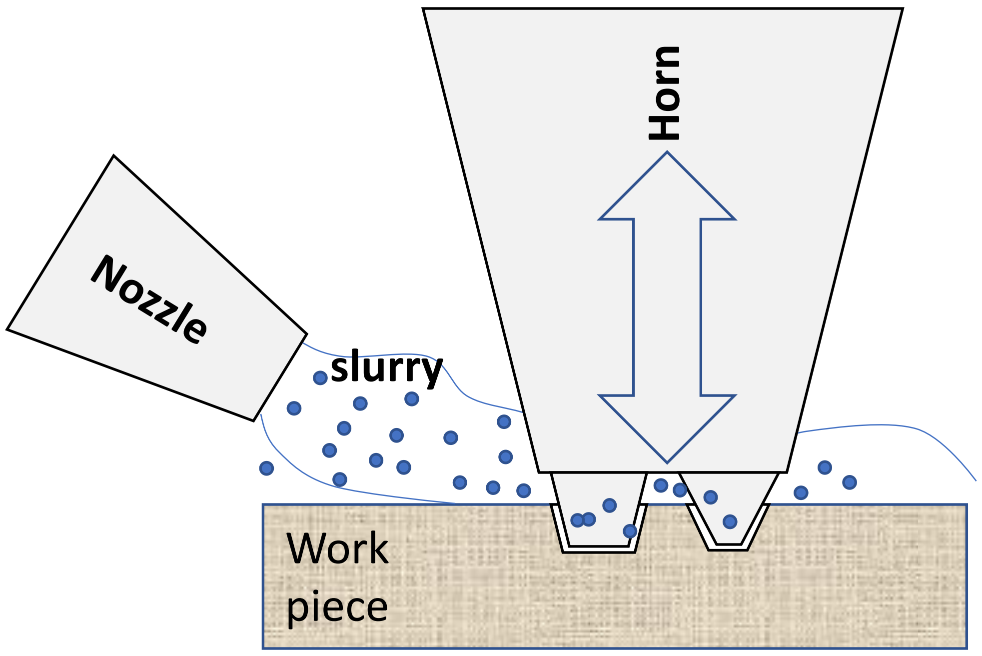


USM machining zone



Material removal mechanisms in USM

- USM – Machining Brittle Materials
- **Material removal primarily due to indentation of abrasives on the brittle work piece material**.
- Apart from brittle failure due to indentation, material due to solid-solid impact erosion due to free-flowing impact of the abrasives. (in significant for practical purposes)

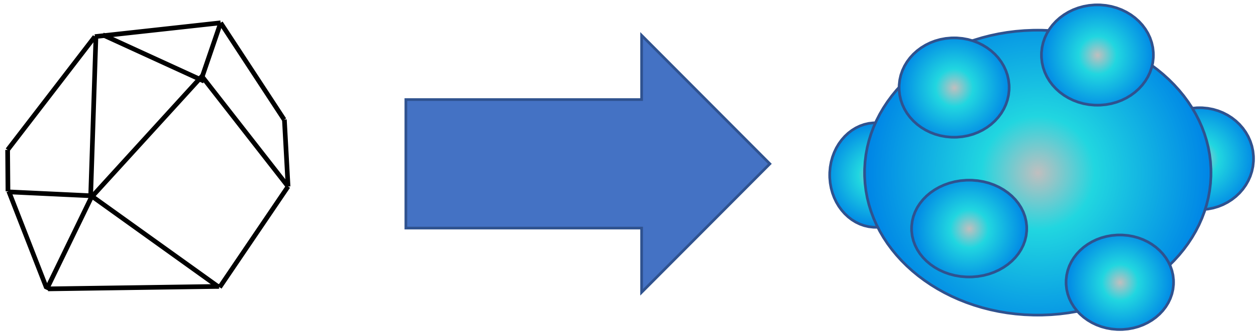


- Tool vibrations lead to indentation by the abrasive grits
- Indentation : Hertzian contact stress more than the flow strength of the material – Brittle crack development.
- Tools Materials – Ductile, High strength, tough – Steels, stainless steels and other alloys.

USM : Process parameters

- Amplitude : 10 – 50 micron
- Frequency of vibration : 10 – 25 kHz
- Feed Force – Tool is given downward force
- Feed Pressure – F/A of the tool
- Flow strength of the working and tool material
- Contact area of the tool
- Volume fraction of the abrasives in the slurry : 20 % to 60 %
- Abrasive size – 15 to 150 micron – Alumina, SiC, B_4C

How is the abrasive considered in analysis



Material removal mechanisms in USM (Derived in Class)

- The material removal rate $\propto \dfrac{c^{0.25} \times A^{0.25} \times F^{0.75} \times a^{0.75} \times \mu^{0.75} \times dg \times f}{\left(\sigma_w(1+\lambda)\right)^{0.75}}$

- Q1 - USM (ultrasonic machining) is carried out on work material A and work material B. The tool is made of material C. The material removal rate for machining material A with tool material C is M_{AC} and that for machining material B with tool material C is M_{BC} . If the hardness values of A, B and C are 7000, 5000 and 1000 (all in N/mm^2) respectively, find the ratio $\frac{M_{AC}}{M_{BC}}$

Problem on hardness of tool and work material

- Q1 - USM (ultrasonic machining) is carried out on work material A and work material B. The tool is made of material C. The material removal rate for machining material A with tool material C is M_{AC} and that for machining material B with tool material C is M_{BC} . If the hardness values of A, B and C are 7000, 5000 and 1000 (all in N/mm^2) respectively, find the ratio $\frac{M_{AC}}{M_{BC}}$
- Given, MRR in case of ultrasonic machining is given by

$$\text{MRR} \propto \frac{c^{1/4} F^{3/4} a_o^{3/4} A^{1/4} d_g f}{\sigma_w^{3/4} (1+\lambda)^{3/4}} \mu^{3/4}$$

- F = Static force, A = Area of cross section of tool, Abrasive grit diameter = d_g, amplitude of vibration = a_o. Work piece material flow stress = Its hardness = σ_w , Tool material flow stress = Its hardness = σ_t, c= abrasive slurry concentration v/v, $\lambda = \sigma_w / \sigma_t$, $\mu = 1$ *Take hardness = flow stress*

- **Solution :**

➢ $M_{AC} = \frac{k}{7000^{3/4}} \times \frac{1}{\left(1+\frac{7000}{1000}\right)^{3/4}}$

➢ $M_{BC} = \frac{k}{5000^{3/4}} \times \frac{1}{\left(1+\frac{5000}{1000}\right)^{3/4}}$

➢ $\frac{M_{AC}}{M_{BC}} = \left\{\frac{5\times6}{7\times8}\right\}^{3/4} = \left\{\frac{15}{28}\right\}^{3/4} = \mathbf{0.6261}$

USM applications

- Used for machining hard and brittle metals, Ceramics (glass, carbides.. Etc.). Non-metallic materials (E.g., Germanium, Silicon) etc.
- Used for machining holes (square or circular cross sections), irregular holes, impressions.
- Suited for thin cross-sections.
- Machining wire drawing, punching dies or small blanking dies.
- Limitations : Low MRR, tool wear. Sometimes depth of the holes is limited.

Homework problem:

- Determine the ratio of material removal rates for an USM operating cutting WC (Tungsten Carbide) plates when the tool material is changed from copper to stainless steel. The hardness of WC is 12750 MPa, Copper is 343 MPa, and Stainless steel is 1275 MPa.