Advanced Manufacturing Processes (AMPs)

Advanced Water Jet Machining Process (AWJM)

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Chapter Description

- Aims
  - To provide and insight on Abrasive Water Jet Machining (AWJM)
  - To provide details on why we need AWJM and its characteristics
- Expected Outcomes
  - Learner will be able to know about AWJM
  - Learner will be able to identify role of AWJM in todays sceneries
- Other related Information
  - Student must have some basic idea of conventional manufacturing and machining
  - Student must have some fundamentals on materials
- References

  Lecture Notes of Mr. Wahaizad (Lecturer, FTeK, UMP)

ABRASIVE WATER JET MACHINING (AWJM)

1974 – Invented, Originally used to uncontaminated metal surfaces before their treatments.

1985 – automated waterjet system was tested.

1990 – study on precision cutting using AWJ.

- AWJM uses filtered water **compressed** to up to 480 MPa (60,000 psi) mixed with **abrasive**s and directed through a **nozzle**.
- Water jet cutting action occurs as a result of high pressure water being forced through a small orifice.
- Pressurized water exits orifice as a coherent waterjet stream, which produces a clean cut with minimal kerf.
- Kerf material (chip) is taken away by the waterjet.

In AWJM, the water is not the primary force anymore, but the **abrasives**.

When coupled with suitable motion-controlled system, AWJM provides accurate cuts with high repeatability.

Advantages of adding **abrasive** particles to water jet:

- cutting **efficiency** increases greatly (example: titanium plate up to 200 mm can be cut)
- problem of **'jumping' over** hard materials in composites is eliminated, cut surfaces are much smoother.

Abrasive type: **garnet** is most commonly used.
Other types: **silicon carbide**, **aluminium oxide**, etc.

For foundry application (to cut gates and risers) **foundry sand** is used although garnet is 30 % more effective.

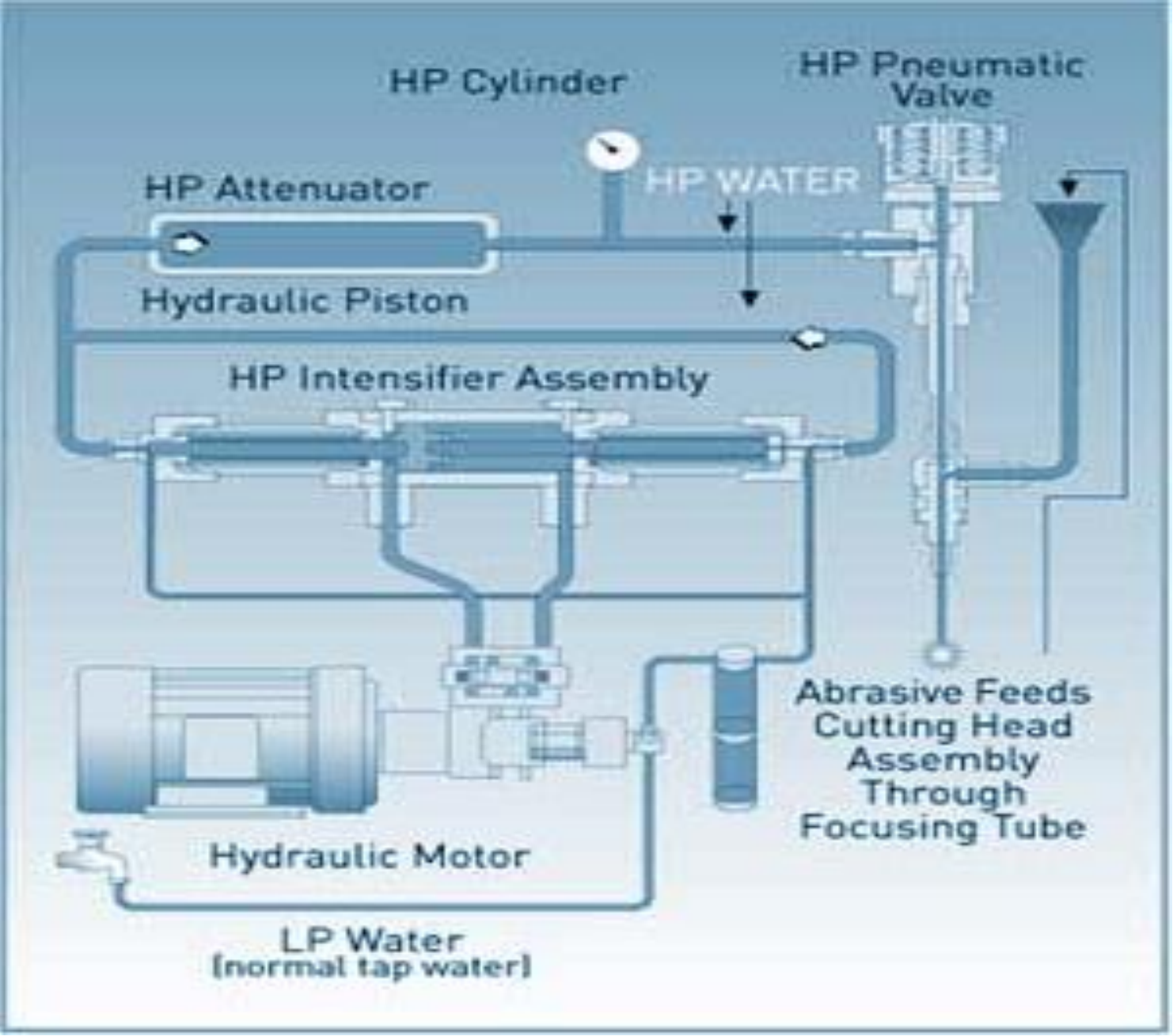
EQUIPMENT

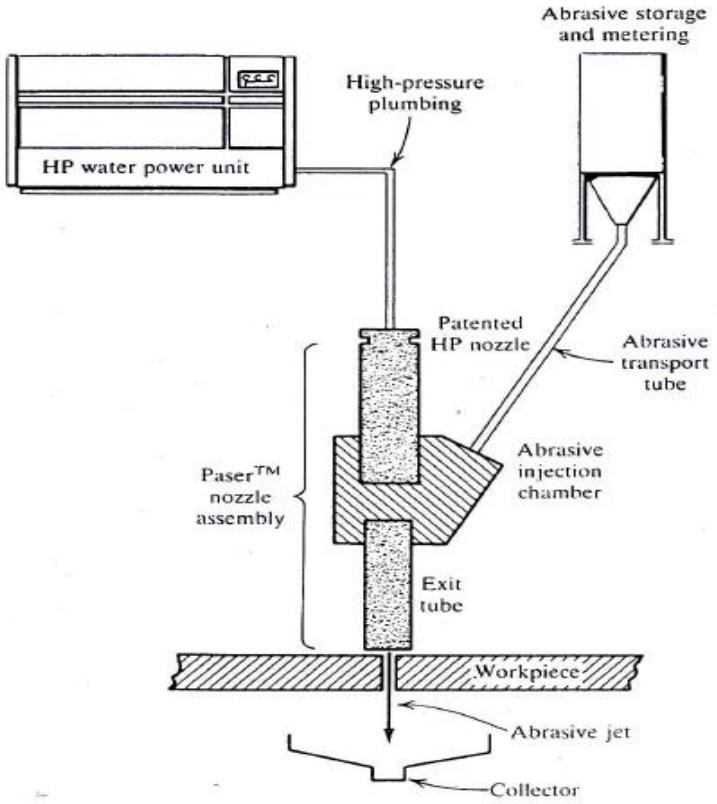
Three major components in AWJM

- **Intensifier** – houses pump to generate the required water pressure.
- **Nozzle** – made of hard material such as sapphire, ruby, tungsten carbide. Nozzle life up to 100 hours has been claimed. Small diameter nozzle makes a deeper and higher-quality cut than larger diameter.
- **Receiver** – catches the blast of abrasive-laden water and directs it to a sorting tank.

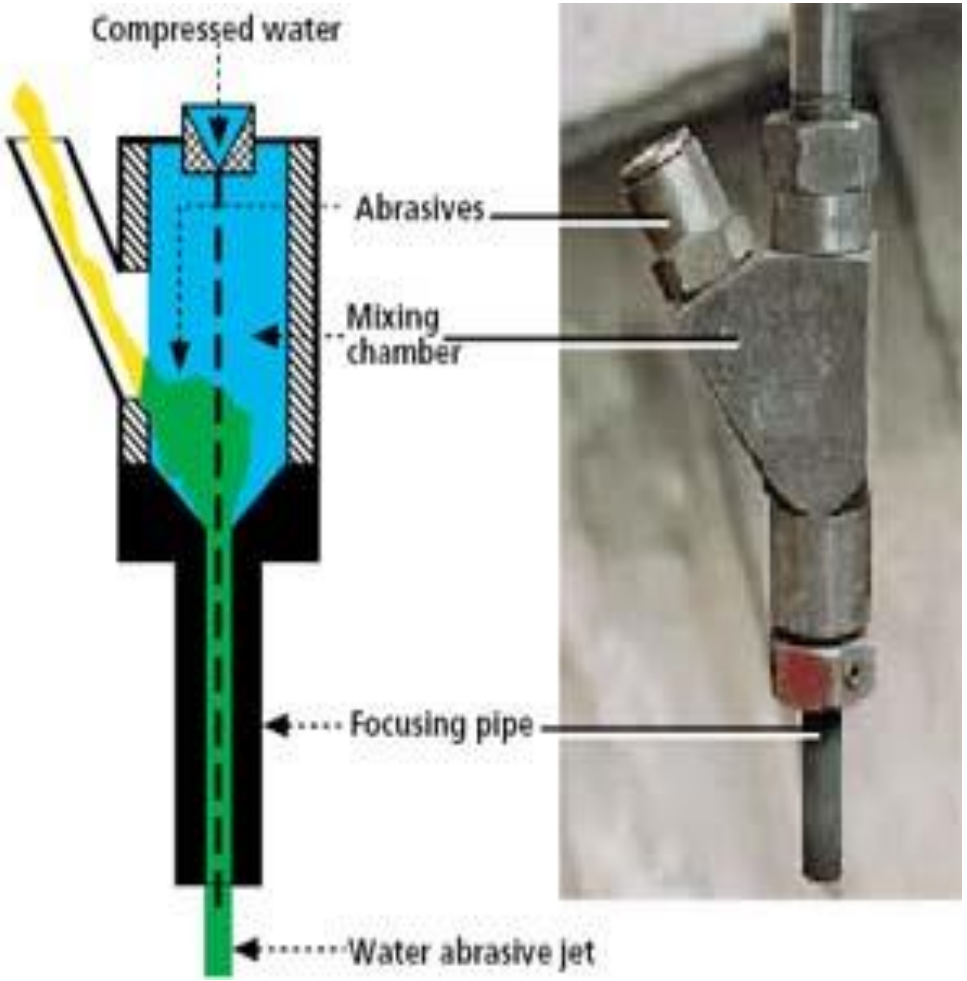
High-pressure intensifier and receiver are heavy and large. However, only cutting head needs to be manipulated.

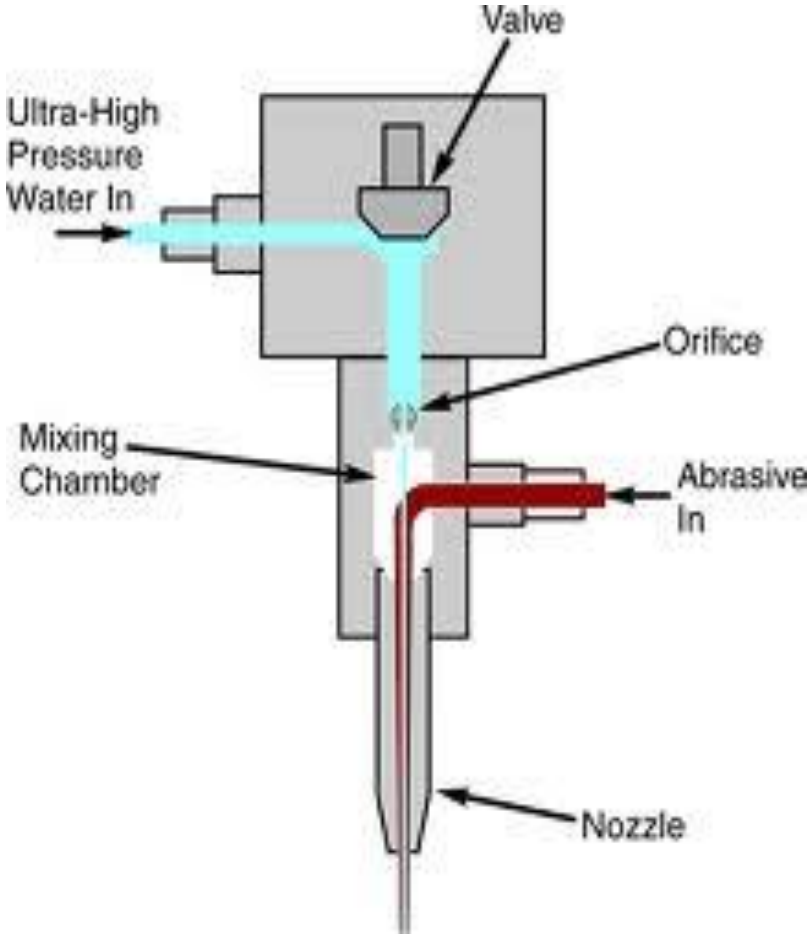
- **Manual** cutting station is available for freehand or template following.
- **Automated** system is also available. Special fixtures or robots are employed to guide the cutting head. Other systems use articulated arm, gantry or CNC tooling for accurate positioning.





Water jet gun equipped with an abrasive injection chamber





Large Range of Materials can be machined

- Thin and thick,
- Hard and soft,
- Brittle and flexible

Typical Materials

- Stainless Steel, Carbon Steel, Armored Steel
- Titanium, Aluminum, Brass, Copper
- Glass, Fiberglass, Bullet Proof glass
- Plastics, Laminates (G10, Kevlar, Mylar, Polyamide, etc)
- Marble, Tiles, Granites, Cement
- Composites, Acrylics
- Wood
- Inflammable materials
- Exotic alloys
- Ceramics, Foam, Rubber
- Gaskets
- Honeycombs

ADVANTAGES

Unlike conventional cutting tools, water jets are sharp in all directions. Robot arms can swing them quickly without regard to orientation

- ✓ Cuts are made without heat, leaving fine surface finish
- ✓ Wide variety of materials can be cut including ferrous and non-ferrous plate, composites of all types, thermoplastics, high strength alloys, elastomers, glass, ceramics and PCB
- ✓ Minimum waste, kerf may be 0.075 mm
- ✓ Airborne particles associated with many processes are eliminated, particularly useful in cutting asbestos, fibre glass, and other toxic materials.
- ✓ Cut edge is smooth requiring no further finishing.

Minimal Lead Time

- minimal tooling is involved
- fast set-ups and programming
- "nesting" minimises scrap and unused material
- software allows calculation of cutting speed so that maximum speed per quality per material type and thickness is always optimized

No Heat Affected Zone

Unlike laser or plasma cutting, in which the section of material can come under the chemically attack due to heat, water jet cut parts remain unpretentious, Since in AWJM water is used as medium. Use of water can be highly effective in all such applications where material cannot show any signs of burning or discoloration Or on all such meta/materials which is difficult to cut with laser due to heat sensitive nature.

Intricate features

Water jets generate very small side forces as they machine. Most of the energy is directed straight down on the material. As a result, it is possible to make parts with very thin features, such as the cheese cutter where the blade is less that 0.5 mm thick, and honeycomb piece with wall thickness of 0.6 mm

Cheese cutter; Stainless steel, blade thickness = 0.5 mm

Honeycomb part; Aluminium, t = 13 mm, wall thickness = 0.6 mm

Easy Programming

With final implementation and design involved, the end product looks exactly like the designer or engineer first imagined - utilizing a comprehensive CAD programme, or reverse engineering from a sample part. Machine manufacturers like MILCO use many different file extensions such as: dxf, iges, bitmap, jpg, ai, pdf, and dwg, etc.

Quality Finish

Compared to saw cut, plasma cut, and laser cutting; waterjet cut finish stands alone - a smoother more sandblasted look, free of burnt edges, chips, burrs, and slag: it can save the end user in unnecessary finishing cost.

Environmentally Friendly

By using natural mediums such as garnet and water, no hazardous or toxic fumes are released, and the residual waste can be disposed of in public or municipal site.

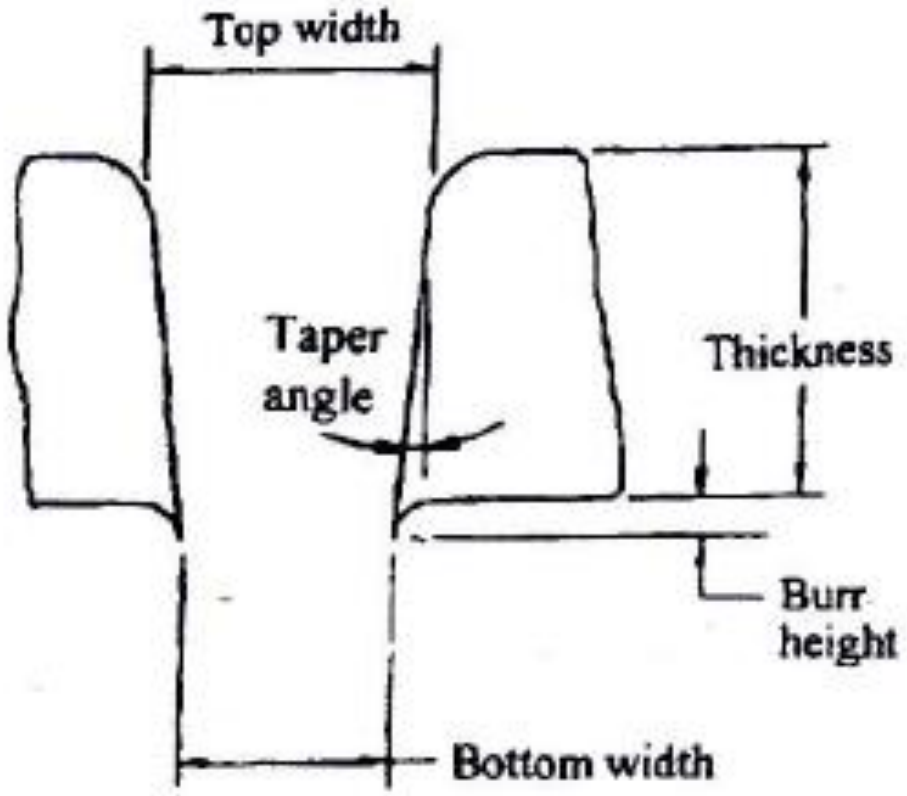
Limitations

- ✓ Greatest enemy of water jet is air. A 0.075 mm stream projected into the atmosphere will completely **vapourise** at about 600 mm from nozzle
- ✓ **Noise** can easily reach high decible level. Either working unit must be sound shielded or workers must wear ear protection
- ✓ Back pressures or reactive forces are present; however not a problem since working energy is concentrated into minute cross-sectional area at any given time
- ✓ Spent water and abrasive must be contained. Typical water consumption is 1 to 2 gal/min with 70 % evaporating during the cut.

ACCURACY

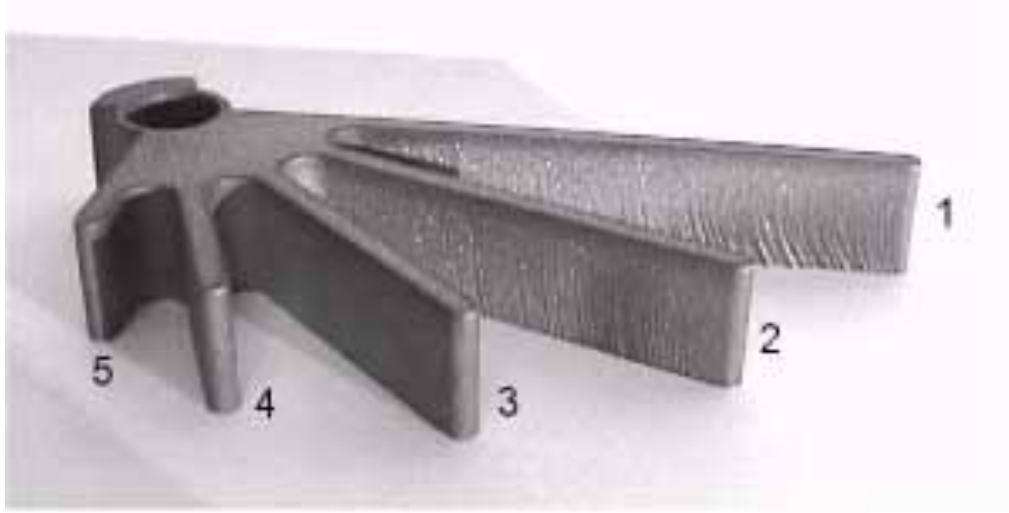
For larger machine (generally of gantry type): ± 3.8 mm. Intermediate (1.5 x 2.5 m envelop): ± 0.127 mm (± .005 in). High accuracy machine: ± 0.065 mm.

Kerf geometry



SURFACE FINISH

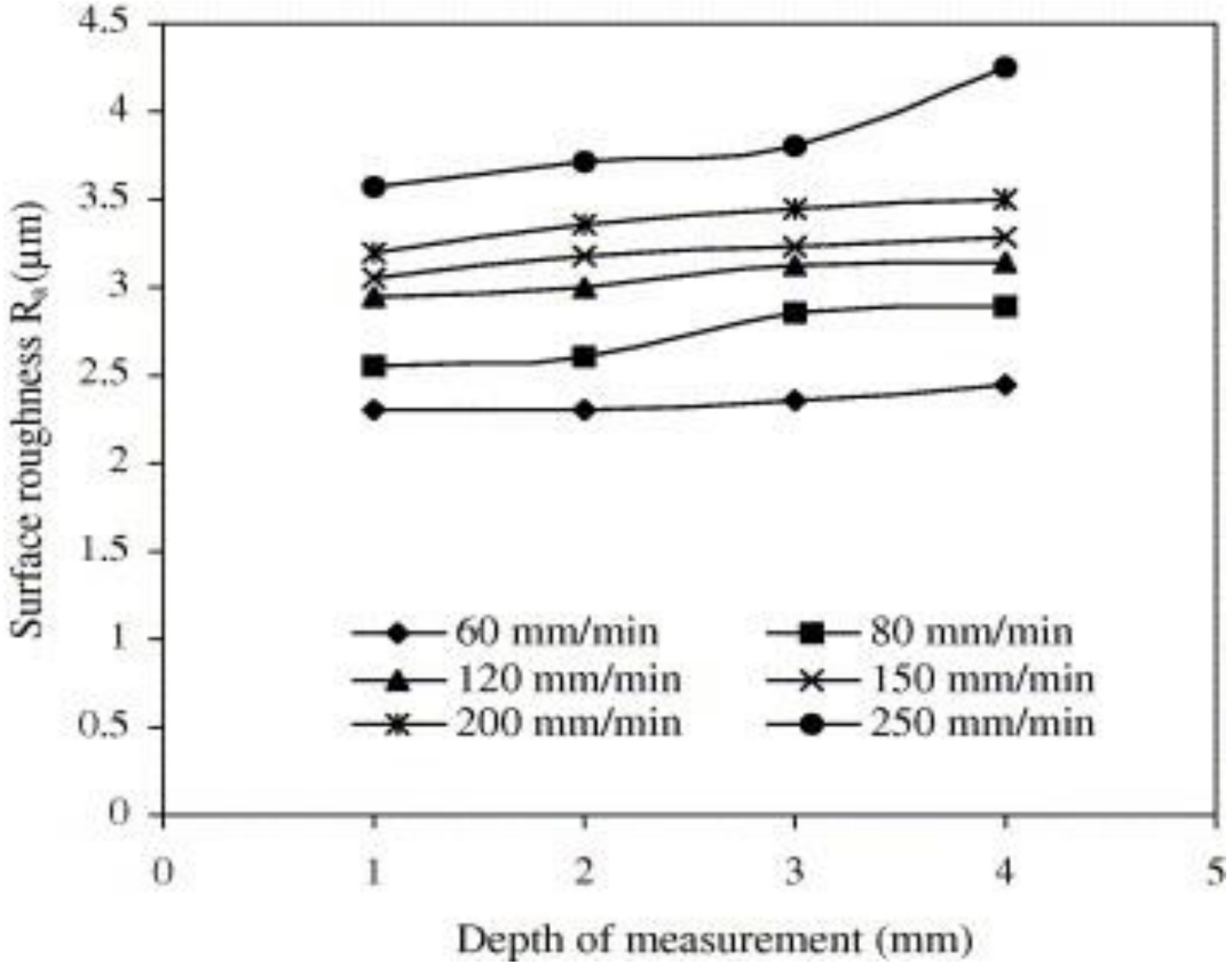
Freshly cut surface has a surface roughness of 3.8 to 6.4 μm



Asthetics

The cut surface can run from a smooth sandblasted appearance to an unpleasant, striated surface, contingent upon the speed at which the fly travels through the material.

At higher rates, the stream (Jet) squirms from side to side inside the cut, with most prominent at the base of the cut. The cutting velocity for a material ordinarily is communicated as far as the speed at which the stream can marginally separate the material. At that point parts are made at different divisions of this speed, contingent upon the surface quality required (see Figure).



[Ahmad Hascalik et al, Ti–6Al–4V alloy, 2007, Elsavier]

The separation speed is given by:

$$V = \left(\frac{fa \cdot M \cdot P^{1.594} \cdot d^{1.374} \cdot Ma^{0.343}}{163 \cdot Q \cdot H \cdot Dm^{0.618}} \right)^{1.15}$$

where:

P = Stagnation pressure of the water jet in thousands of psi (Ksi), typically 50,000

d = Orifice diameter in inches, typically 0.014

Ma = Abrasive flow rate in lb./min. typically 0.8

fa = Abrasive factor (1.0 for garnet)

Q = Quality - set to 1.0 to calculate separation speed and modify as required

H = Material thickness in inches

Dm = Mixing tube diameter in inches, typically 0.030 to 0.040

V = Traverse speed in inches/min.

- Real parts will be made at 10 % to 50 % of the separation speed, depending on the surface finish and corner qualities required.
- As the thickness is doubled, the cutting speed is more than halved.

APPLICATIONS

AWJM can cut harder materials than WJM. Examples: glass, metals, superalloys, ceramics, concrete. AWJM is very suitable for advanced ceramics which are used more and more in aircraft industry, especially in military aircraft.

Machinability (M) of Various Materials:

Material	M
Hardened Tool Steel	80
Mild Steel	87
Copper	110
Titanium	115
Aluminum	213
Granite	322
Plexiglas™	690
Pine Wood	2,637

Pressure: 320 MPa; Orifice diameter: 0.46 mm; Nozzle dist.: 3 mm; Abrasive: garnet; Abrasive rate: 1.7 kg/min.		
Material	Thickness (mm)	Cutting speed (mm/min)
Titanium	31.75	50
Hy-80 steel	19	50
Hy-80 steel	50	38

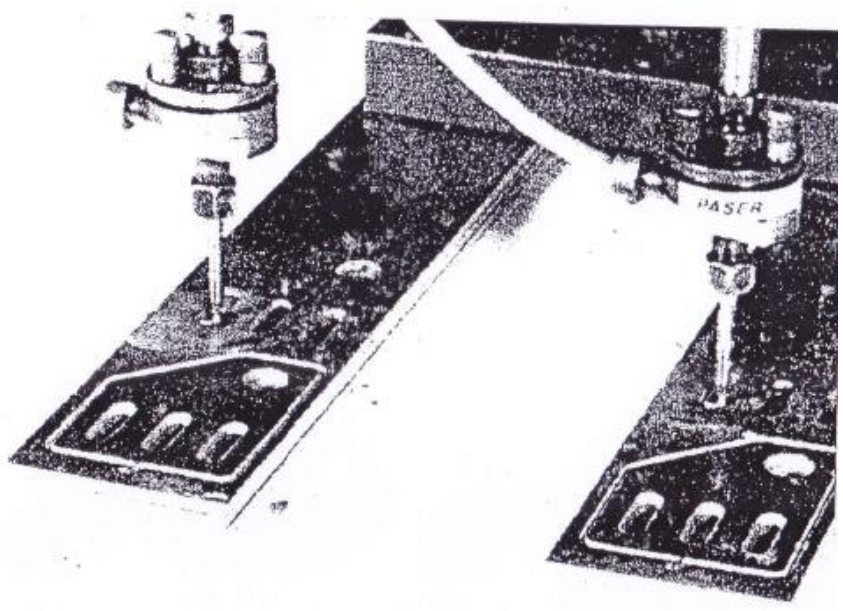
Table I Cutting data for water with abrasive

Material	Thickness mm	Cutting speed mm/min	Pressure bar
Al casting	6	600	3,300
Carbon steel	3	430	3,300
Inconel 600	16	95	3,300
Stainless steel	14	120	3,300
Titanium	6	380	3,300

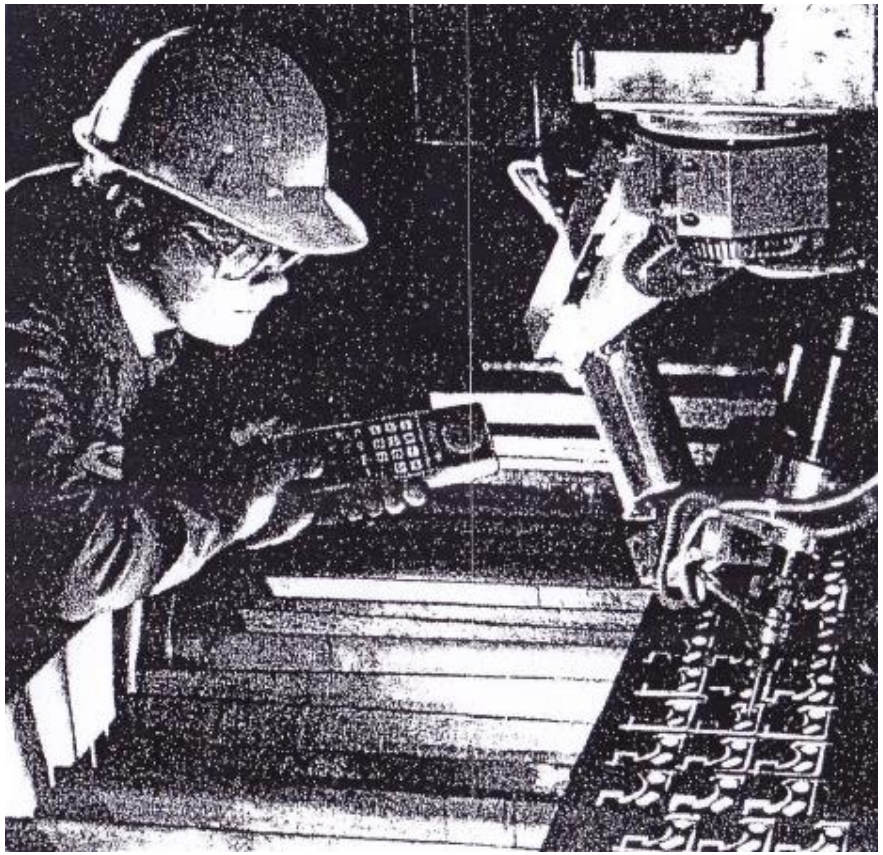
Note: Cutting speeds calculated with software using 0.35/1.1 orifice/focus combination; 400 g/min abrasive, Barton 80 mesh

AWJM can cut 1.7 mm thick gray cast iron at 910 mm/min and 22.5 mm thickness at 100 mm/min. 355 mm concrete slab or 75 mm thick tool steel plate at 38 mm/min in single pass.

Another application: concrete bridge inspection – portable AWJM can slice thick slabs of reinforced concrete to expose steel framework. This permits easy inspection of framework, requires less extensive clean-up, and is less expensive than using jackhammers and saws.



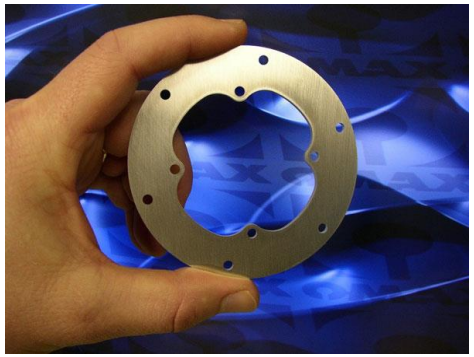
Twin nozzles and stacking multiple sheets to increase production

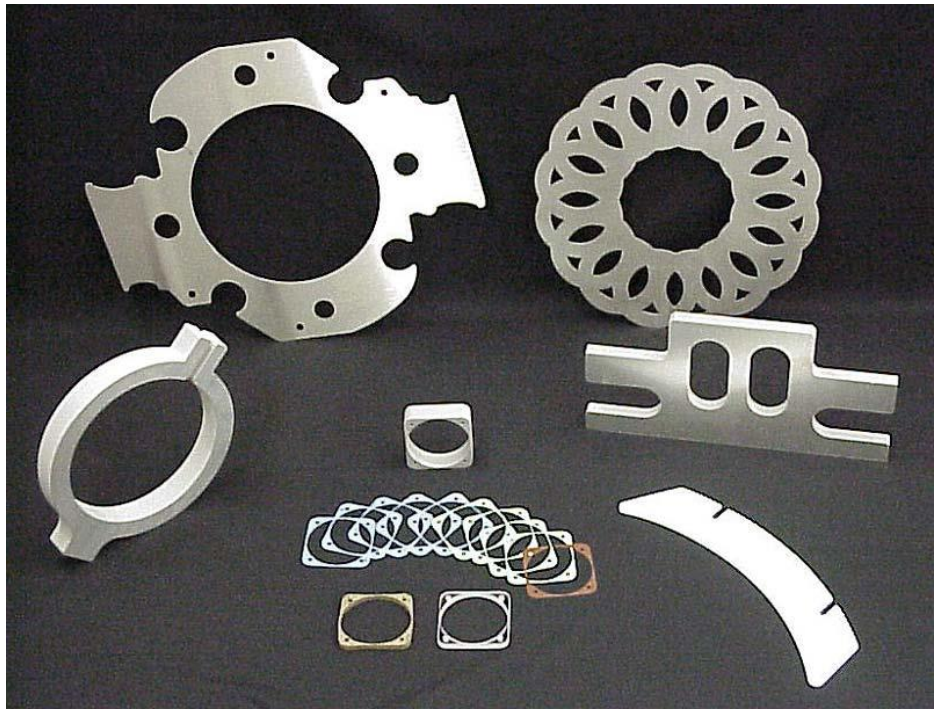


Mass producing parts [*Flow, Inc, Kentucky*]

Examples of applications:

- Automotive





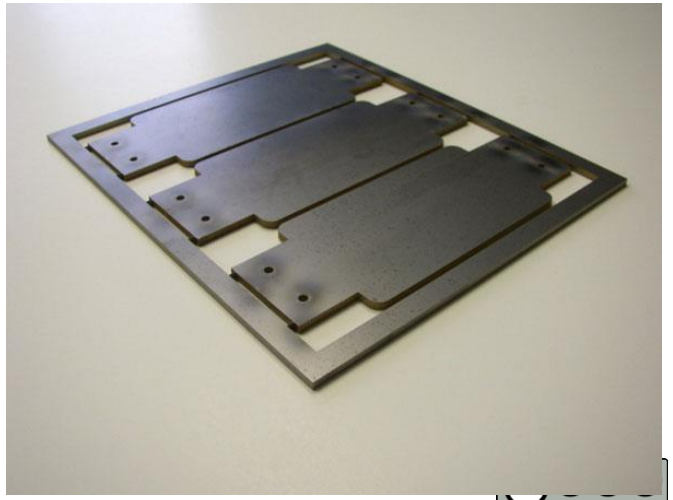
[*JRD Technocrafts*]

Freehub cog (6Al-4V titanium; t = 2 mm)

Examples of applications:

- Mechanical

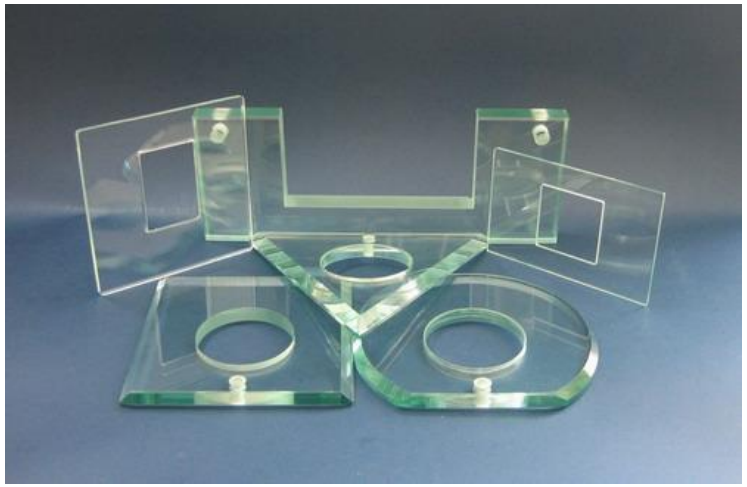
[*JRD Technocrafts*]



Examples of applications:

❖ Glass products

[*JRD Technocrafts*]



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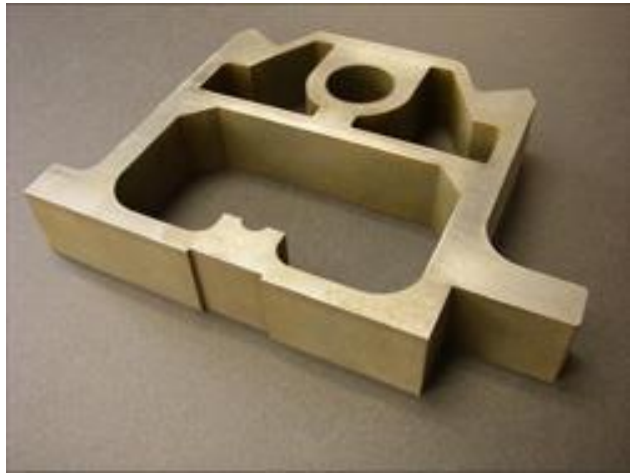

[CAMM Metals]

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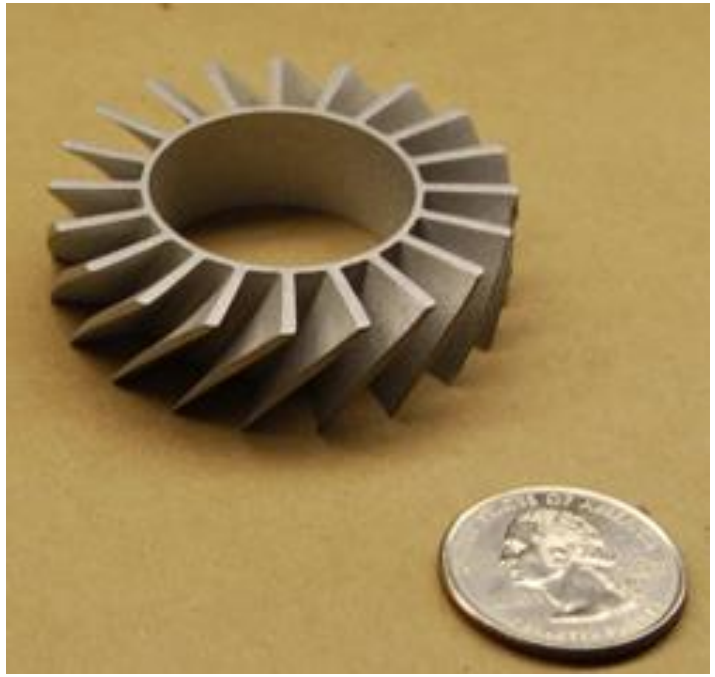

Bevel cutting using tilting head and 5-axis system

Tilting head

PARAMETERS

Design and dimension of orifice, mixing tube and nozzle.
Properties of workpiece material, abrasive material and particle size. Abrasive mass flow rate. Jet velocity or water pressure. Traverse or feed speed. Jet impact angle. Standoff distance.

COMPETITIVE PROCESSES

LBM may be more cost-effective at cutting metal thicknesses less than 9.5 mm, but AWJM may be better for thicker metals.

In some situations, PAM can cut faster but heat-affected zone might make it prohibitive.

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