INDUSTRIAL PROCESS

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SESSION 5 CUTTING

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Cutting

Shearing (manufacturing)

Shearing, also known as **die cutting**,[1] is a process which cuts stock without the formation of chips or the use of burning or melting. Strictly speaking, if the cutting blades are straight the process is called shearing; if the cutting blades are curved then they are shearing-type operations.[2] The most commonly sheared materials are in the form of sheet metal or plates, however rods can also be sheared. Shearing-type operations include: blanking, piercing, roll slitting, and trimming. It is used in metalworking and also with paper and plastics.

Principle

A punch (or moving blade) is used to push the workpiece against the die (or fixed blade), which is fixed. Usually the clearance between the two is 5 to 40% of the thickness of the material, but dependent on the material. Clearance is defined as the separation between the blades, measured at the point where the cutting action takes place and perpendicular to the direction of blade movement. It affects the finish of the cut (burr) and the machine's power consumption. This causes the material to experience highly localized shear stresses between the punch and die. The material will then fail when the punch has moved 15 to 60% the thickness of the material, because the shear stresses are greater than the shear strength of the material and the remainder of the material is torn. Two distinct sections can be seen on a sheared workpiece, the first part being plastic deformation and the second being fractured. Because of normal inhomogeneities in materials and inconsistencies in clearance between the punch and die, the shearing action does not occur in a uniform manner. The fracture will begin at the weakest point and progress to the next weakest point until the entire workpiece has been sheared; this is what causes the rough edge. The rough edge can be reduced if the workpiece is clamped from the top with a die cushion. Above a certain pressure the fracture zone can be completely eliminated.[3] However, the sheared edge of the workpiece will usually experience workhardening and cracking. If the workpiece has too much clearance, then it may experience roll-over or heavy burring.

Saw

Saw

A crosscut hand saw about 620 mm (24 inches) long

Classification	Cutting
Types	Hand saw Back saw Bow saw Circular saw Reciprocating saw Bandsaw
Related	Milling cutter

A **saw** is a tool consisting of a hard blade, wire, or chain with a toothed edge. It is used to cut through relatively hard material, most often wood. The cut is made by placing the toothed edge against the material and moving it forcefully back and forth. This force may be applied by hand, or powered by steam, water, electricity or other power source. An abrasive saw has a powered circular blade designed to cut through metal.

Terminology

"Kerf" redirects here. For other meanings, see Kerf (disambiguation).

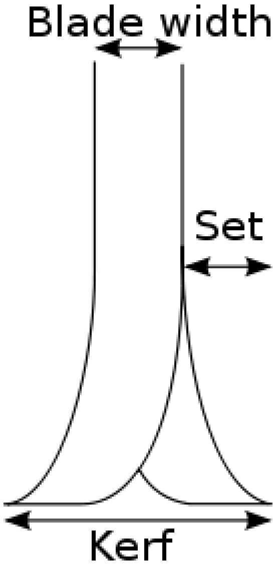

Diagram showing the teeth of a saw blade when looking front-on. The teeth protrude to the left and right, so that the saw cut (kerf) is wider than the blade width. The term *set* describes how much the teeth protrude. The kerf may be sometimes be wider than the set, depending on wobble and other factors.

- **Heel**: The end closest to the handle.
- **Toe**: The end farthest from the handle.
- **Front**: The side with the teeth (the "bottom edge").
- **Back**: The side opposite the front (the "top edge").
- **Teeth**: Small, sharp protrusions along the cutting side of the saw.
- **Gullet**: The valley between the **points** of the teeth.
- **Fleam**: The angle of the faces of the teeth relative to a line perpendicular to the face of the saw.
- **Rake**: The angle of the front face of the tooth relative to a line perpendicular to the length of the saw. Teeth designed to cut with the grain (*ripping*) are generally steeper than teeth designed to cut across the grain (*crosscutting*)
- **Points per inch** (25 mm): The most common measurement of the frequency of teeth on a saw blade. It is taken by setting the tip (or **point**) of one tooth at the zero point on a ruler, and then counting the number of points between the zero mark and the one-inch mark, inclusive (that is, including both the point at the zero mark and any point that lines up precisely with the one-inch mark). There is always one more point per inch than there are teeth per inch (e.g., a saw with 14 points per inch will have 13 teeth per inch, and a saw with 10 points per inch will have 9 teeth per inch). Some saws do not have the same number of teeth per inch throughout their entire length, but the vast majority do.

- **Teeth per inch**: An alternative measurement of the frequency of teeth on a saw blade. Usually abbreviated TPI, as in, "A blade consisting of 18TPI." [Compare **points per inch**.]
- **Kerf**: The width of a saw cut, which depends on several factors: the width of the saw blade; the **set** of the blade's teeth; the amount of wobble created during cutting; and the amount of material pulled out of the sides of the cut. Although the term "kerf" is often used informally, to refer simply to the width of the saw blade, or to the width of the set, this can be misleading, because blades with the same thickness and set may create different kerfs. For example, a too-thin blade can cause excessive wobble, creating a wider-than-expected kerf. The kerf created by a given blade can be changed by adjusting the set of its teeth with a tool called a saw tooth setter.
- **Set**: The degree to which the teeth are bent out sideways away from the blade, usually in both directions. In most modern serrated saws, the teeth are set, so that the **kerf** (the width of the cut) will be wider than the blade itself. This allows the blade to move through the cut easily without *binding* (getting stuck). The set may be different depending on the kind of cut the saw is intended to make. For example, a rip saw has a tooth set that is similar to the angle used on a chisel, so that it rips or tears the material apart. A "flush-cutting saw" has no set on one side, so that the saw can be laid flat on a surface and cut along that surface without scratching it. The set of the blade's teeth can be adjusted with a tool called a saw tooth setter.
- **Abrasive saw**: A saw that cuts with an abrasive disc or band, rather than a serrated blade.

History[

Roman sawblades from Vindonissa approx. 3rd to 5th century AD

Saws were at first serrated materials such as flint, obsidian, sea shells and sharks teeth. [1]

In ancient Egypt, open (unframed) saws made of copper are documented as early as the Early Dynastic Period, circa 3,100–2,686 BC.[2][*page needed*] Examples of saws used for cutting both wood and stone and as a tool for execution of people and models of saws have been found in many contexts throughout Egyptian history. Particularly useful are tomb wall illustrations of carpenters at work that show sizes and the use of different types. Egyptian saws were at first serrated, hardened, copper which cut on both pull and push strokes. As the saw developed teeth were raked to cut only on the pull stroke and set with the teeth projecting only on one side, rather than in the modern fashion with an alternating set. Saws were also made of bronze and later iron. In the Iron Age frame saws were developed holding the thin blades in tension.[1] The earliest known sawmill is the Roman Hierapolis sawmill from the third century AD and was for sawing stone.

Bronze-age saw blade from Akrotiri, late Cycladic period c. 17th century BC

According to Chinese legend, the saw was invented by Lu Ban.[3] In Greek mythology, as recounted by Ovid,[4] Talos, the nephew of Daedalus, invented the saw. In archeological reality, saws date back to prehistory and most probably evolved from Neolithic stone or bone tools. "[T]he identities of the axe, adz, chisel, and saw were clearly established more than 4,000 years ago."[5]

Plasma cutting performed by an industrial robot

Plasma cutting is a process that is used to cut steel and other metals of different thicknesses (or sometimes other materials) using a plasma torch. In this process, an inert gas (in some units, compressed air) is blown at high speed out of a nozzle; at the same time an electrical arc is formed through that gas from the nozzle to the surface being cut, turning some of that gas to plasma. The plasma is hot enough to melt the metal being cut and moves fast enough to blow molten metal away from the cut.

Process

Freehand cut of a thick steel plate

The HF type plasma cutting machine uses a high-frequency, high-voltage spark to ionize the air through the torch head and initiate an arc. These do not require the torch to be in contact with the job material when starting, and so are suitable for applications involving computer numerical controlled (CNC) cutting. More basic machines require tip contact (scratch) with the parent metal to start and then gap separation can occur similar to DC type TIG welders. These more basic type cutters are more susceptible to contact tip and shield damage on starting.

The Pilot Arc type uses a two cycle approach to producing plasma, avoiding the need for initial contact. First, a high-voltage, low current circuit is used to initialize a very small high-intensity spark within the torch body, thereby generating a small pocket of plasma gas. This is referred to as the *pilot arc*. The pilot arc has a return electrical path built into the torch head. The pilot arc will maintain itself until it is brought into proximity of the workpiece where it ignites the main plasma cutting arc. Plasma arcs are extremely hot and are in the range of 25,000 °C.[1]

Plasma is an effective means of cutting thin and thick materials alike. Hand-held torches can usually cut up to 38mm thick steel plate, and stronger computer-controlled torches can cut steel up to 150 mm thick. Since plasma cutters produce a very hot and very localized "cone" to cut with, they are extremely useful for cutting sheet metal in curved or angled shapes.

History

Plasma cutting with a tilting head

Plasma cutting grew out of plasma welding in the 1960s, and emerged as a very productive way to cut sheet metal and plate in the 1980s.[2] It had the advantages over traditional "metal against metal" cutting of producing no metal chips, giving accurate cuts, and producing a cleaner edge than oxy-fuel cutting. Early plasma cutters were large, somewhat slow and expensive and, therefore, tended to be dedicated to repeating cutting patterns in a "mass production" mode.

As with other machine tools, CNC (computer numerical control) technology was applied to plasma cutting machines in the late 1980s into the 1990s, giving plasma cutting machines greater flexibility to cut diverse shapes "on demand" based on a set of instructions that were programmed into the machine's numerical control.[3] These CNC plasma cutting machines were, however, generally limited to cutting patterns and parts in flat sheets of steel, using only two axes of motion (referred to as X Y cutting).

Water jet cutter

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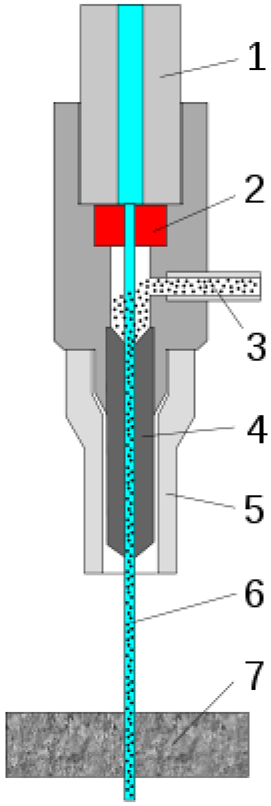

A diagram of a water jet cutter. #1: high-pressure water inlet. #2: jewel (ruby or diamond). #3: abrasive (garnet). #4: mixing tube. #5: guard. #6: cutting water jet. #7: cut material

A **water jet cutter**, also known as a **water jet** or **waterjet**, is an industrial tool capable of cutting a wide variety of materials using a very high-pressure jet of water, or a mixture of water and an abrasive substance. The term **abrasivejet** refers specifically to the use of a mixture of water and abrasive to cut hard materials such as metal or granite, while the terms **pure waterjet** and **water-only cutting** refer to waterjet cutting without the use of added abrasives, often used for softer materials such as wood or rubber.[1]

Waterjet cutting is often used during fabrication of machine parts. It is the preferred method when the materials being cut are sensitive to the high temperatures generated by other methods. Waterjet cutting is used in various industries, including mining and aerospace, for cutting, shaping, and reaming.

Waterjet CNC cutting machine.

Waterjet

While using high-pressure water for erosion dates back as far as the mid-1800s with hydraulic mining, it was not until the 1930s that narrow jets of water started to appear as an industrial cutting device. In 1933, the Paper Patents Company in Wisconsin developed a paper metering, cutting, and reeling machine that used a diagonally moving waterjet nozzle to cut a horizontally moving sheet of continuous paper.[2] These early applications were at a low pressure and restricted to soft materials like paper.

Waterjet technology evolved in the post-war era as researchers around the world searched for new methods of efficient cutting systems. In 1956, Carl Johnson of Durox International in Luxembourg developed a method for cutting plastic shapes using a thin stream high-pressure waterjet, but those materials, like paper, were soft materials.[3] In 1958, Billie Schwacha of North American Aviation developed a system using ultra-high-pressure liquid to cut hard materials.[4] This system used a 100,000 psi (690 MPa) pump to deliver a hypersonic liquid jet that could cut high strength alloys such as PH15-7-MO stainless steel. Used as a honeycomb laminate on the Mach 3 North American XB-70 Valkyrie, this cutting method resulted in delaminating at high speed, requiring changes to the manufacturing process.[5]

While not effective for the XB-70 project, the concept was valid and further research continued to evolve waterjet cutting. In 1962, Philip Rice of Union Carbide explored using a pulsing waterjet at up to 50,000 psi (345 MPa) to cut metals, stone, and other materials.[6] Research by S.J. Leach and G.L. Walker in the mid-1960s expanded on traditional coal waterjet cutting to determine ideal nozzle shape for high-pressure waterjet cutting of stone,[7] and Norman Franz in the late 1960s focused on waterjet cutting of soft materials by dissolving long chain polymers in the water to improve the cohesiveness of the jet stream.[8] In the early 1970s, the desire to improve the durability of the waterjet nozzle led Ray Chadwick, Michael Kurko, and Joseph Corriveau of the Bendix Corporation to come up with the idea of using corundum crystal to form a waterjet orifice,[9] while Norman Franz expanded on this and created a waterjet nozzle with an orifice as small as 0.002 inches (0.05 mm) that operated at pressures up to 70,000 psi (483 MPa).[10] John Olsen, along with George Hurlburt and Louis Kapcsandy at Flow Research (later Flow Industries), further improved the commercial potential of the waterjet by showing that treating the water beforehand could increase the operational life of the nozzle.[11]

High pressure[

High-pressure vessels and pumps became affordable and reliable with the advent of steam power. By the mid-1800s, steam locomotives were common and the first efficient steam-driven fire engine was operational.[12] By the turn of the century, high-pressure reliability improved, with locomotive research leading to a sixfold increase in boiler pressure, some reaching 1600 psi (11 MPa). Most high-pressure pumps at this time, though, operated around 500–800 psi (3–6 MPa

Electrical discharge machining

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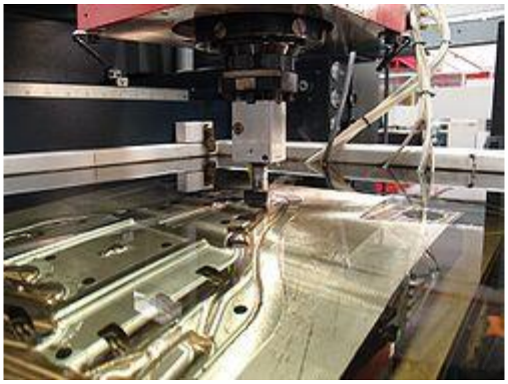
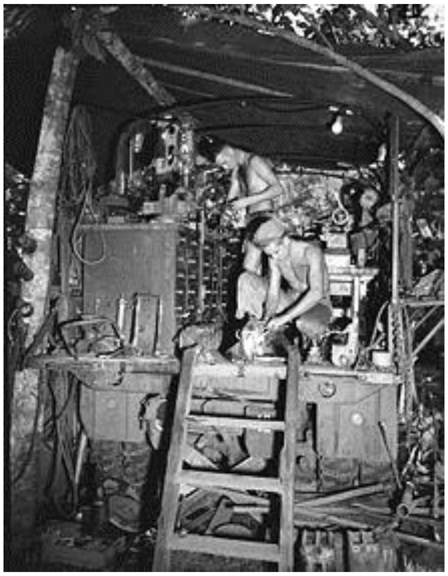


An electrical discharge machine

Electric discharge machining (**EDM**), sometimes colloquially also referred to as **spark machining**, **spark eroding**, **burning**, **die sinking**, **wire burning** or **wire erosion**, is a manufacturing process whereby a desired shape is obtained using electrical discharges (sparks).[1] Material is removed from the workpiece by a series of rapidly recurring current discharges between two electrodes, separated by a dielectric liquid and subject to an electric voltage. One of the electrodes is called the tool-electrode, or simply the ‘tool’ or ‘electrode’, while the other is called the workpiece-electrode, or ‘workpiece’.

When the distance between the two electrodes is reduced, the intensity of the electric field in the volume between the electrodes becomes greater than the strength of the dielectric (at least in some point(s)), which breaks, allowing current to flow between the two electrodes. This phenomenon is the same as the breakdown of a capacitor (condenser) (see also breakdown voltage). As a result, material is removed from both the electrodes. Once the current flow stops (or it is stopped – depending on the type of generator), new liquid dielectric is usually conveyed into the inter-electrode volume enabling the solid particles (debris) to be carried away and the insulating properties of the dielectric to be restored. Adding new liquid dielectric in the inter-electrode volume is commonly referred to as flushing. Also, after a current flow, a difference of potential between the two electrodes is restored to what it was before the breakdown, so that a new liquid dielectric breakdown can occur.

Machining



New Guinea in 1943. Mobile machine shop truck of the US Army with machinists working on automotive parts

Machining is any of various processes in which a piece of raw material is cut into a desired final shape and size by a controlled material-removal process. The many processes that have this common theme, controlled material removal, are today collectively known as **subtractive manufacturing**, in distinction from processes of controlled material addition, which are known as additive manufacturing. Exactly what the "controlled" part of the definition implies can vary, but it almost always implies the use of machine tools (in addition to just power tools and hand tools).

The precise meaning of the term *machining* has evolved over the past one and a half centuries as technology has advanced. In the 18th century, the word *machinist* simply meant a person who built or repaired machines. This person's work was done mostly by hand, using processes such as the carving of wood and the hand-forging and hand-filing of metal. At the time, millwrights and builders of new kinds of *engines* (meaning, more or less, machines of any kind), such as James Watt or John Wilkinson, would fit the definition. The noun *machine* *tool* and the verb *to machine* (*machined, machining*) did not yet exist. Around the middle of the 19th century, the latter words were coined as the concepts that they described evolved into widespread existence. Therefore, during the Machine Age, *machining* referred to (what we today might call) the "traditional" machining processes, such as turning, boring, drilling, milling, broaching, sawing, shaping, planing, reaming, and tapping.[1] In these "traditional" or "conventional" machining processes, machine tools, such as lathes, milling machines, drill presses, or others, are used with a sharp cutting tool to remove material to achieve a desired geometry.[2] Since the advent of new technologies such as electrical discharge machining, electrochemical machining, electron beam machining, photochemical machining, and ultrasonic machining, the retronym "conventional machining" can be used to differentiate those classic technologies from the newer ones. In current usage, the term "machining" without qualification usually implies the traditional machining processes.

Machining is a part of the manufacture of many metal products, but it can also be used on materials such as wood, plastic, ceramic, and composites.[3] A person who specializes in machining is called a machinist. A room, building, or company where machining is done is called a machine shop. Machining can be a business, a hobby, or both.[4] Much of modern day machining is carried out by computer numerical control (CNC), in which computers are used to control the movement and operation of the mills, lathes, and other cutting machines.

Laser cutting is a technology that uses a laser to cut materials, and is typically used for industrial manufacturing applications, but is also starting to be used by schools, small businesses, and hobbyists. Laser cutting works by directing the output of a high-power laser most commonly through optics. The laser optics and CNC (computer numerical control) are used to direct the material or the laser beam generated. A typical commercial laser for cutting materials would involve a motion control system to follow a CNC or G-code of the pattern to be cut onto the material. The focused laser beam directed at the material, which then either melts, burns, vaporizes away, or is blown away by a jet of gas,[1] leaving an edge with a high-quality surface finish. Industrial laser cutters are used to cut flat-sheet material as well as structural and piping materials.