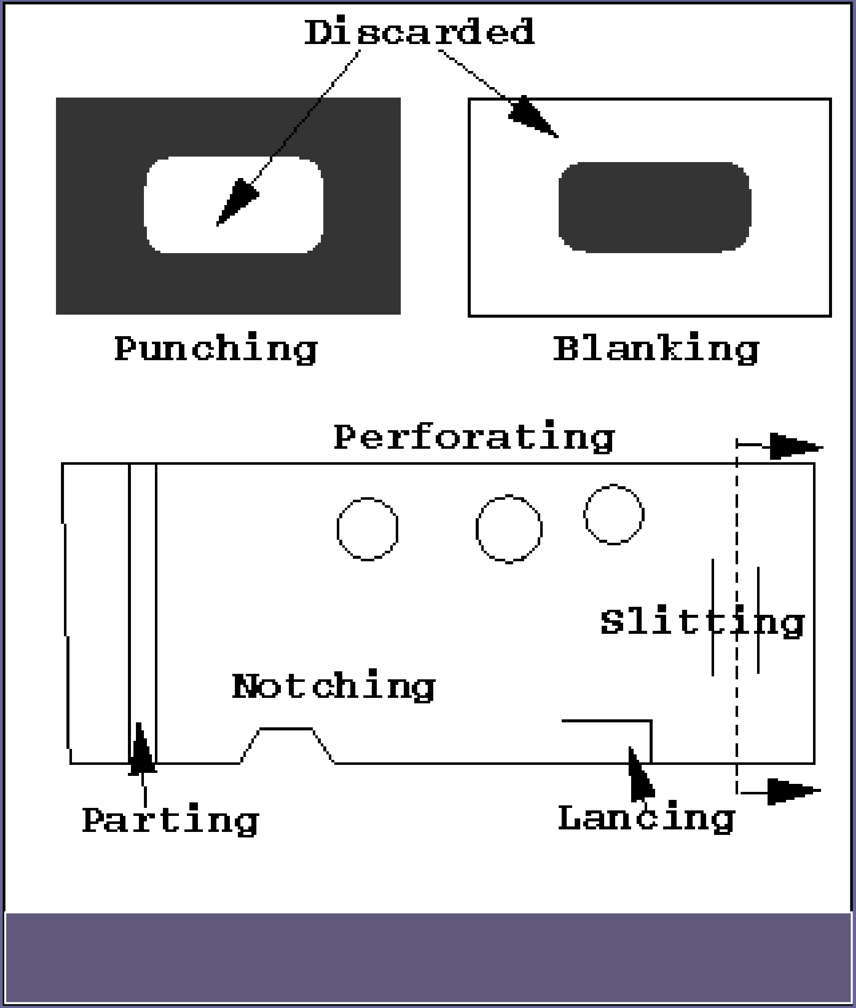
Profiling Sheet Metal

Blanking and Piercing

Sheet Metal Cutting Methods

Cutting operations:

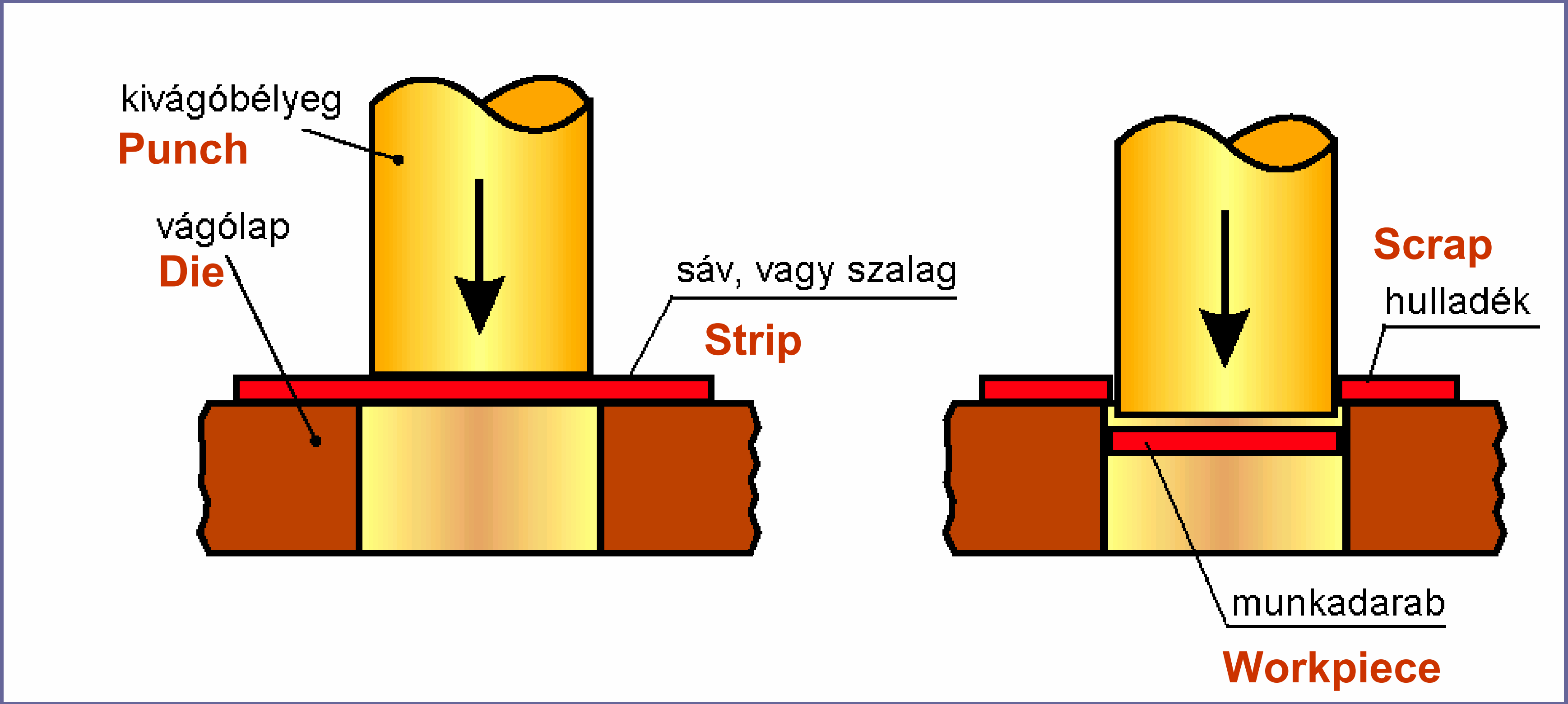
- Blanking
- Piercing
- Cutoff
- Parting
- Notching
- Lancing



Blanking

- The cutting of the complete outline of a workpiece in a single press stroke
- It involves some material waste
- Fastest, and most economical way to make flat parts
- Large quantities

Blanking tool

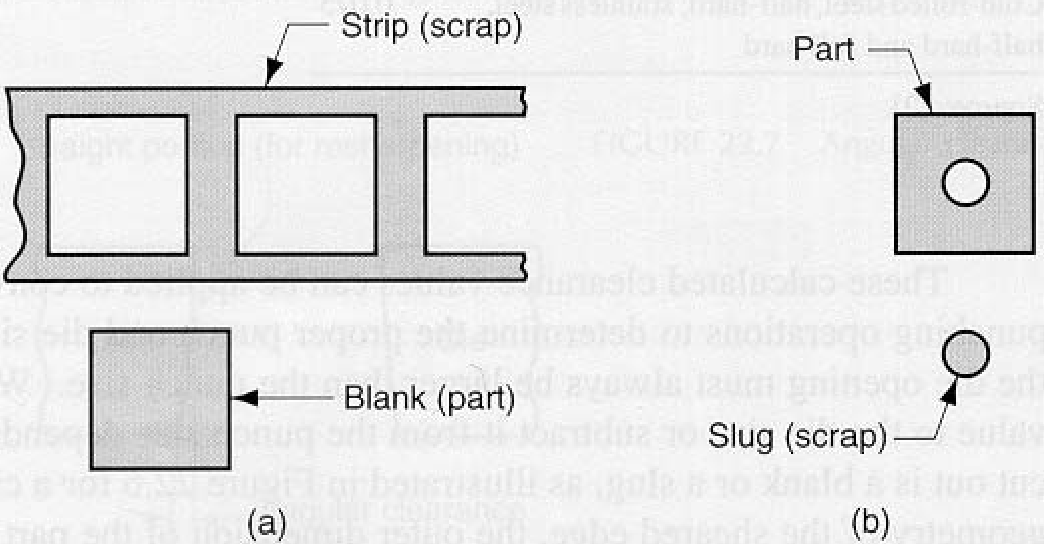


Blanking is the cutting of the complete outline of a workpiece

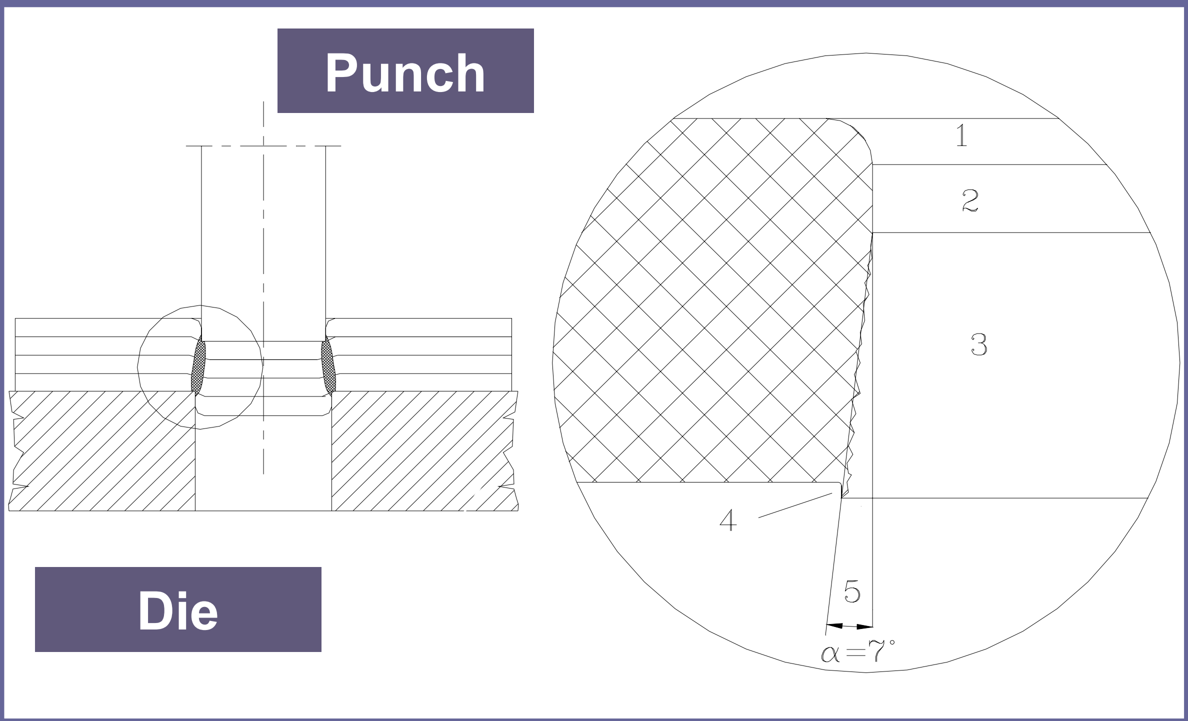
Piercing

Similar to blanking, except that the punched-out slug is the waste and the surrounding metal is the workpiece

FIGURE 22.4 (a) Blanking and (b) punching.



Sheared edge of a blank



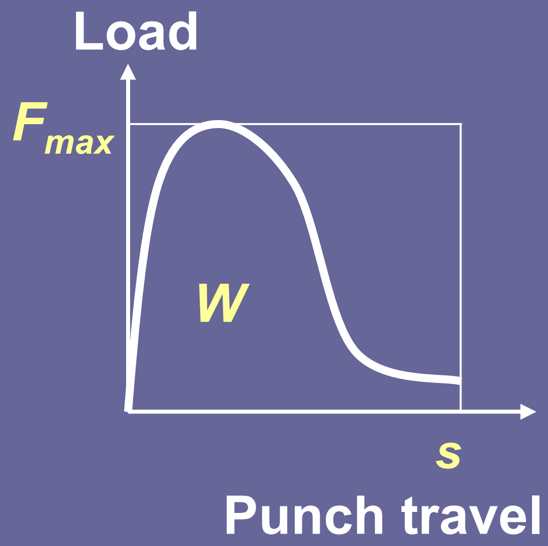
1. Plastic deformation
2. Plastic shearing
3. Fracture
4. Burr
5. Fracture angle

Die clearance

- The space between punch and die
- Important for
  - the reliable operation of the blanking equipment
  - the quality and type of cut edges
  - and the life of the punch and die
- Value of die clearence
  - Steel: ~0,08*thickness
  - Aluminium: ~0,04*thickness

Punch Load and Work

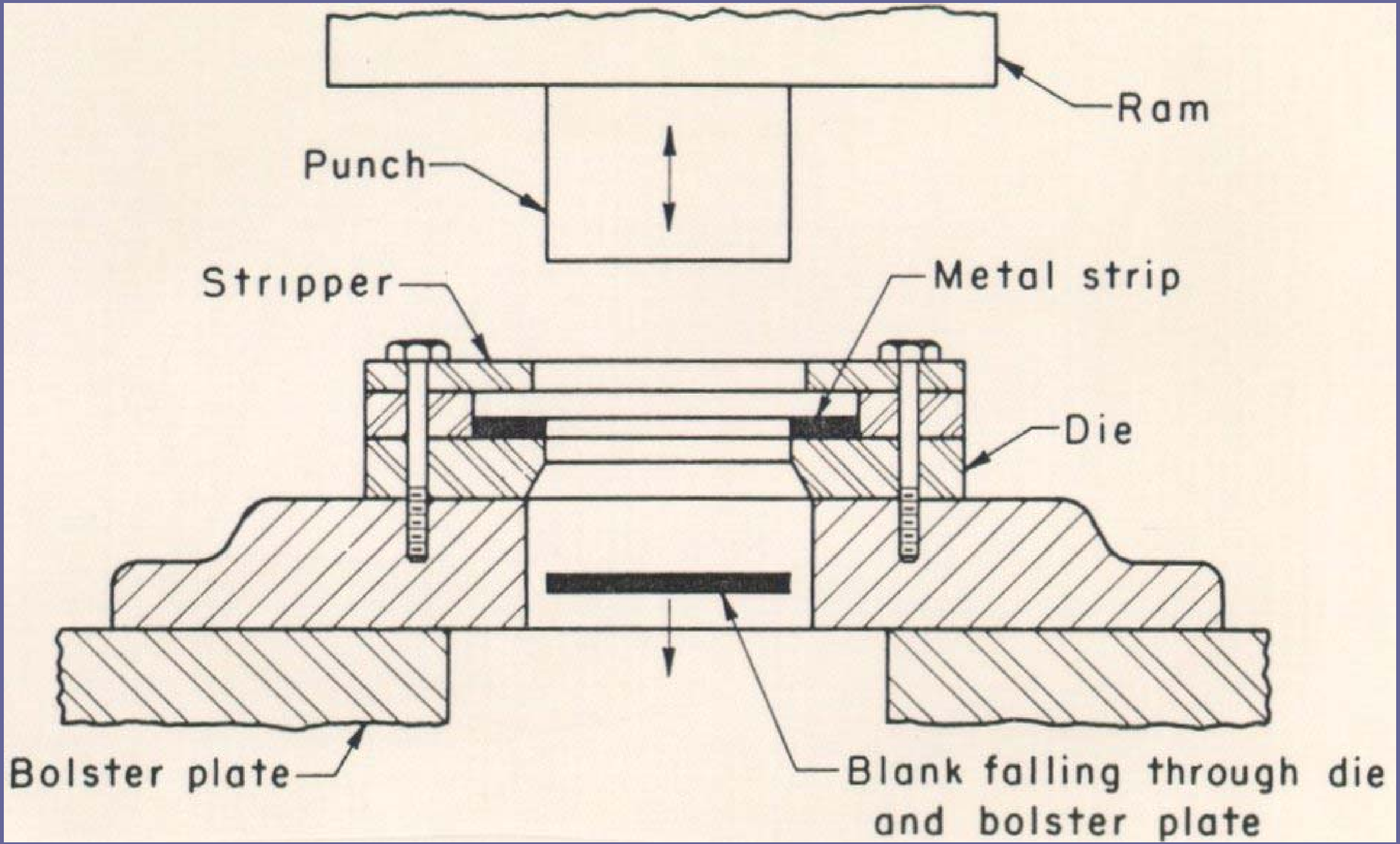
- Load = shear strength x sheared area
  $F_{max} = \tau \times A = 0{,}8\ R_m \times A$
- Work =
  Load x thickness x correction factor
  $W = F_{max} \times s \times c$
  where c = 0,4…0,6



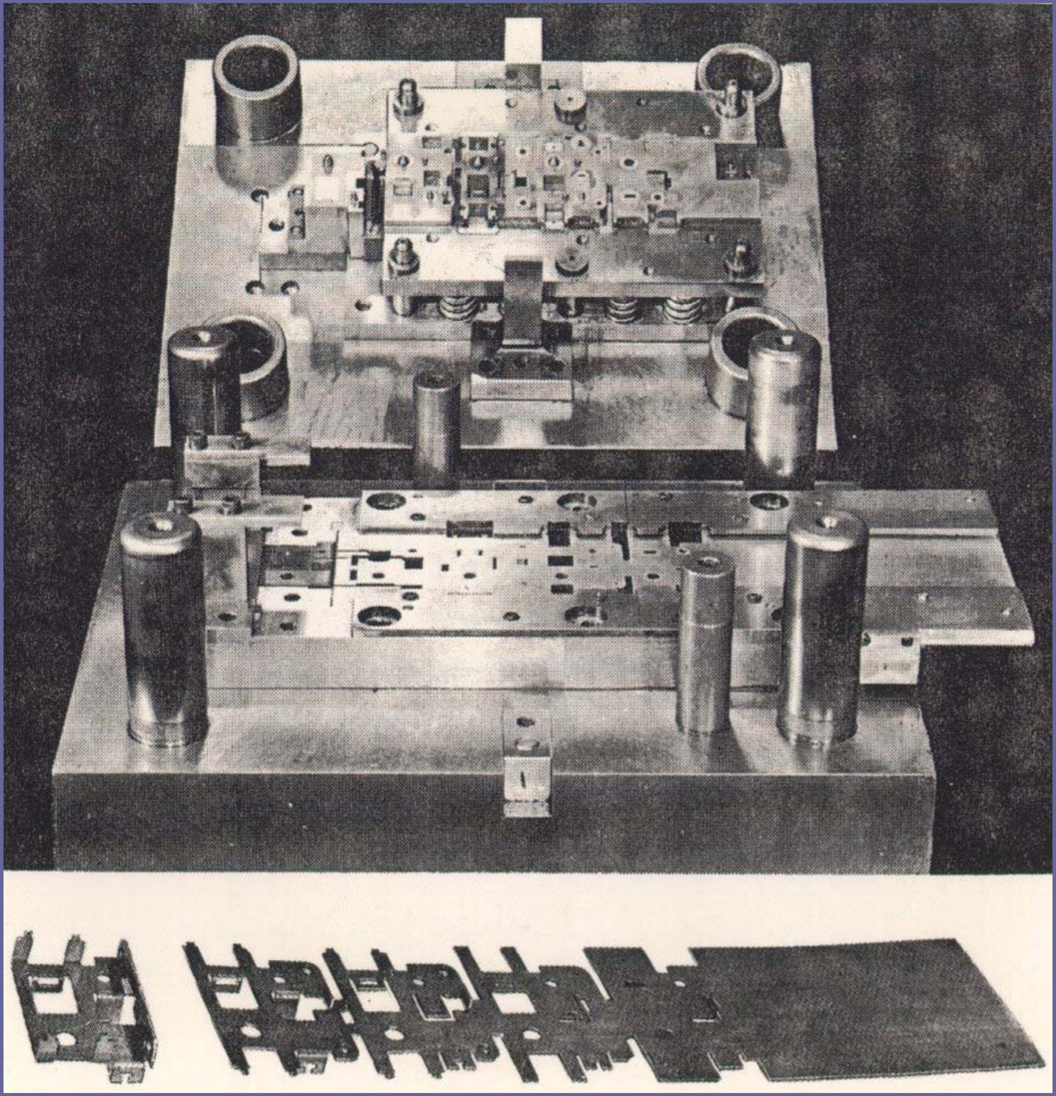
Types of blanking tools

- Single-operation die
  - One blank is produced for one stroke
- Compound die
  - Combination of blanking and piercing operations producing one workpiece
- Progressive die
  - Series of piercing and blanking operations step-by-step

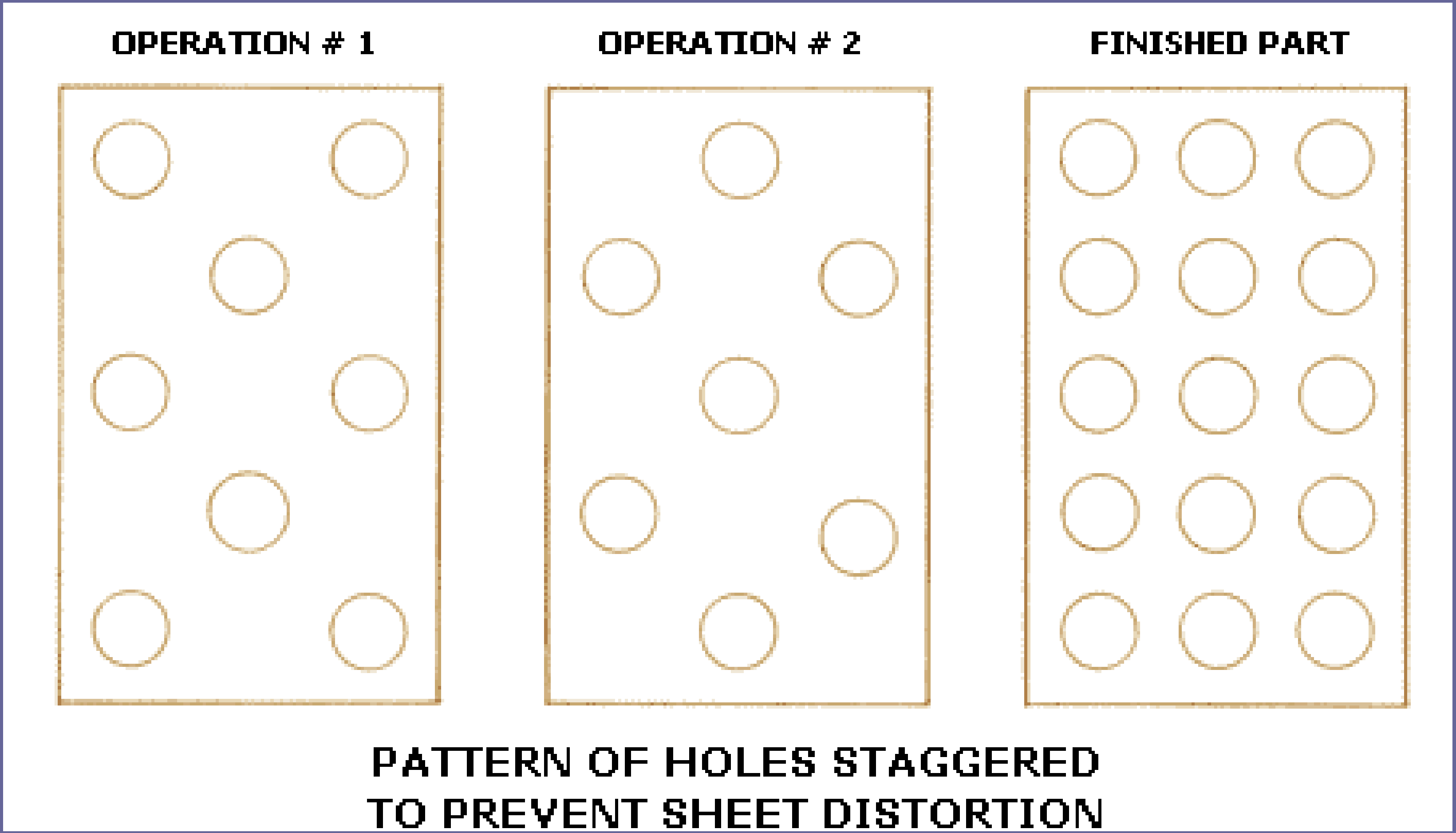
Components of blanking dies (single-operation die)



Progressive blanking die



Sheet distortion



Blank layout

- To use the material most effectively
- Percentage of material use: quotient of the area of blank and used material: A_{blank}/A_{strip}

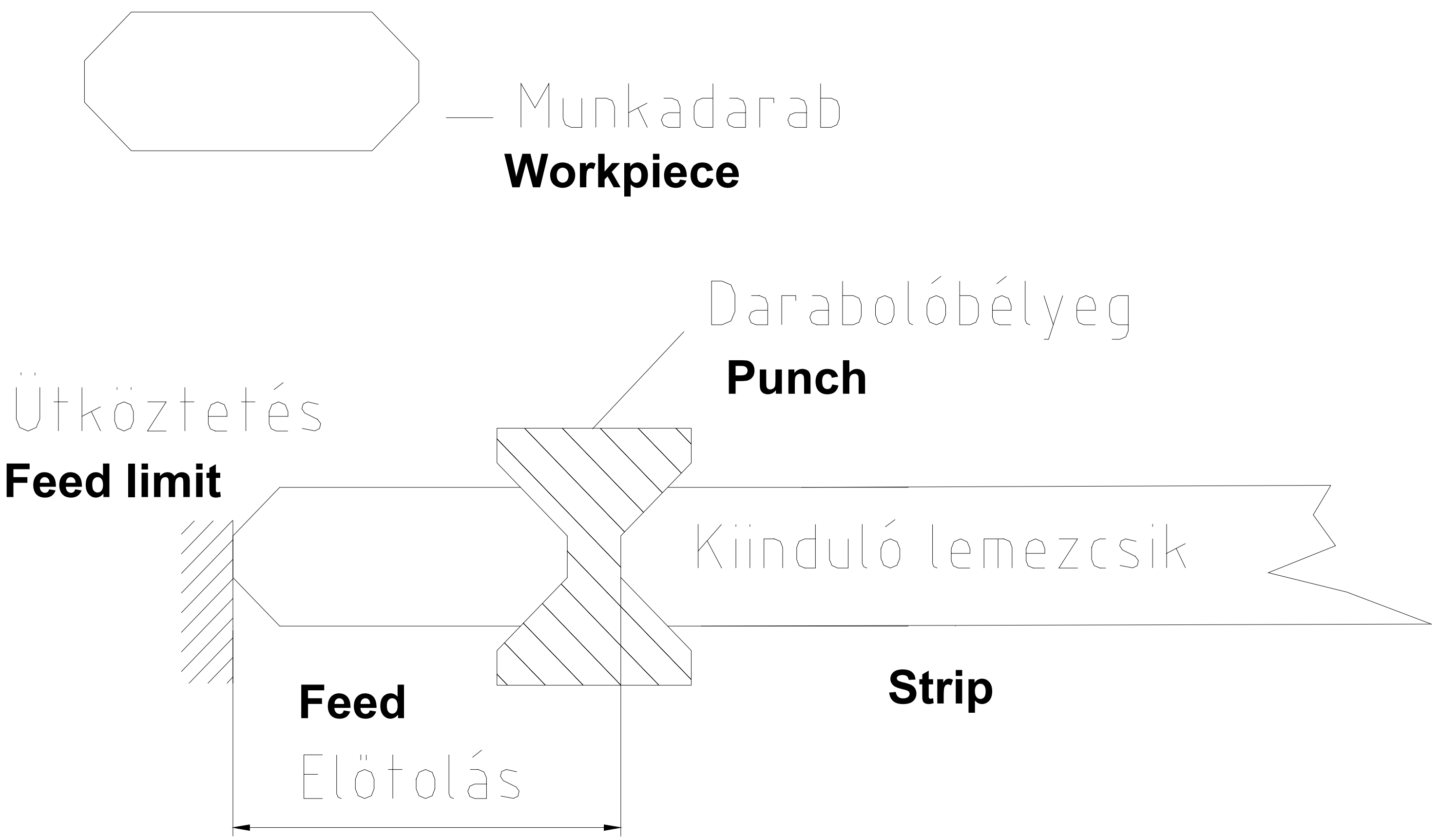
Cutoff

- It means cutting along a line to produce blanks without any scrap material
- Advantages:
  - die has few components, inexpensive
  - waste of material is minimal
  - die can be easily reshaped, low maintenance cost
- Disadvantages:
  - cutting of one edge causes one-way deflection and stress
  - accuracy is dependent on feeding

Parting

- The separation of blanks by cutting away a strip of material between them
- Used to make blanks that do not have mating adjacent surfaces for cutoff
- Some scrap is produced, hence it is less efficient

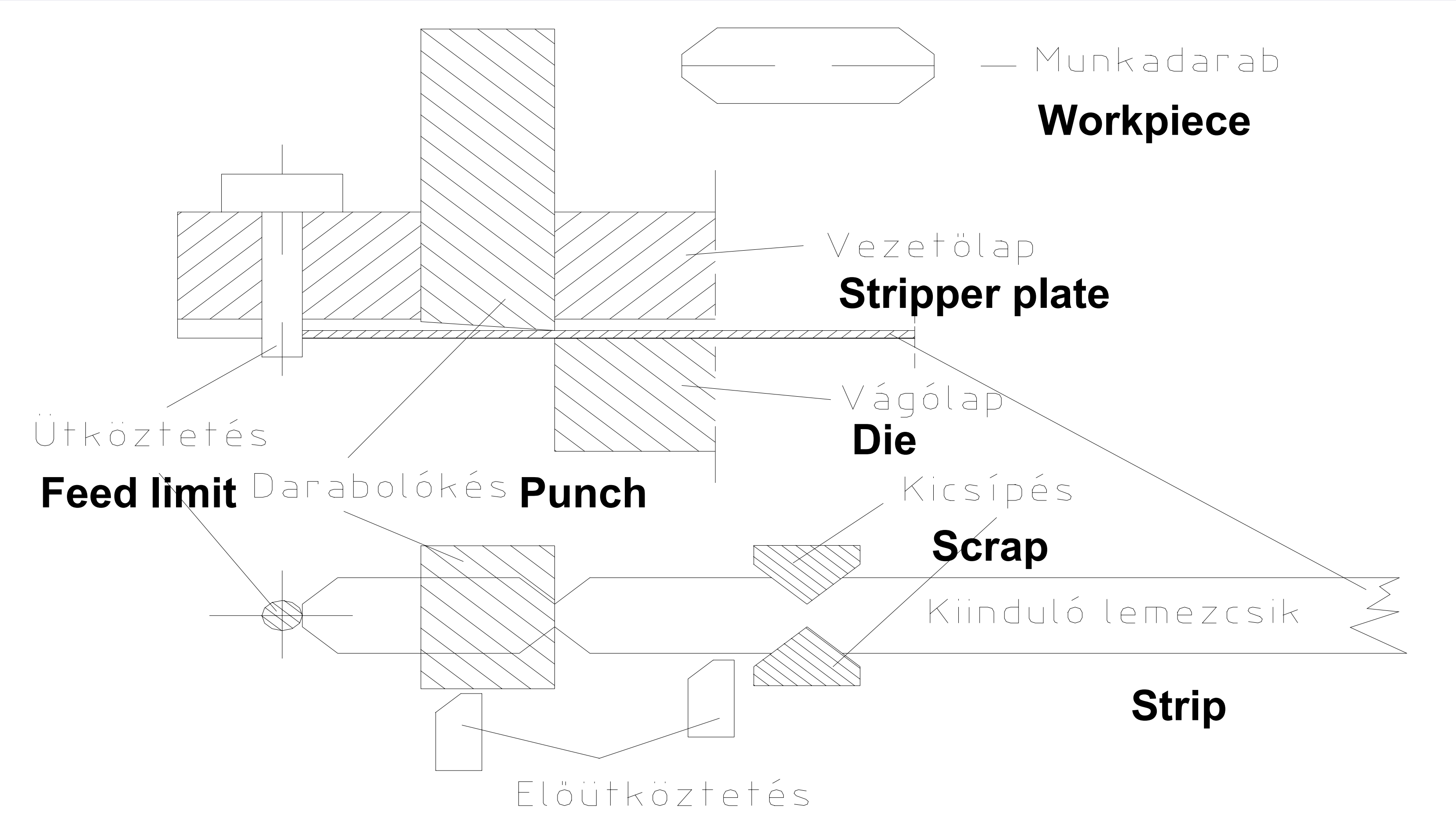
Parting tool



Notching

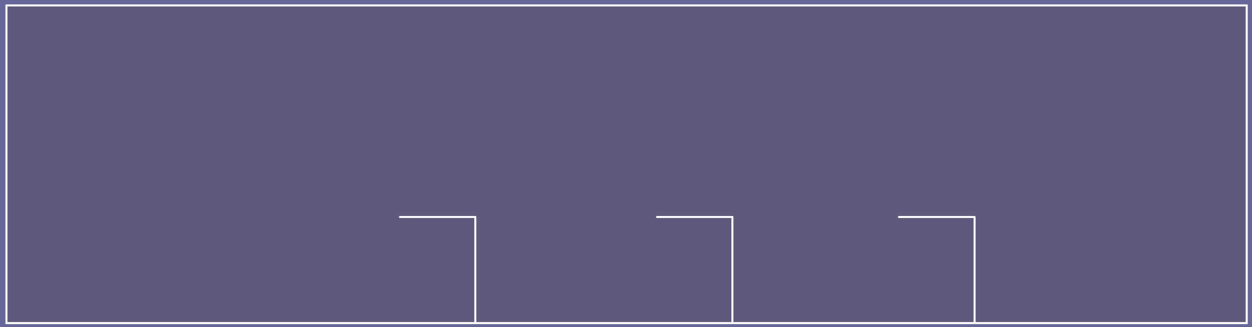
- The individual punch removes a piece of metal from the edge of the blank or strip
- Used to:
  - Free some metal for drawing and for forming
  - Remove excess metal before forming
  - Cut off the outline of a blank that would be difficult to cut otherwise

Notching tool



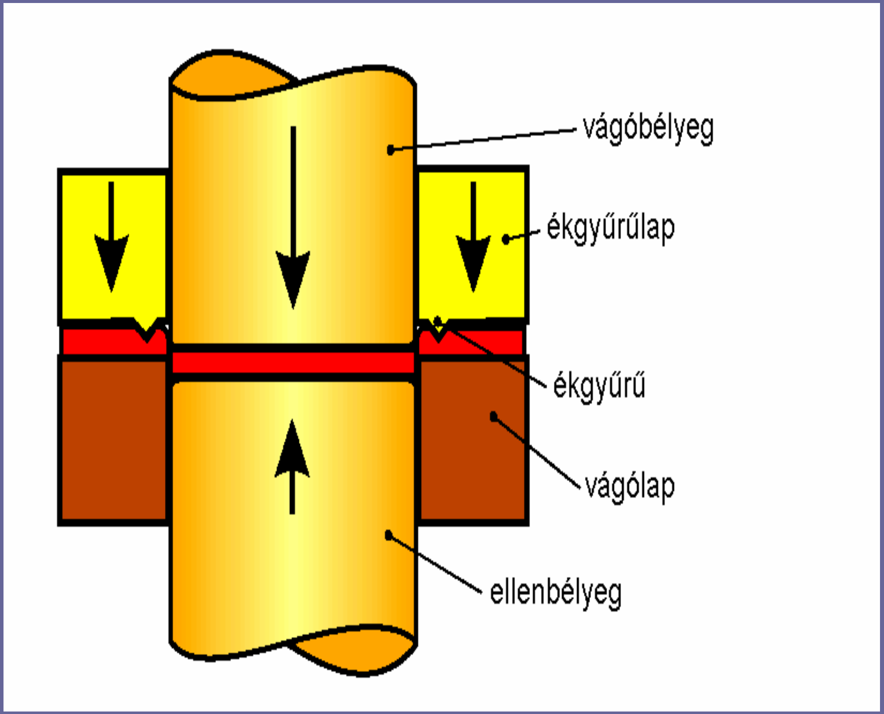
Lancing

- Press operation in which a single-line cut or slit is made part way across the strip stock without removing any metal
- Usually done to free metal for forming (bending)
- Does not have a closed contour and does not release a blank or a piece of scrap



Improving blank quality: Fine Blanking

- Four active tool elements are used
- 3-axial compressive stress state in the sheared zone
- Blank separation by plastic deformation
- Result: sheared surface is smooth and free of cracks, high dimensional accuracy.



Punch

Hold-down ring

Die

Counter punch

Profiling Sheet Metal

Punching and nibbling

Principle of punching and nibbling

- Conventional blanking tool can produce only one workpeece
- Strong demand on flexibile tooling
- Solution:
  - General purpose tool set (circles, rectangules, other shapes)
  - Turret punch press with CNC control
  - Tool magazine, rotating multitool station
  - Moving table for positioning sheet metal (X-Y direction)

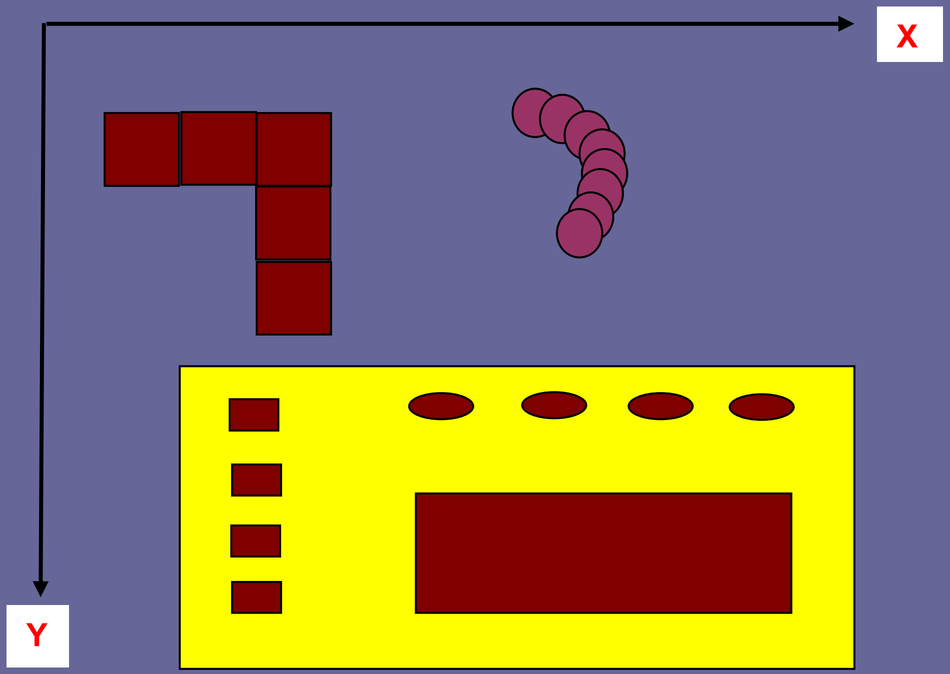
Applications

- All sheet metal components, which have more regular or irregularly shaped holes
- Typical components: panels for instruments, household appliances, car body panels, …
- Punching and nibbling function is combined with laserjet cutting in one machine

CNC Sheetmetal Machining Centre

Nibbling

Series of piercing operations to form the desired contour



Manufacturing flexibility

- Optimised tool sets
- Combination of punching, nibbling and laserjet cutting
- Reduced set up times
- Increased manufacturing capacity
- Economical production even for individual components or low batch size

Profiling Sheet Metal

Laser cutting

Use of industrial lasers

- Operations
  - Welding
  - Cutting
- Definition
  - **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation
  - Types:
    - Carbon dioxide (CO_2)
    - Neodyum-yttrium (Nd-YAG)

Generating a Laser Beam (1)

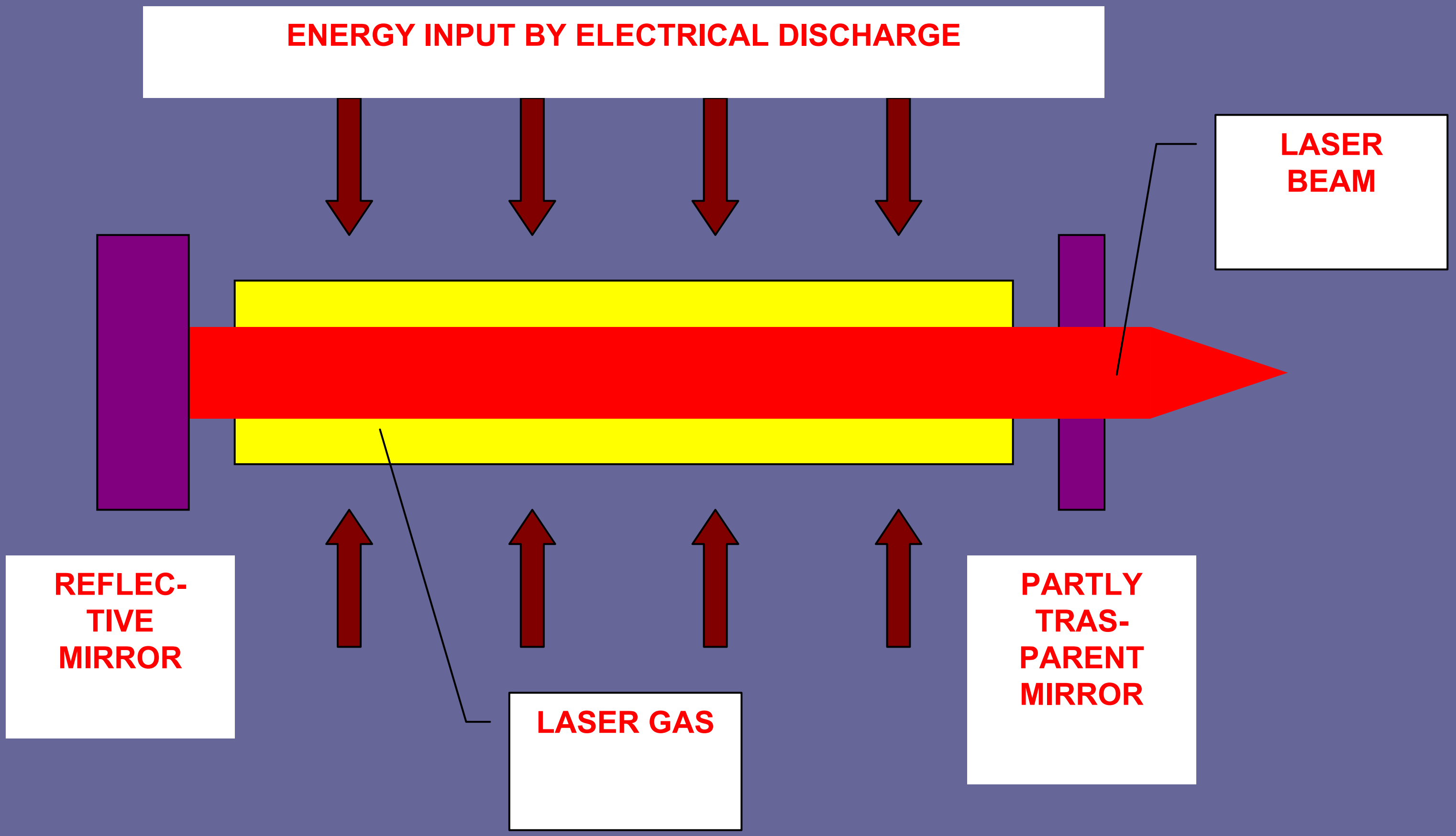
Three components

1. Active media that can be excited (eg. CO_2)
2. A method of exciting the media, such as a periodic electrical discharge between an anode and cathode
3. Resonator

Supplementary equipment

- High-voltage power supply
- Cooling system
- Gas supply
- Mirrors

Generating a Laser Beam (2)



Process variables

- Thickness (steel): 6…12,5 mm
- Power: 800…1500 W (up to 30 kW)
- Travel speed: 1…10 m/min
- HAZ (Heat Affected Zone), slag
- Materials: all metals and nonmetal materials (quartz, ceramics, aramid fibers, …)

LJC Machines

- LJC with CNC controlled motion in x-y directions (2D components)
- LJC combined with piercing and nibbling
- LJC by robot (3D motion)
- Robot applications: 3D car body panels, doors, …

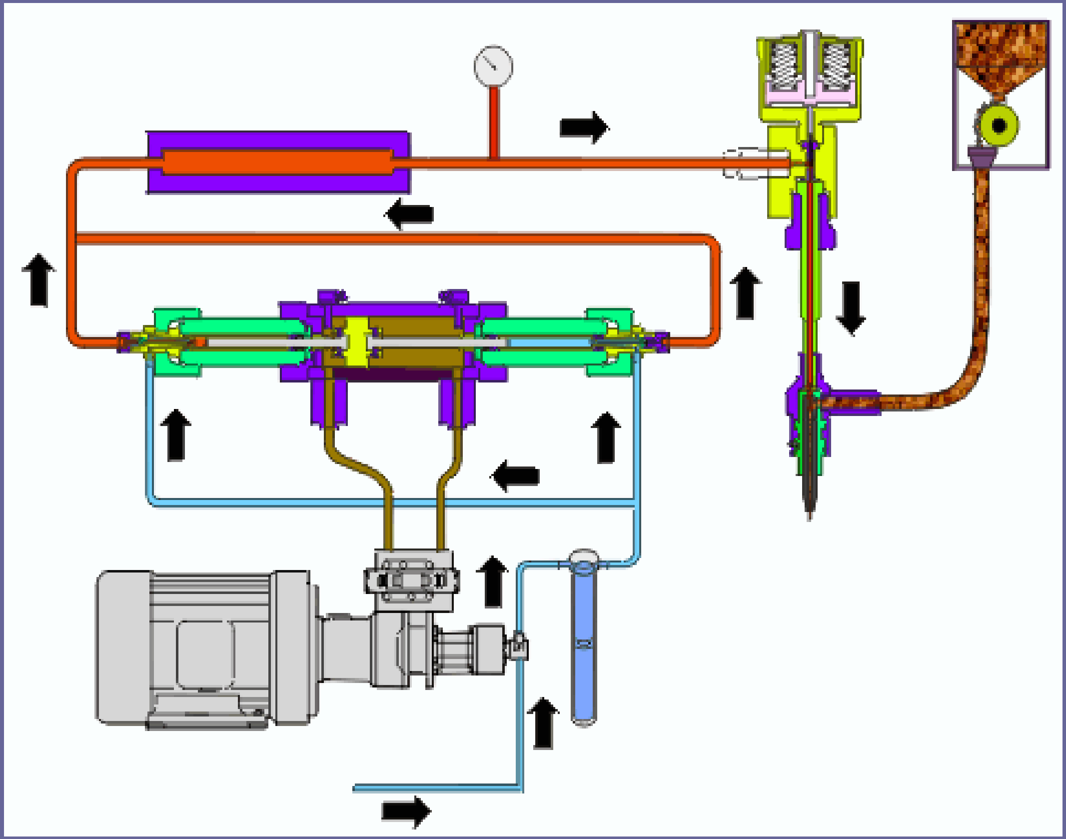
Profiling Sheet Metal

Abrasive Waterjet Cutting

Abrasive Waterjet Cutting

Main steps:

- pressurizing the water
- mix with abrasive (or not)
- focus the water on the cut surface
- cut the material



Use in Cases

- where the workpiece material is either too hard or too brittle
- or its shape is difficult to produce

Abrasive

- small, hard particle
- sharp edges
- irregular shape
- capable of removing small amounts of material from a surface

Abrasives used in

- finishing very hard or heat-treated parts
- shaping hard nonmetallic materials (ceramics, glasses)
- removing unwanted weld beads
- cutting of lengths of bars, structural shapes, masonry and concrete
- cleaning surfaces with jets of air or water containing abrasive parts

Abrasive materials

- **Al_2O_3 (Aluminium Oxide)**
- **SiC (Silicon Carbide)**
- **CBN (Cubic Boron Nitride)**
- **Diamond**

  Diamond and CBN are generally called superabrasives.

The hardness of abrasive grains

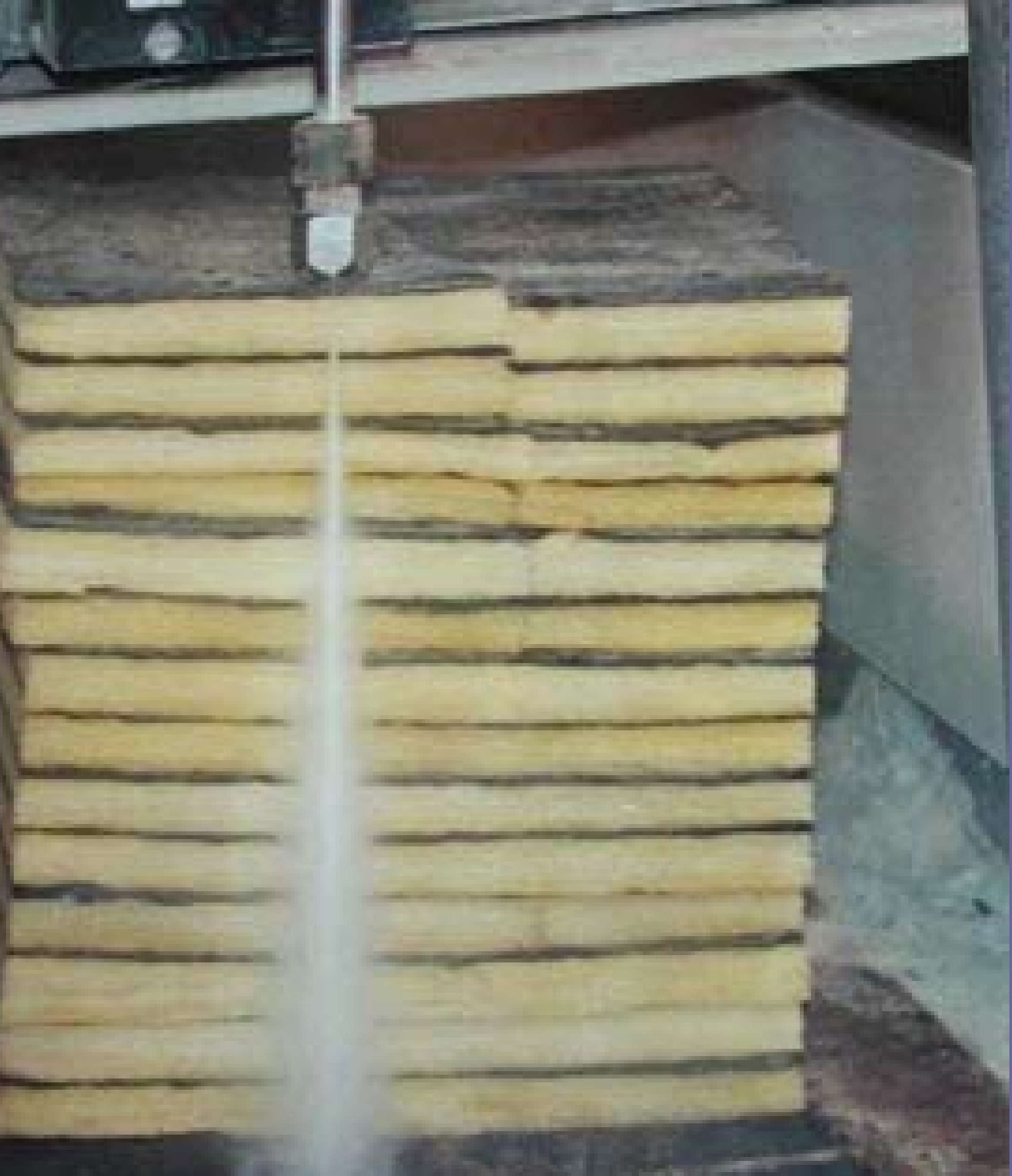
KNOOP HARDNESS FOR VARIOUS MATERIALS AND ABRASIVES			
Common Glass	300 - 500	Zirconium Carbide	2100
Flint, quartz	800 - 1100	Titanium Nitride	2000
Zirconium oxide	1000	Titanium Carbide	1800 - 3200
Hardened Steel	700 - 1300	Silicon Carbide	2100 - 3000
Emery, garnet,	1350	Boron Carbide	2800
Tungsten Carbide	1800 - 2400	Cubic Boron Nitride	4000 - 5000
Al. Oxide	2000 - 3000	Diamond	7000 - 8000

Two types of WJC Examples

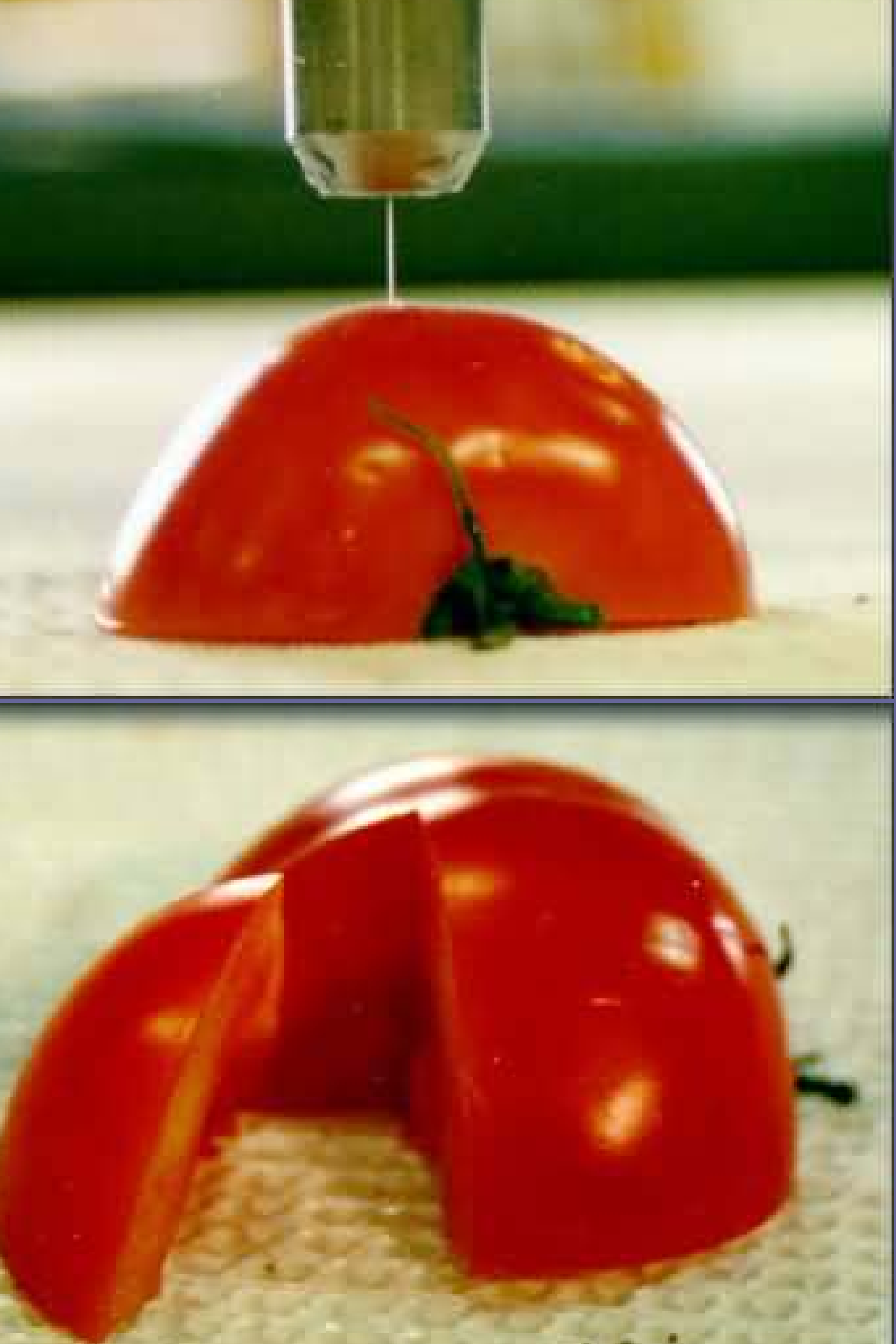
- Simple water jet cutting (no abrasive)
- Abrasive water jet cutting

Waterjet cutting is used in the cutting of materials such as :

- Plastics
- Corrugated Cardboard
- Insulation
- Rubber
- Foods
- Non-wovens
- Paper
- Automotive Carpeting and Headliners

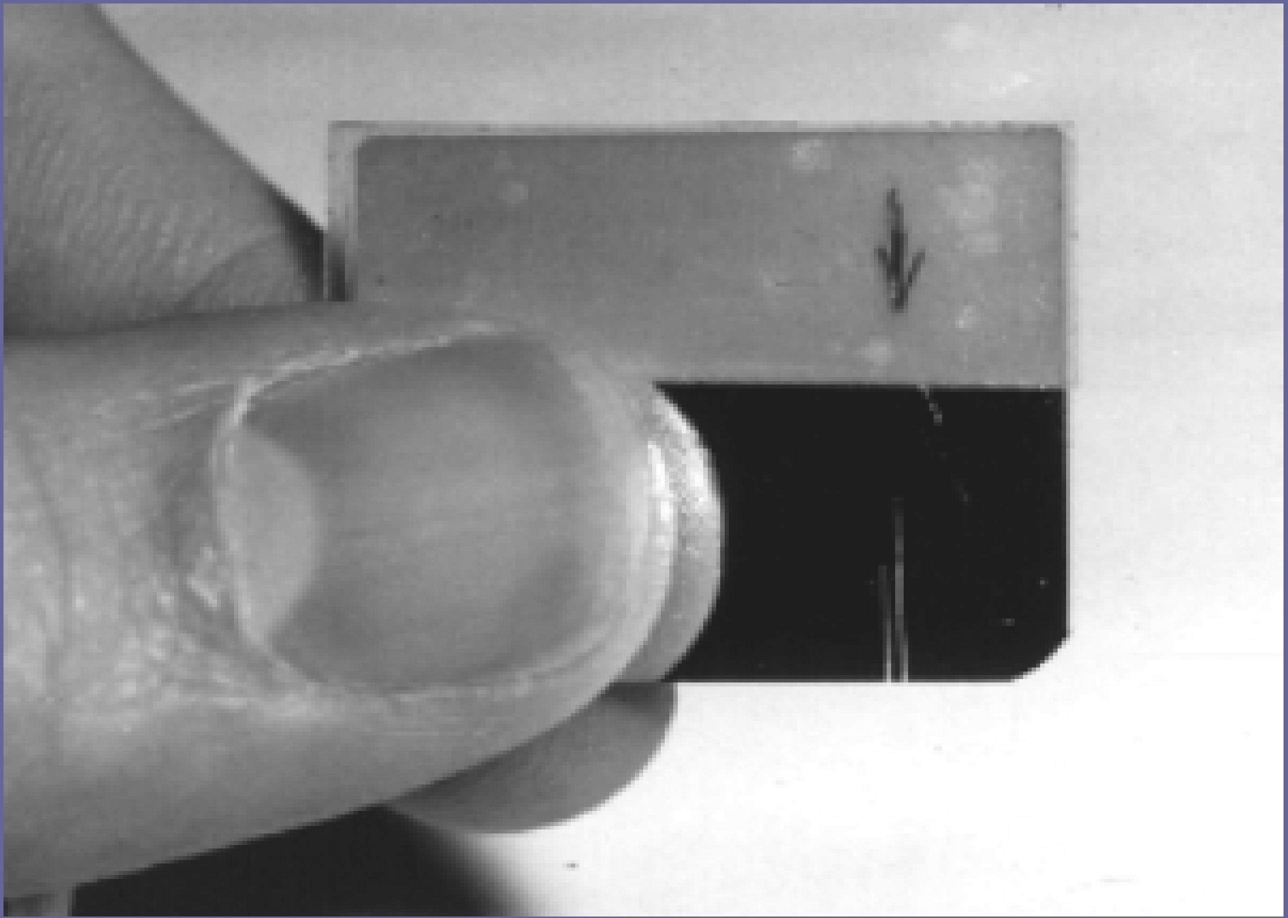


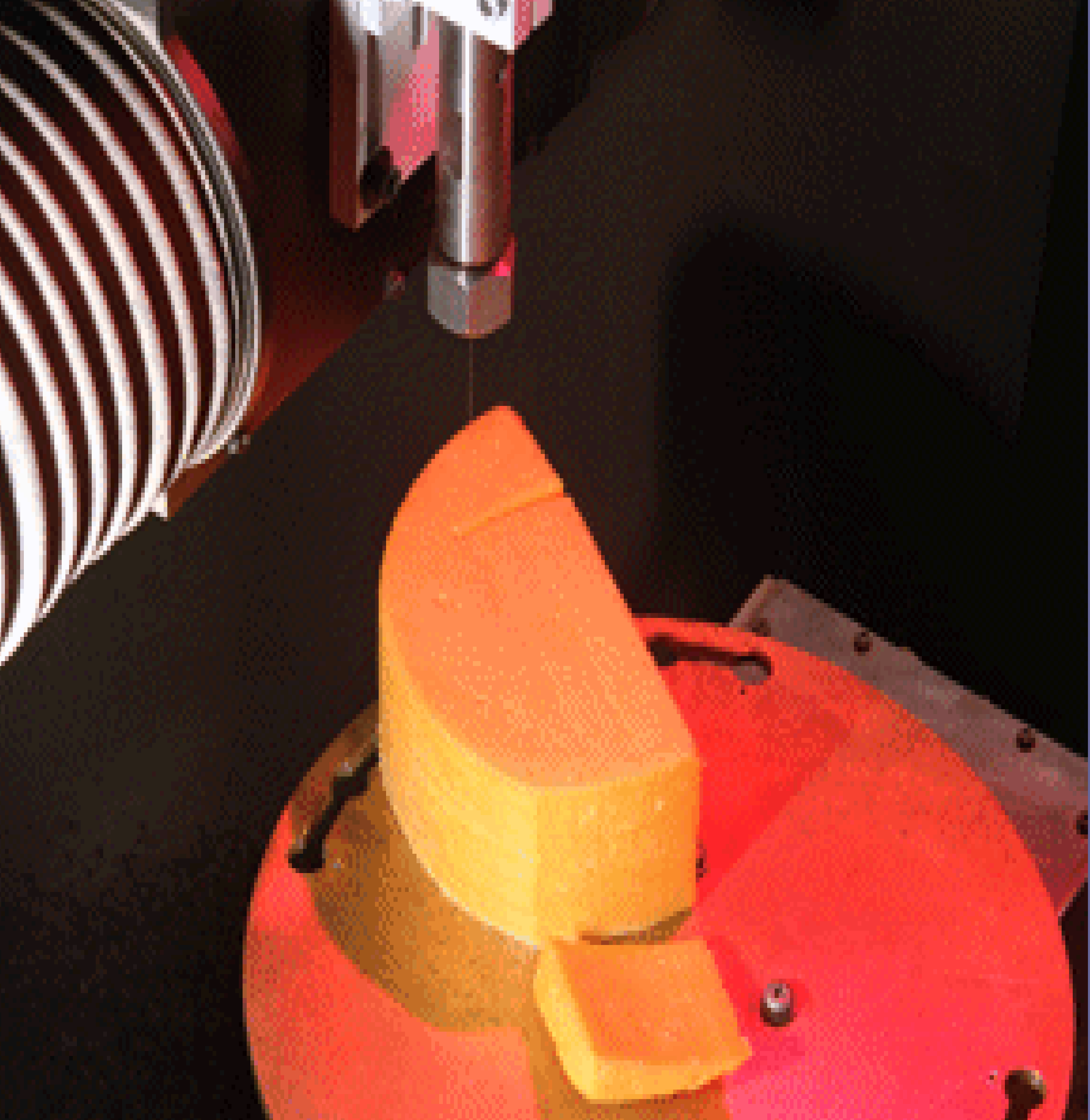
14 Layers of Fiberglass Being Cut at 50,000 psi



Application: Waterjet cutting tomatoes for a food processing plant utilizing an OmniJetIII® Cutting Head.

An abrasive suspension microjet can make cuts as narrow as 0.006 inch in width in materials as thin as this 0.02-inch-thick quartz plate.





Food products and other soft materials maintain their integrity when cut with SwRI-developed water jet cutting methods.

Advantages of Waterjet Cutting

- Cold cutting – no heat affected zones, no hardening
- Omni-directional cutting – ability to cut in any direction
- Perforates most materials without starting holes
- Cuts virtually all material
- Net-shape or near-net shape parts (no secondary processing required)
- Minimal fixturing required
- Environmentally friendly
- Reduces dust and hazardous gases
- Does not workload material – stress-free cutting
- Flexible machine integration
- Saves raw materials (small cutting kerf width, nesting capabilities)
- Faster than many conventional cutting tools

Abrasive Waterjet Cutting

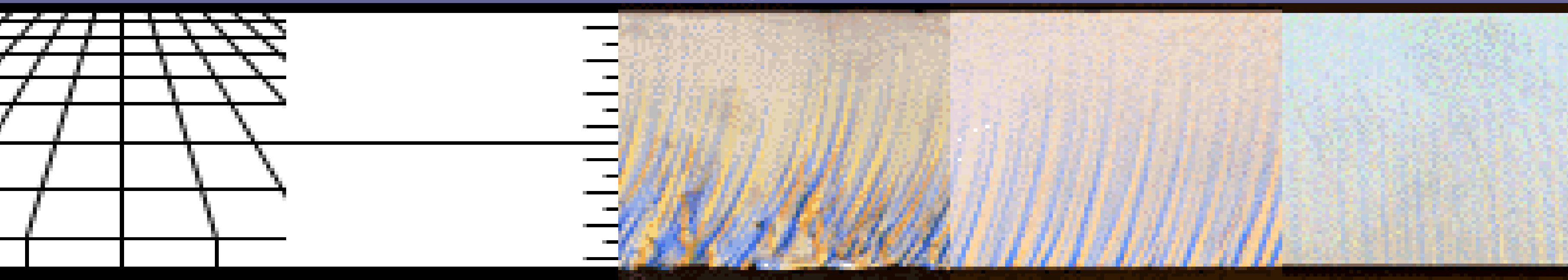
- Use a combination of water and garnet to cut through materials
- Abrasivejet can cut through materials ranging from 1.6mm to 305mm with accuracy of 0.13mm.

Abrasive waterjet cutting is used in the cutting of materials such as :

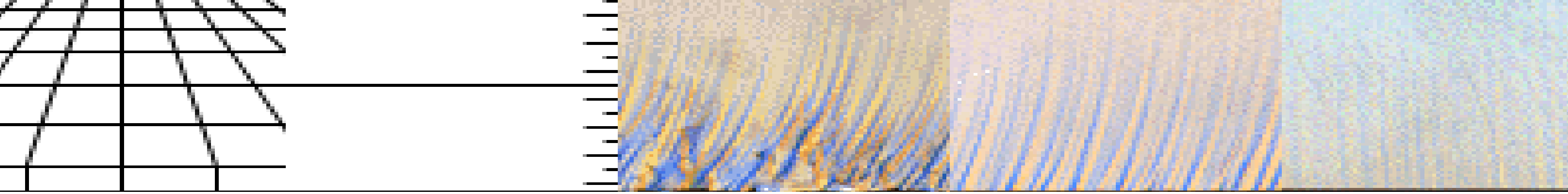
- Titanium
- Brass
- Aluminium
- Stone
- Inconel
- Any Steel
- Glass
- Composites

Cutting Feedrates For a Given Material (millimeters per minute)

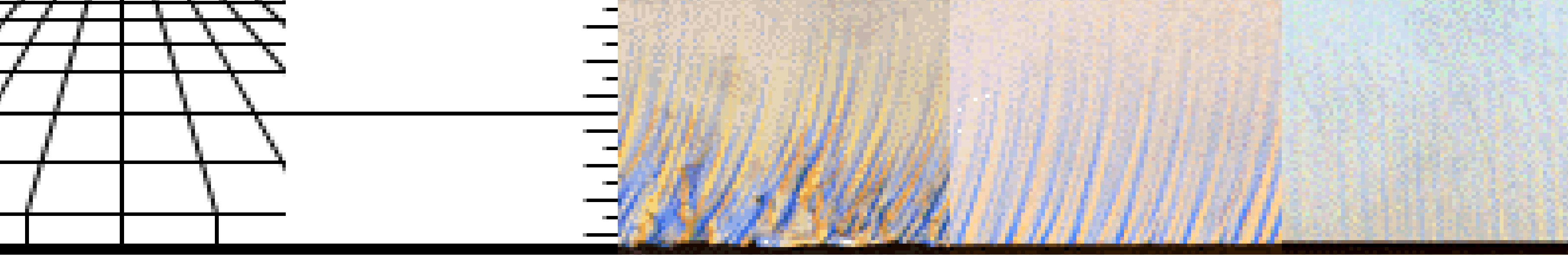
Cut at 3800bar using 4.2 liters per minute, 0.38mm Orifice / 1.14mm Nozzle Combination 680 g/min of Abrasive



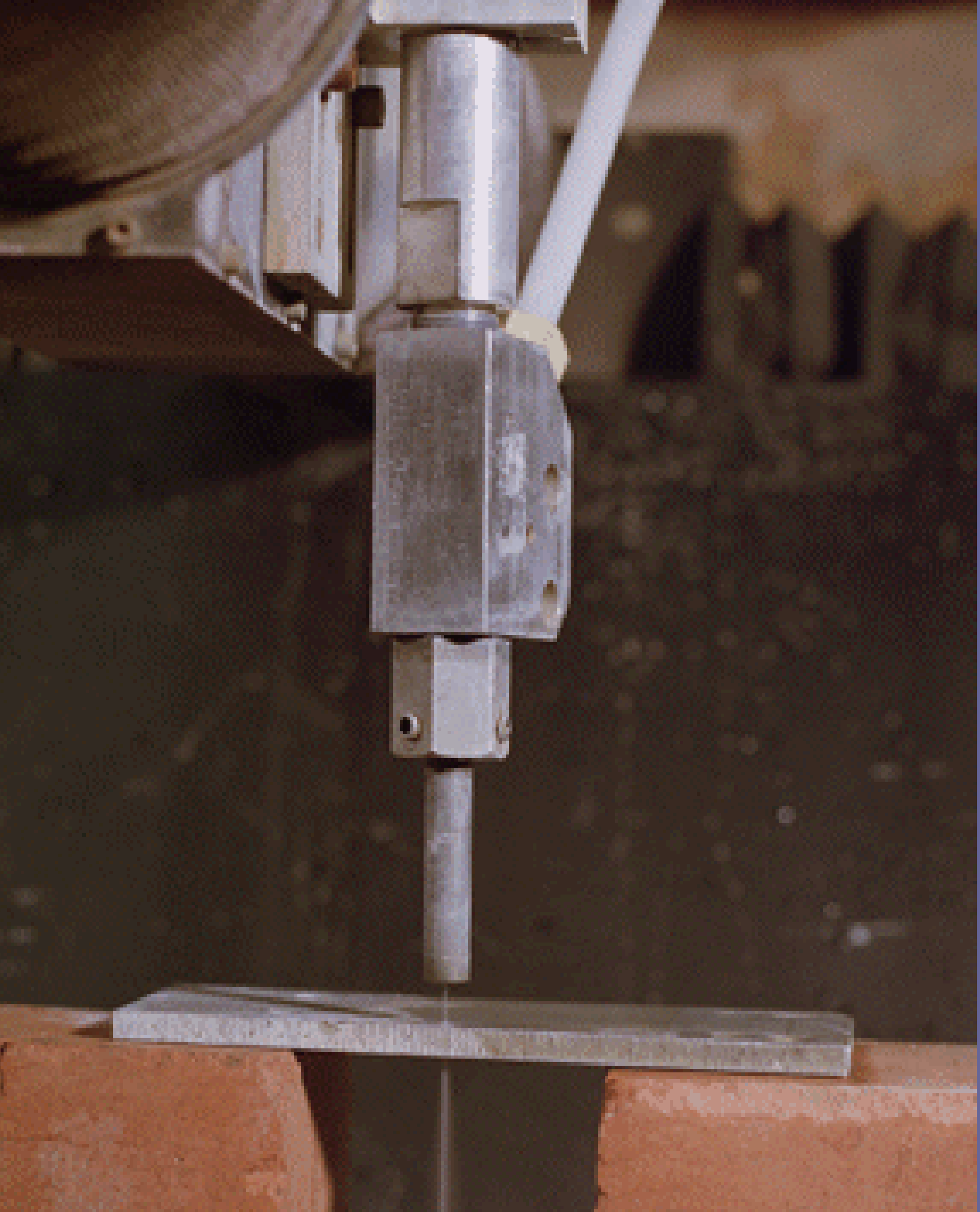
Material	Thickness	Separation cut	Medium Quality cut	High Quality cut
Copper	12.7mm	475	193	122
	38.1mm	132	43	25
	76.2mm	58	18	10
304 SS	12.7mm	330	132	84
	38.1mm	91	30	18
	76.2mm	41	13	8



Material	Thickness	Separation cut	Medium Quality cut	High Quality cut
Aluminium	12.7mm	1021	414	259
	38.1mm	284	97	58
	76.2mm	127	38	23
Mild Steel	12.7mm	366	147	94
	38.1mm	102	33	20
	76.2mm	46	13	8
Titanium	12.7mm	511	208	130
	38.1mm	142	48	28
	76.2mm	64	20	13



aterial	Thickness	Separation cut	Medium Quality cut	High Quality cu
Granite	12.7mm	912	371	231
	38.1mm	254	86	51
	76.2mm	114	36	20
nconel 718	12.7mm	292	119	74
	38.1mm	81	28	15
	76.2mm	36	10	8



An abrasive water jet tool cuts a 0.25-inch-thick stainless steel plate in a single pass.

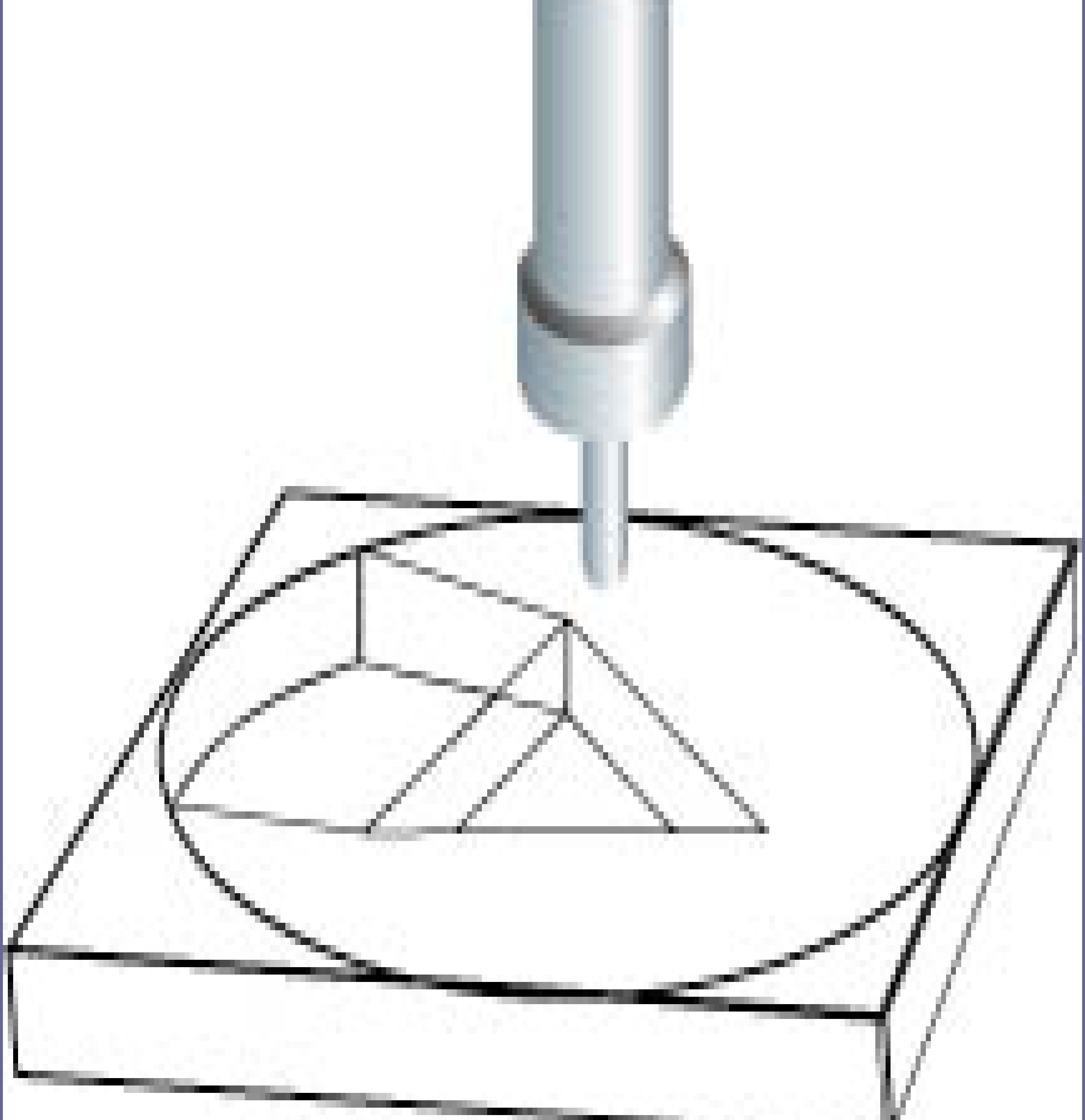
Abrasive Water Jet Cutting of Composite Material

Application: Portable Abrasivejet cuts 15 inch concrete block from a factory wall.

Application: Portable abrasivejet cutting of a slab of concrete using a Versacutter.

Application: Portable abrasivejet cutting of pipe 16 in. (406 mm) in diameter with a Versacutter.

Application: Abrasivejet cutting of 6.0 in. (152 mm) Inconel using a Permalign® Cutting Head.



Profiling Sheet Metal

Comparison of laser and water jet cutting

1. Kerf size
2. Material hardness
3. Material thickness
4. Abrasive resistance
5. Material composition
6. Material quality
7. Recast layer
8. Heat affected zone
9. Stresses
10. Tapering
11. Complicated geometry
12. Start hole drilling

Kerf size

Both processes produce a small kerf, which permits very fine cutting and drilling. It allows close nesting of parts, this can save a lot of money for costy materials.

Typical kerf width:

- AWJ: 0.875mm
- Laser: 0.250mm

In general use these numbers are practicall the same, but there might be high-precision needs, that laser can suit better.

Material hardness effects

Materials can be heat treated before the cutting/drilling process

The heat generated by both processes is insignificant and can be considered helpful, because they reduce disortion and stresses.

Material thickness

Laser is very depending on the material thickness.
Carbon steels over 10 mm are hard to cut.
The thickness limitation is further reduced by the composition of the material.

AWJ can process much thicker material.
150 mm thick carbon steels can be cut with the AWJ.
AWJ seems to be most effective at 25 mm thick steel.

Abrasive resistance

The more abrasive resistance, the more difficult it is to cut with AWJ. The process is slowed down to compensate for the abrasive resistance of the material.

Laser cutting is not affected by abrasive resistance of materials.

Material composition

The composition of the material will affect laser processing dramatically over that of AWJ cutting. Once the combinations are correct, the cutting speed can be 2 to 5 times faster than AWJ.

Material composition other than abrasion resistance has little effect on AWJ cutting, so set-up time can be much shorter. The parameters set for one material can generally be used for other materials. This allows AWJ to cut a combination of material in layers very easily.

Material quality

Laser processing is obviously more sensitive to material quality than AWJ cutting. The surface finish can dramatically affect the quality of cutting. Surface texture must be smooth, otherwise the assist gas and laser focus can be altered, affecting quality of the cut.

In AWJ these problems do not matter.

Recast layer

Laser processing will leave a recast layer on the surface. Laser cutting melts and burns some of the metal. It will deposit some re-melted materials on the side of the cut edges and on the bottom of the cut. This layer of deposited materials is highly stressed and may crack, especially if it is oxide. Although these cracks are small, they can propagate into the material creating larger cracks.

AWJ cutting does not melt the material so there is no problem with recast.

Heat affected zone (HAZ)

Laser cutting does produce a heat affected zone (HAZ). HAZ occurs in metals when the temperature rises above the critical transformation point. In laser cutting this is localized near the cutting zone. In carbon steel, the higher the hardenability the greater HAZ.

Since HAZ is brittle, this area has a low tolerance for cracking during bending or stress. In most cases the HAZ can be eliminated by post heat treating the part, but there is a risk of distortion.

In AWJ there is virtually no HAZ.

Stresses

Laser cutting creates more stresses in material than does AWJ cutting. In most cases, laser processing will produce little distortion in material, but this is dependent on the laser parameters, material thickness, and composition of material.

AWJ does not create any stress.

Tapering

AWJ can produce more taper than laser cutting. One of the biggest contrast of AWJ cutting is the taper created during the process. Typical taper in AWJ is twice that of laser.
Although taper can be controlled with speed, it is usually about 25% of the nozzle diameter (typically .23 mm) at the most cost effective speed. Slowing down the process speed can correct this problem, but will increase part price.

This taper can actually be a benefit in some cases. Taper can be programmed into a part by altering the angle and speed of the jet.

Complicated Geometry

AWJ is more capable of cutting more geometric shapes.

Laser has limitations to side wall thickness. This thickness limitation is dependent upon the material and thickness.

Start hole drilling

Drilling starting holes is faster with laser but not as safe. Laser can drill holes very quickly. Often during the drilling process with laser, there will be a "blowout", especially if the hole is small in relation to the thickness. This can scrap parts.

AWJ is much slower, but the drilling with AWJ is more controllable.

Fundamental process differences

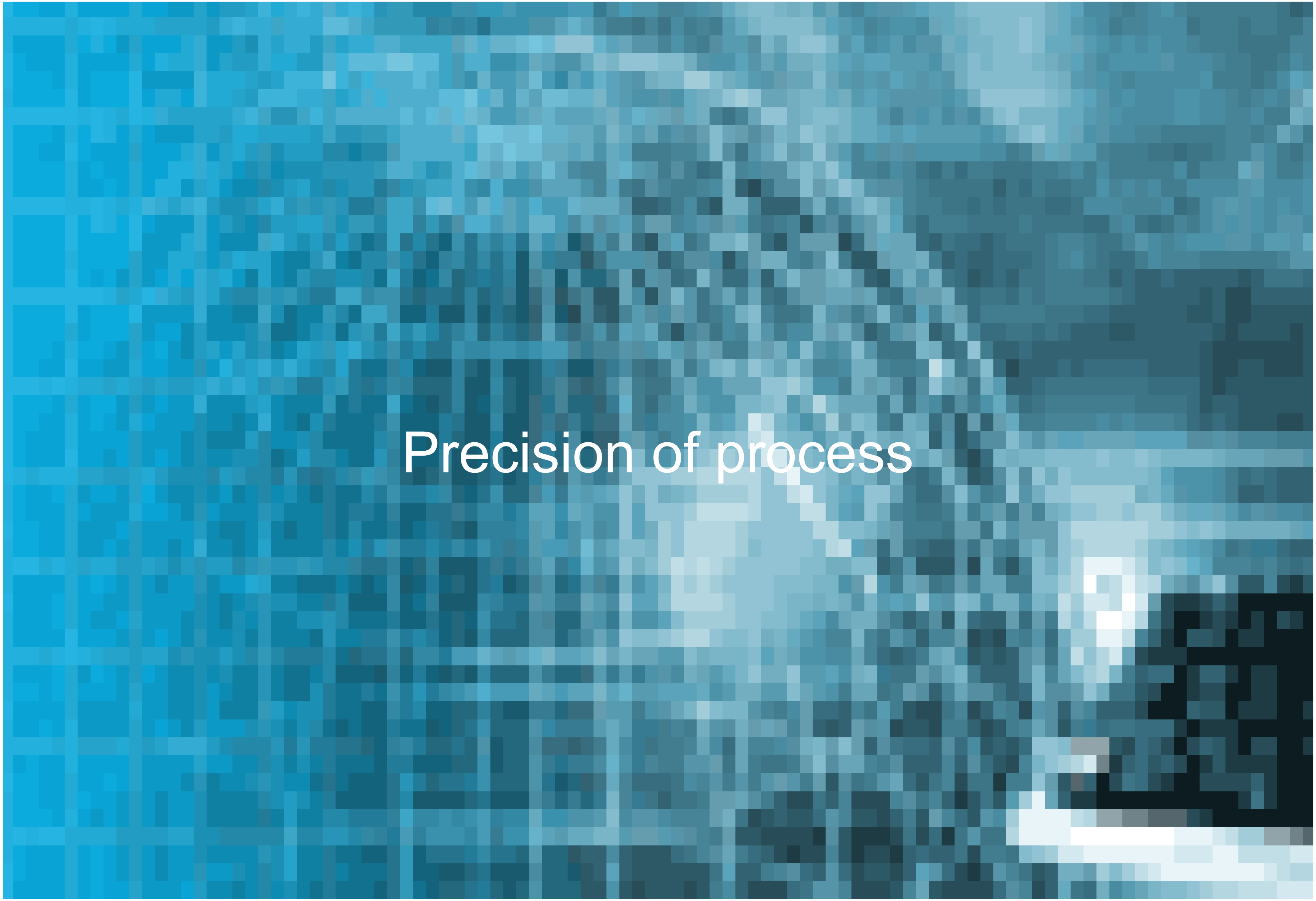
Subject	CO_2 Laser	Water Jet Cutting
Method of imparting energy	Light 10.6 µm (far infrared range)	Water
Source of energy	Gas laser	High-pressure pump
How energy is transmitted	Beam guided by mirrors (flying optics); fiber-transmission not feasible for CO2 laser	Rigid high-pressure hoses transmit the energy
How cut material is expelled	Gas jet, plus additional gas expels material	A high-pressure water jet expels waste material
Distance between nozzle and material and maximum permissable tolerance	Approximately 0.2" ± 0.004", distance sensor, regulation and Z-axis necessary	Approximately 0.12" ± 0.04", distance sensor, regulation and Z-axis necessary
Physical machine set-up	Laser source always located inside machine	The working area and pump can be located separately
Range of table sizes	8' x 4' to 20' x 6.5'	8' x 4' to 13' x 6.5'
Typical beam output at the workpiece	1500 to 2600 Watts	4 to 17 kilowatts (4000 bar)

Typical process applications and uses

Subject	CO_2 Laser	Water Jet Cutting
Typical process uses	Cutting, drilling, engraving, ablation, structuring, welding	Cutting, ablation, structuring
3D material cutting	Difficult due to rigid beam guidance and the regulation of distance	Partially possible since residual energy behind the workpiece is destroyed
Materials able to be cut by the process	All metals (excluding highly reflective metals), all plastics, glass, and wood can be cut	All materials can be cut by this process
Material combinations	Materials with different melting points can barely be cut	Possible, but there is a danger of delamination
Sandwich structures with cavities	This is not possible with a CO2 laser	Limited ability
Cutting materials with liminted or impaired access	Rarely possible due to small distance and the large laser cutting head	Limited due to the small distance between the nozzle and the material
Properties of the cut material which influence processing	Absorption characteristics of material at 10.6 µm	Material hardness is a key factor
Material thickness at which cutting or processing is economical	~0.12" to 0.4" depending on material	~0.4" to 2.0"
Common applications for this process	Cutting of flat sheet steel of medium thickness for sheet metal processing	Cutting of stone, ceramics, and metals of greater thickness

Initial investment and average operating costs

Subject	CO_2 Laser	Water Jet Cuttin
Initial capital investment required	$300,000 with a 20 kW pump, and a 6.5' x 4' table	$300,000+
Parts that will wear out	Protective glass, gas nozzles, plus both dust and the particle filters	Water jet nozzle, focusing nozzle, and all high-pressure components such as valves, hoses, and seals
Average energy consumption of complete cutting system	Assume a 1500 Watt CO2 laser: Electrical power use: 24-40 kW Laser gas (CO2, N2, He): 2-16 l/h Cutting gas (O2, N2): 500-2000 l/h	Assume a 20 kW pump: Electrical power use: 22-35 kW Water: 10 l/h Abrasive: 36 kg/h Disposal of cutting waste



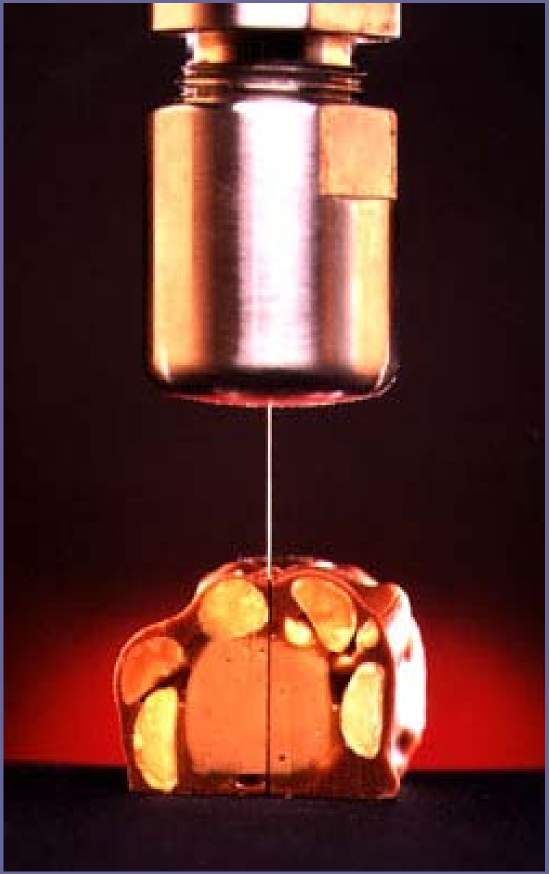
Precision of process

Subject	CO_2 Laser	Water Jet Cuttin
Minimum size of the cutting slit	0.006", depending on cutting speed	0.02"
Cut surface appearance	Cut surface will show a striated structure	The cut surface will appear to have been sand-blasted, depending on the cutting speed
Degree of cut edges to completely parallel	Good; occasionally will demonstrate conical edges	Good; there is a "tailed" effect in curves in the case of thicker materials
Processing tolerance	Approximately 0.002"	Approximately 0.008"
Degree of burring on the cut	Only partial burring occurs	No burring occurs
Thermal stress of material	Deformation, tempering and structural changes may occur in the material	No thermal stress occurs
Forces acting on material in direction of gas or water jet during processing	Gas pressure poses problems with thin workpieces, distance cannot be maintained	High: thin, small parts can thus only be processed to limited degree

Safety considerations and operating environment

Subject	CO_2 Laser	Water Jet Cuttin
Personal safety equipment requirements	Laser protection safety glasses are **not** absolutely necessary	Protective safety glasses, ear protection, and protection against contact with high pressure water jet are needed
Production of smoke and dust during processing	Does occur; plastics and some metal alloys may produce toxic gases	Not applicable for water jet cutting
Noise pollution and danger	Very low	Unusually high
Machine cleaning requirements due to process mess	Low clean up	High clean up
Cutting waste produced by the process	Cutting waste is mainly in the form of dust requiring vacuum extraction and filtering	Large quantities of cutting waste occur due to mixing water with abrasives

And Some Applications: Water Jet Cutting



Laser Cutting

Summary

- We have more methods for profiling sheet metals and other materials, these are:
- Blanking and piercing
- Nibbling
- Laser jet cutting
- Water jet cutting
- Optimal use of methods is important