Handbook of Power Tools

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Chapter 1

Impact Wrench

A 1/2" drive pistol-grip air impact wrench

An **impact wrench** (also known as an **impactor**, **air wrench**, **air gun**, **rattle gun**, **torque gun**) is a socket wrench power tool designed to deliver high torque output with minimal exertion by the user, by storing energy in a rotating mass, then delivering it suddenly to the output shaft.

Compressed air is the most common power source, although electric or hydraulic power is also used, with cordless electric devices becoming increasingly popular in recent times.

Impact wrenches are widely used in many industries, such as automotive repair, heavy equipment maintenance, product assembly (often called "pulse tools" and designed for precise torque output), major construction projects, and any other instance where a high torque output is needed.

Impact wrenches are available in every standard socket wrench drive size, from small 1/4" drive tools for small assembly and disassembly, up to 3.5" and larger square drives for major construction. Impact wrenches are one of the most commonly used air tools, and are found in virtually every mechanic's shop.

In operation, a rotating mass (the hammer) is accelerated by the motor, storing energy, then suddenly connected to the output shaft (the anvil), creating a high-torque impact. The hammer mechanism is designed such that after delivering the impact, the hammer is again allowed to spin freely, and does not stay locked. With this design, the only reaction force applied to the body of the tool is the motor accelerating the hammer, and thus the operator feels very little torque, even though a very high peak torque is delivered to the socket. This is similar to a conventional hammer, where the user applies a small, constant force to swing the hammer, which generates a very large impulse when the hammer strikes an object. Energy is stored over time, allowing a very strong, but short output impulse to be generated from a relatively weak, but constant input force. The hammer design requires a certain minimum torque before the hammer is allowed to spin separately from the anvil, causing the tool to stop hammering and instead smoothly drive the fastener if only low torque is needed, rapidly installing/removing the fastener.

Power source

Compressed air is the most common power source for impact wrenches, providing a low-cost design with the best power-to-weight ratio. A simple vane motor is almost always used, usually with four to seven vanes, and various lubrication systems, the most common of which uses *oiled air*, while others may include special oil passages routed to the parts that need it and a separate, sealed oil system for the hammer assembly. Most impact wrenches drive the hammer directly from the motor, giving it fast action when the fastener requires only low torque. Other designs use a gear reduction system before the hammer mechanism, most often a single-stage planetary gearset usually with a heavier hammer, delivering a more constant speed and higher "spin" torque. Electric impact wrenches are available, either mains powered, or for automotive use, 12-volt or 24-volt DC-powered. Recently, cordless electric impact wrenches have become common, although typically their power outputs are significantly lower than corded electric or air-powered equivalents. Some industrial tools are hydraulically powered, using high-speed hydraulic motors, and are used in some heavy equipment repair shops, large construction sites, and other areas where a suitable hydraulic supply is available. Hydraulically powered impact wrench has the advantage of high power to weight ratio and are able to deliver more power in smaller size.

Sizes and styles

A variety of impact wrenches, in all common sizes from 1/4" to 1", of different styles, including inline, butterfly, and pistol grip.

This "reactionless" ratchet uses a miniature pin clutch impact mechanism instead of a gear reduction.

Large 2½" Drive Ingersoll Rand impact vs regular ½" impact wrench.

Impact wrenches are available in all sizes and in several styles, depending on the application. 1/4" drive wrenches are commonly available in both inline (the user holds the tool like a screwdriver, with the output on the end) and pistol grip (the user holds a handle which is at right angles to the output) forms, and less commonly in an angle drive, which is similar to an inline tool but with a set of bevel gears to rotate the output 90 degrees. 3/8" impacts are most commonly available in pistol grip form and a special inline form known as a "butterfly" wrench, which has a large, flat throttle paddle on the side of the tool which may be tilted to one side or the other to control the direction of rotation, rather than using a separate reversing control, and shaped to allow access into tight areas. Regular inline and angle 3/8" drive impact wrenches are uncommon, but available. 1/2" drive units are virtually only available in pistol grip form, with any inline type being virtually impossible to obtain, due to the increased torque transmitted back to the user and the greater weight of the tool requiring the larger handle. 3/4" drive impact wrenches are again essentially only available in pistol grip form. 1" drive tools are available in both pistol grip and "D handle" inline, where the back of the tool has an enclosed handle for the user to hold. Both forms often also incorporate a side handle, allowing both hands to hold the tool at once. 1.25" and larger wrenches are usually available in "T handle" form, with two large handles on either side of the tool body, allowing for maximum torque to be applied to the user, and giving the best control of the tool. Very large impact wrenches (up to several hundred thousand foot-pounds of torque) usually incorporate eyelets in their design, allowing them to be suspended from a crane, lift, or other device, since their weight is often more than a person can move. A recent design combines an impact wrench and an air ratchet, often called a "reactionless air ratchet" by the manufacturers, incorporating an impact assembly before the ratchet assembly. Such a design allows very high output torques with minimal effort on the operator, and prevents the common injury of slamming one's knuckles into some part of the equipment when the fastener tightens down and the torque suddenly increases. Specialty designs are available for certain applications, such as removing crankshaft pulleys without removing the radiator in a vehicle.

Various methods are used to attach the socket or accessory to the anvil, such as a spring-loaded pin that snaps into a matching hole in the socket, preventing the socket being removed until an object is used to depress the pin, a hog ring which holds the socket by friction or by snapping into indents machined into the socket, and a through-hole, where a pin is inserted completely through the socket and anvil, locking the socket on. Hog rings are used on most smaller tools, with though-hole used only on larger impact wrenches, typically 3/4" drive or greater. Pin retainers used to be more common, but seem to be being replaced by hog rings on most tools, despite the lack of a positive lock. 1/4" female hex drive is becoming increasingly popular for small impact wrenches, especially cordless electric versions, allowing them to fit standard screwdriver tips rather than sockets.

Many users choose to equip their air-powered impact wrenches with a short length of air hose rather than attaching an air fitting directly to the tool. Such a hose greatly aids in fitting the wrench into tight areas, by not having the complete coupler assembly sticking out the back of the tool, as well as making it easier for the user to position the tool. An additional benefit is greatly reduced wear on the coupler, by isolating it from the vibration of the tool. A short length of hose also prevents the air fitting from being broken off in the base of the tool if the user loses their grip and the tool is allowed to spin.

Effects of impact drive

As the output of an impact wrench, when hammering, is a very short impact force, the actual effective torque is difficult to measure, with several different ratings in use. As the tool delivers a fixed amount of energy with each blow, rather than a fixed torque, the actual output torque changes with the duration of the output pulse. If the output is springy or capable of absorbing energy, the impulse will simply be absorbed, and virtually no torque will ever be applied, and somewhat counter-intuitively, if the object is very springy, the wrench may actually turn backwards as the energy is delivered back to the anvil, while it is not connected to the hammer and able to spin freely. A wrench that is capable of freeing a rusted nut on a very large bolt may be incapable of turning a small screw mounted on a spring. "Maximum torque" is the number most often given by manufacturers, which is the instantaneous peak torque delivered if the anvil is locked into a perfectly solid object. "Working torque" is a more realistic number for continually driving a very stiff fastener. "Nut-busting torque" is often quoted, with the usual definition being that the wrench can loosen a nut tightened with the specified amount of torque in some specified time period. Accurately controlling the output torque of an impact wrench is very difficult, and even an experienced operator will have a hard time making sure a fastener is not undertightened or overtightened using an impact wrench. Special socket extensions are available, which take advantage of the inability of an impact wrench to work against a spring, to precisely limit the output torque. Designed with spring steel, they act as large torsion springs, flexing at their torque rating, and preventing any further torque from being applied to the fastener. Some impact wrenches designed for product assembly have a built-in torque control system, such as a built-in torsion spring and a mechanism that shuts the tool down when the given torque is exceeded. When very precise torque is required, an impact wrench is only used to snug down the fastener, with a torque wrench used for the final tightening. Due to the lack of standards when measuring the maximum torque, some manufacturers are believed to inflate their ratings, or to use measurements with little bearing on how the tool will perform in actual use. Many air impact wrenches incorporate a flow regulator into their design, either as a separate control or part of the reversing valve, allowing torque to be roughly limited in one or both directions, while electric tools may use a variable speed trigger for the same effect.

Hammer mechanisms

The pin clutch mechanism from a 3/4" drive impact wrench.

The hammer mechanism in an impact wrench needs to allow the hammer to spin freely, impact the anvil, then release and spin freely again. Many designs are used to accomplish this task, all with some drawbacks. Depending on the design, the hammer may drive the anvil either once or twice per revolution (where a revolution is the difference between the hammer and the anvil), with some designs delivering faster, weaker blows twice per revolution, or slower, more powerful ones only once per revolution.

A common hammer design has the hammer able to slide and rotate on a shaft, with a spring holding it in the downwards position. Between the hammer and the driving shaft is a steel ball on a ramp, such that if the input shaft rotates ahead of the hammer with enough torque, the spring is compressed and the hammer is slid backwards. On the bottom of the hammer, and the top of the anvil, are dog teeth, designed for high impacts. When the tool is used, the hammer rotates until its dog teeth contact the teeth on the anvil, stopping the hammer from rotating. The input shaft continues to turn, causing the ramp to lift the steel ball, lifting the hammer assembly until the dog teeth no longer engage the anvil, and the hammer is free to spin again. The hammer then springs forward to the bottom of the ball ramp, and is accelerated by the input shaft, until the dog teeth contact the anvil again, delivering the impact. The process then repeats, delivering blows every time the teeth meet, almost always twice per revolution. If the output has little load on it, such as when spinning a loose nut on a bolt, the torque will never be high enough to cause the ball to compress the spring, and the input will smoothly drive the output. This design has the advantage of small size and simplicity, but energy is wasted moving the entire hammer back and forth, and delivering multiple blows per revolution gives less time for the hammer to accelerate. This design is often seen after a gear reduction, compensating for the lack of acceleration time by delivering more torque at a lower speed.

A stop-motion of a pin clutch hammer. Normally the hammer rotates while the anvil remains stationary attached to the fastener, but rotating the anvil more clearly demonstrates the action of the pins.

Another common design uses a hammer fixed directly onto the input shaft, with a pair of pins acting as clutches. When the hammer rotates past the anvil, a ball ramp pushes the pins outwards against a spring, extending them to where they will hit the anvil and deliver the impact, then release and spring back into the hammer, usually by having the balls "fall off" the other side of the ramp at the instant the hammer hits. Since the ramp need only have one peak around the shaft, and the engagement of the hammer with the anvil is not based on a number of teeth between them, this design allows the hammer to accelerate for a full revolution before contacting the anvil, giving it more time to accelerate and delivering a stronger impact. The disadvantages are that the sliding pins must handle very high impacts, and often cause the early failure of tool.

Yet another design uses a rocking weight inside the hammer, and a single, long protrusion on the side of the anvil's shaft. When the hammer spins, the rocking weight first contacts the anvil on the opposite side than used to drive the anvil, nudging the weight into position for the impact. As the hammer spins further, the weight hits the side of the anvil, transferring the hammer's and its own energy to the output, then rocks back to the other side. This design also has the advantage of hammering only once per revolution, as well as its simplicity, but has the disadvantage of making the tool vibrate as the rocking weight acts as an eccentric, and can be less tolerant of running the tool with low input power. To help combat the vibration and uneven drive, sometimes two of these hammers are placed in line with each other, at 180 degree offsets, both striking at the same time.

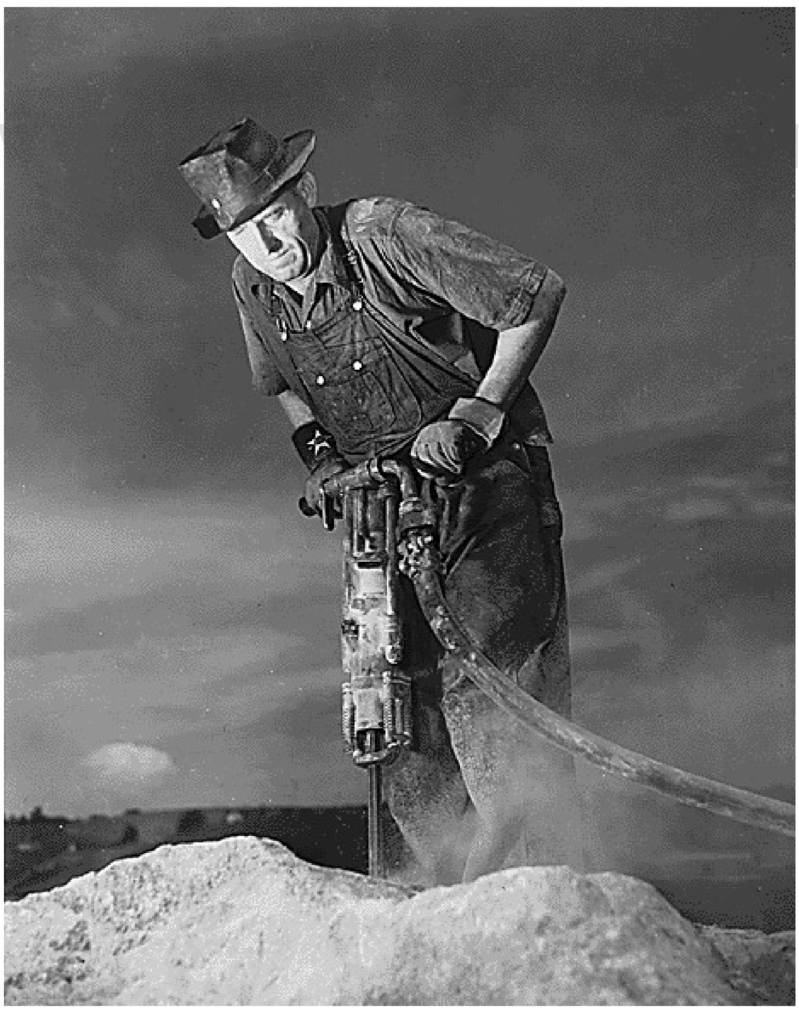
Many other designs are used, but all of them accomplish the same goal of allowing the hammer to spin freely of the anvil, allowing it to be accelerated and store energy, then delivering that energy suddenly to the anvil, before allowing the process to repeat.

Sockets and accessories

Sockets and extensions for impact wrenches are made of high tensile metal, as any spring effect will greatly reduce the torque available at the fastener. Even so, the use of multiple extensions, universal joints, and so forth will weaken the impacts, and the operator needs to minimize their use. Using non-impact sockets or accessories with an impact wrench will often result in bending, fracturing, or otherwise damaging the accessory, as most are not capable of withstanding the sudden high torque of an impact tool, and can result in stripping the head on the fastener. Non-impact sockets and accessories are made of a harder more brittle metal. Safety glasses should always be worn when working with impact tools, as the strong impacts will generate high-speed shrapnel if a socket, accessory, or fastener fails, unlike the steady torque of a hand ratchet where a broken accessory usually does nothing worse than cause bruised knuckles.

Chapter 2

Jackhammer



Drilling a blast hole with a jackhammer

A **jackhammer** is a power tool that combines a hammer and chisel. Hand-held jackhammers are typically powered by compressed air, but some used electric motors.

Larger jackhammers used on construction machinery are usually hydraulically powered. They are usually used to breakup rock, pavement, and concrete.

A jackhammer operates by driving an *internal* hammer up and down. The hammer is first driven down to strike the back of the *bit* and then back up to return the hammer to the original position to repeat the cycle. The bit usually recovers from the stroke by means of a spring. The effectiveness of the jackhammer is dependent on how much force is applied to the tool.

Terminology

The word "jackhammer" is used in North American English and Australia, while "pneumatic drill" is used colloquially elsewhere in the English speaking world, although strictly speaking a "pneumatic drill" refers to a pneumatically driven jackhammer. In Britain, the term "jackhammer" usually refers to electromechanical version of the tool.

Use

A full-sized portable jackhammer is impractical for use against walls and steep slopes, except for a very strong man, as the user would have to both support the weight of the tool, and push the tool back against the work after each blow. A technique developed by experienced workmen is a two-man team to overcome this obstacle of gravity: one man operates the hammer and the second assists by holding the hammer either on his shoulders or cradled in his arms. Both use their combined weight to push the bit into the workface. This method is commonly referred to as horizontal jackhammering.

Another method is overhead jackhammering, requiring strength conditioning and endurance to hold a smaller jackhammer, called a rivet buster, over one's head.

Types

Pneumatic

A compressor for running a pneumatic jackhammer

A pneumatic jackhammer, also known as a *pneumatic hammer*, is a jackhammer that uses compressed air as the power source. The air supply usually comes from a portable air compressor driven by a diesel engine. Reciprocating compressors were formerly used. The unit comprised a reciprocating compressor driven, through a centrifugal clutch, by a diesel engine. The engine's governor provided only two speeds:

- idling, when the clutch was disengaged
- maximum, when the clutch was engaged and the compressor was running

Modern versions use rotary compressors and have more sophisticated variable governors. The unit is usually mounted on a trailer and sometimes includes an electrical generator to supply lights or electric power tools.

Electromechanical

A single phase demolition breaker.

This tool is useful where the work is light and inaccessible to a compressor.

Hydraulic

An excavator-mounted hydraulic jackhammer being used to break up concrete.

A hydraulic jackhammer, much larger than portable ones, may be fitted to mechanical excavators or backhoes and is widely used for roadwork, quarrying and general demolition or construction groundwork. Such tools can also be used against vertical walls (or ceilings for that matter), since the vehicles involved are massive enough and powerful enough to exert the forces involved without needing the help of gravity in operating the tool. Pneumatic or hydraulic tools are particularly likely to be used in mines where there is an explosion risk (such as underground coal mines), since they lack any high-power electrical circuitry that might cause a triggering spark.

Hydraulic breakers usually use a hydraulic motor driving a sealed pneumatic hammer system, as a hydraulic hammer would develop a low strike speed and transfer unacceptable shock loads to the pump system.

Bits

Bit types include:

- Spade - provides flat finish for concrete or edging in asphalt or dirt
- Flat tip - allows direction control or finer edge finish
- Point - general breaking
- Stake driver - drives concrete form stakes
- Scrabbler - finishes surface smooth or for cleaning prior to bonding

Health

A jackhammer with black silencer attached

The sound of the hammer blows, combined with the explosive air exhaust, makes pneumatic jackhammers dangerously loud, emitting 100 decibels at two meters. Sound-blocking earmuffs must be worn by the operator to prevent a form of hearing damage of which tinnitus is the main symptom. Most pneumatic jackhammers now have a silencer around the barrel of the tool.

Prolonged exposure to the pronounced vibration set up by the tool can lead to blood-circulation failures in the fingers, a condition known as white finger. Applying athletic tape is not effective in preventing white finger but seems to help alleviate some of its discomfort. Pneumatic drill usage can also lead to a predisposition for development of carpal tunnel syndrome.

References

Air hose connection on pneumatic drill

Chapter 3

Air Hammer (Fabrication)

A German pistol-type air hammer

An **air hammer**, also known as an **air chisel**, is a pneumatic hand tool used to break or cut metal objects apart. It is designed to accept different tools depending on the required function.

Function

Tools

The following are various tools that can be used in the air hammer:

Universal joint and tie-rod tool

Used to separate universal joints and tie-rod ends.

Ball joint separator

Used to separate ball joints.

Shock absorber chisel

Used to break loose shock absorber nuts.

Exhaust pipe cutter

Used to cut through exhaust pipe for disassembly.

Tapered punch

A general tool that can be used to free frozen nuts, insert pins, and align holes.

Rubber bushing splitter

Used to remove rubber bushings.

Free-standing style

Free-standing air hammers are an adaptation of the hand-held version. An air hammer can stretch or shrink (shape) a variety of metals, from thin aircraft aluminums, all the way down to 10-gauge steel. They are also used for smoothing metal that has already been roughed, shaped or formed.

History

In the 1920s, two pneumatic devices were invented that would permanently change the way metal and stone were hammered. The pneumatic rivet gun was originally developed to set hot rivets on girder bridges and high steel buildings. This tool was later scaled down for sheet metal, as the 1930s saw the advent of monocoque aluminum aircraft. The other new device, hitting at twice or three times the speed of the rivet gun, was the stone carver's hammer – a great blessing for smooth and rapid dressing of granite and marble.

In 1930 F.J. Hauschild adapted the original stone carver's hammer into a portable hand-held steel tube frame for the purpose of straightening auto bodies. For the next 25 years his "Ram's Head Body and Fender Machine" improved and increased production for auto body work men all over the U.S. Copying Hauschild’s patented design, a pneumatic tool company in Chicago marketed a number of "destined-to-be-classic" pneumatic planishing hammers, both hand-held for auto body work, and also free-standing ones, with a variety of throat depths for industry and manufacturing.

By World War II, rivet guns were used widely in U.S. aircraft factories both for riveting aluminum sheets, and for flow forming, the process of working aluminum sheet into and over wooden forms by the application of the pneumatic rivet gun.

Post-war industry brought many new applications for the "air hammer" technology. Among these were:

- sand rammers and tampers for sand casting metal
- plating rack scalers
- weld chippers
- destruction guns for cleaning up concrete
- needle scalers
- pavement breakers
- metal chisels.

Each of these tools has a different purpose despite nearly identical appearance in many cases.

Chapter 4

Air Knife

An **air knife** is a tool used to blow off liquid or debris from products as they travel on conveyors. Air knives are normally used in manufacturing or as the first step in a recursive recycling process to separate lighter or smaller particles from other components for use in later or subsequent steps, post manufacturing parts drying and conveyor cleaning, part of component cleaning. The knife consists of a high intensity, uniform sheet of laminar airflow sometimes known as streamline flow.

An industrial air knife is a pressurized air plenum containing a series of holes or continuous slots through which pressurized air exits in a laminar flow pattern. The exit air velocity then creates an impact air velocity onto the surface of whatever object the air is directed. This impact air velocity can range from a gentle breeze to greater than Mach 0.6 (40,000 ft/min) to alter the surface of a product without mechanical contact.

Air knives remove liquids, control the thickness of liquids, dry the liquid coatings, remove foreign particles, cool product surfaces or create a hold down force to assist in the mechanical bonding of materials to the surface. Electrical currents from anti-static bars can also be injected into the exit air knife stream to neutralize the static electricity charge on some surfaces.

In the majority of manufacturing applications for air knives, the air knives are stationary while the product passes through the air velocity air stream. In other circumstances, the product is stationary and the air knives moves (reciprocate or rotate) over the surface of the stationary product. Although there are very few applications where an air knife can actually cut a product (break mechanical bonds between two points), air knives are often the most efficient method of removing or controlling unwanted or foreign substances on any surface.

History

In the 1950s and 60s, the term air doctor was first used to refer to the non-contact method of debris blow-off using compressed air. The printing and textile industries were some of the largest users of air doctors at that time. They often needed wide paths of air from a compressed air system to control the thickness of liquids on a surface, or to blow debris off the surface of materials prior to the next process. Other terms used were air bar, air squeegee, air curtain, air jet, air blast, air blow off, air nozzle, air comb, air blade and air doctor blade. Today the most commonly used term is simply, air knife.

Although air knives powered by compressed plant air are used in a wide variety of industrial applications, industrial blower powered air knives have proven to reduce the energy usage versus compressed air knives by 50-75% for most applications. Blower powered air knife systems really came of age with the advent of the 1987 Montreal Protocol which started the clock on the worldwide phase-out of atmospheric ozone depleting CFC's (chlorofluorocarbons) then used as cleaning agents in most industries.

Most of these solvent based cleaning agents simply evaporated which required no blow off or other drying methods. Although the printed circuit board industry was still in its infancy, it was among the first to initiate the conversion to aqueous and semi-aqueous based parts cleaning systems.

With nearly every existing and all future circuit board factories using the new environmentally friendly cleaning technology, they also needed a new method of drying the p.c. boards following their water-based cleaning to remove the solder fluxes and other contaminants. The trend away from other types of solvent-based parts cleaning to water-based cleaning for all other industries began soon thereafter. Additionally, the conversion to water based inks, paints, coatings, adhesives and other solutions used in all manufacturing sectors has resulted in the need for air knife dryers where none had previously existed. As a result of the Montreal Protocol and the worldwide industry compliance to meet its environmental stewardship mandates, the former niche business of air knives became an industry.

Description of operation

Air knives on a production line commonly range from 0.25 to 200 inches (6.3 to 5,100 mm) in length with a discharge air slot or holes ranging from 0.001 to 0.25 in (0.025 to 6.3 mm). A stationary air knife configuration can require from one to a dozen air knives depending on the application criteria. Air is blasted through the air knife slots via an air generator, either an industrial blower or air compressor, to deliver the predetermined exit air volume and velocity needed.

There are many application, environmental, efficiency and duty cycle aspects to consider when choosing between compressors and blowers. Compressed air, which is least efficient when used for air knives discharging into free air, allows for use of primary plant air. The piping sizes supplying the air knives can be as little as ¼ in (6.4 mm) diameter so they are ideal for confined spaces. Blower powered air knives must be larger in size along with larger diameter supply piping, but the efficiency improvement over compressed air is easily justified with the electrical power cost savings.

Air knife designs today have evolved to where some manufacturers produce a very efficient “teardrop” shape with a .95 coefficient of discharge. These blower powered air knife designs typically have a profile of approximately 3.5 in (89 mm) wide x 5.5 in (140 mm) tall x any length, but the teardrop profile can range from 1.5 to 10 in (38 to 250 mm) tall depending on the criteria of the product for which the impact air velocity must be engineered. With construction ranging from ⅛ in (3.2 mm) thick aluminum extrusion to 11 gage fabricated stainless steel, air knives can weigh 1 lb/ft to 25 lbs/ft. Depending on the width and speed of the product, the air knife can provide effective blow off performance from 0.5 to 12 in (13 to 300 mm) or more away from the surface of the product. Round air nozzles of 1 to 4 in (25 to 100 mm) diameter can be effective against surfaces which are up to several feet (1 to 2 meters) from the product surface when engineered for such applications.

Types and applications

The most common use of air knives is to contain or remove free-standing materials (liquids or solids) from the surface of material. The applications include drying bottles and cans after filling and rinsing, printed circuit boards following the conveyorized wash to remove solder paste and flux, metals castings after automatic machining and many more. They can also deliver heated or cooled air to a surface, or create an invisible air barrier to separate heated or cooled environments from one another in industrial applications such as continuous metal heat treating ovens, cold process or storage areas in food processing or dust containment for the entrance to clean rooms.

There is a variety of uses for air knives in many different industries, applications and environments. The invisible high velocity air streams can be discharged by air knife designs of numerous shapes and sizes. These range from “garage built” devices with a low level of precision to the most exotic metals of construction used in air knives for class 100 clean rooms.

Basic design features

Compressed air powered air knives

There has always been a wide assortment of blow off appliances. Air knives and nozzles for compressed air blow off range from home made round pipes with holes to engineered high pressure air knives. In order to achieve the highest efficiency using compressed air, many manufacturers of compressed air knives utilize the Coandă effect to improve compressed air knife design over other types of knives and nozzles. Although the efficiency of compressed air for low pressure blow off air is much lower than blowers, the Coanda inspired air knives entrain ambient air into the high velocity stream to enhance the blow off effect.

Blower powered air knives

In the 1990s, many blower and air knife manufacturers adopted the tear drop shaped air knife having a bulbous plenum which tapers down to a precise air discharge slot as the standard of the blower driven air knife industry. Whereas a round pipe with holes drilled has an average coefficient of discharge of 0.6 (60% efficient), the tear drop shape air knife is commonly 0.95 (95% efficient) which provides much higher impact air velocity to the surface at which the air is directed with the lowest blower motor power demand. These tear drop designs are available in extruded aluminum shapes as well as fabricated carbon and stainless steels.

Chapter 5

Nail Gun

Pneumatic nail gun in use

A **nail gun**, **nailgun** or **nailer** is a type of tool used to drive nails into wood or some other kind of material. It is usually driven by electromagnetism, compressed air (pneumatic), highly flammable gases such as butane or propane, or, for powder-actuated tools, a small explosive charge. Nail guns have in many ways replaced hammers as tools of choice among builders.

Usage

Nail guns do not use individual fasteners. Instead, the fasteners are mounted in long strips (similar to a stick of staples) or collated in a paper or plastic carrier, depending on the design of the nailgun. Some full head nail guns, especially those used for pallet making and roofing, use long plastic or wire collated coils. Some strip nailers use a clipped head so the nails can be placed closer together, which necessitates less frequent reloading. Industrial nailers designed for use against steel or concrete may have a self-loading action for the explosive caps, but most require nails to be loaded by hand. Nail guns vary in the length and gauge (thickness) of nails they can drive.

Air compressor supplies air into a nail gun

The smallest size of fasteners are normally 24 to 22 gauge (0.60 to 0.71 mm diameter) and generally have no head. They are used for attaching beadings, mouldings and so forth to furniture, etc. Lengths are normally in the range ⅜ to 1¼ in. (10 to 32 mm) although some specialist manufacturers supply up to 2 in. (50 mm)

The next size up is the 18 gauge (1.22 mm diameter) fixing, often referred to as a "brad nail". These fastenings are also used to fix mouldings but can be used in the same way as the smaller 22 to 24 gauge fastenings. Their greater strength leads to their use in trim carpentry on hardwoods where some hole filling is acceptable. Whilst most 18 gauge brads have heads, some manufacturers do offer headless fastenings. Lengths range from ⅝ in to 2 in. (16 mm to 50 mm)

Going up from 18 gauge fastenings the next sizes are 16 and 15 gauge (1.63 and 1.83 mm diameter). These are generally referred to a "finish nails". They come in lengths between ⅝ and 2½ in. (16 to 64 mm) and are used in the general fixing of much softwood and MDF trim work (such as baseboard/skirtings, architraves, etc.) where the holes will be filled and the work painted afterwards.

The largest sizes of conventional collated fastenings are the clipped head and full head nails which are used in framing, fencing and other forms of structural and exterior work. These nails generally have a shank diameter of 0.11 to 0.13 in. (2.9 to 3.1 mm) although some manufacturers offer smaller diameter nails as well. General lengths are in the range 2 in to 3 ⅓ in (50 to 90 mm). Shank styles include plain, ring annular, twisted, etc. and a variety of materials and finishes are offered including plain steel, galvanised steel, sherardised steel, stainless steel, etc. depending on the pull-out resistance, corrosion resistance, etc. required for the given application. These sizes of fastenings are available in stick collated form (often 20° to 21° for full head, 28° to 34° for clipped head) or coil form (for use in pallet/roofing nailers) depending on the application. Full-head nails have greater pull-out resistance than clipped head nails and are mandated by code in many hurricane zones for structural framing.

Another type of fastening commonly found in construction is the strap fastening which is roughly analogous to the large head clout nail. These are used in conjunction with a strap shot nailer (or positive placement nailer *UK*) to fix metalwork such as joist hangers, corner plates, strengthening straps, etc. to timber structures. They differ from conventional nailers in that the point of the fastening is not sheathed so it can be exactly positioned before firing the nail gun.

Other specialist nailers are also available which can drive spikes up to 6¼ inches long, fix wood to steel, etc.

A variation on the nail gun is the palm nailer which is a lightweight handheld pneumatic nailer that straps to the hand. It is convenient for working in tight spaces where a conventional nailer will not fit and is flexible enough to drive either short nails into metal straps or six inch nails into timber. By repeated hammer action (of around 40 hits per second) the fastener is driven into the material by a more constant palm pressure (as opposed to a conventional nailgun which drives the nail against the inertia of the nailgun itself).

Safety

In the United States, about 37,000 people every year go to emergency rooms with injuries from nail guns, according to the U.S. Centers for Disease Control (CDC). Forty percent of those injuries occur to consumers. Nail gun injuries tripled between 1991 to 2005. Foot and hand injuries are among the most common. The U.S. Consumer Product Safety Commission estimates that treating nail gun wounds costs at least $338 million per year nationally in emergency medical care, rehabilitation, and workers' compensation.

All kinds of nail guns can be dangerous, so safety precautions similar to those for a firearm are usually recommended for their use. For safety, nail guns are designed to be used with the muzzle touching the target. Unless specifically modified for the purpose, they are not effective as projectile weapons.

The most common firing mechanism is the dual-action contact-trip trigger, which requires that the manual trigger and nose contact element both be depressed for a nail to be discharged. The sequential-trip trigger, which is safer, requires the nose contact to be depressed before the manual trigger, rather than simultaneously with the trigger. Approximately 65% to 69% of injuries from contact-trip tools could be prevented through the use of a sequential-trip trigger, according to the CDC.

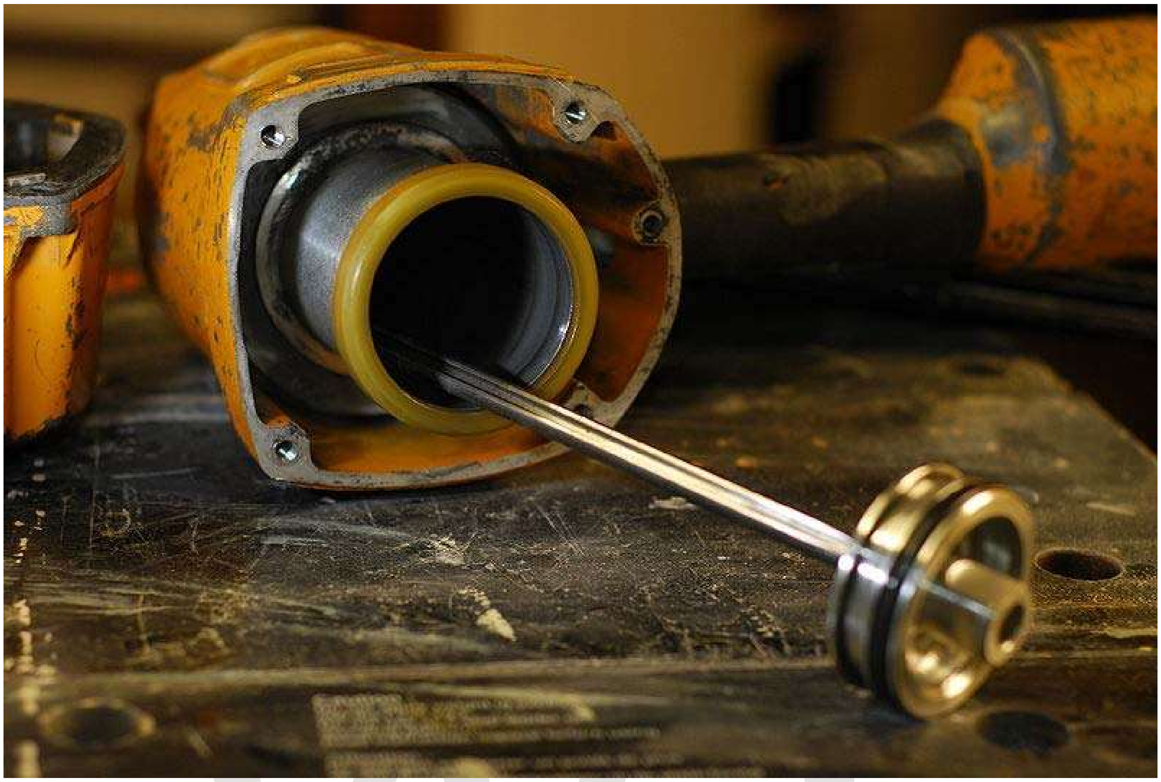
Powder actuation

Explosive-powered ("powder actuated") nailguns fall into two broad categories:

- Direct drive or high velocity devices. This uses gas pressure acting directly on the nail to drive it.
- Indirect drive or low velocity devices. This uses gas pressure acting on a heavy piston which drives the nail. Indirect drive nailers are safer because they cannot launch a free-flying projectile even if tampered with or misused, and the lower velocity of the nails is less likely to cause explosive shattering of the work substrate.

Either type can, with the right cartridge loads, be very powerful, driving a nail or other fastener into hard concrete, stone, rolled steelwork, etc., with ease.

Pneumatic nail guns require air hoses to fire



In the nailgun's head, the inner chamber contains the piston assembly which drives the nail.

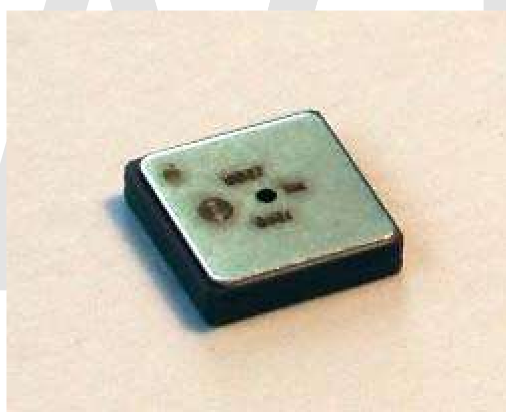
Nails come in clips for use in nail guns

Cartridges, used in powder actuated nail guns

Chapter 6

Pressure Sensor

Digital air pressure sensor



Compact digital barometric pressure sensor

A **pressure sensor** measures pressure, typically of gases or liquids. Pressure is an expression of the force required to stop a fluid from expanding, and is usually stated in terms of force per unit area. A pressure sensor usually acts as a transducer; it generates a signal as a function of the pressure imposed.

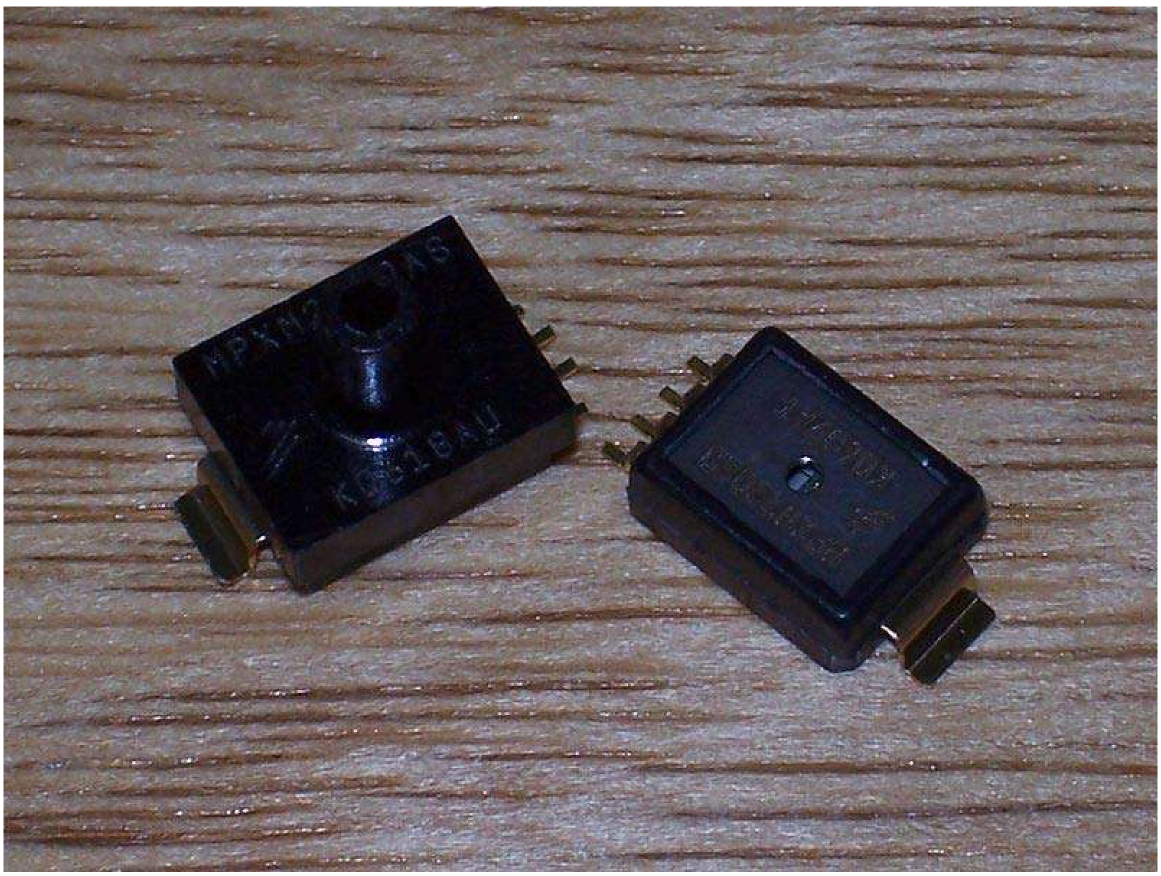
Pressure sensors are used for control and monitoring in thousands of everyday applications. Pressure sensors can also be used to indirectly measure other variables such as fluid/gas flow, speed, water level, and altitude. Pressure sensors can alternatively be called **pressure transducers**, **pressure transmitters**, **pressure senders**, **pressure indicators** and **piezometers**, **manometers**, among other names.

Pressure sensors can vary drastically in technology, design, performance, application suitability and cost. A conservative estimate would be that there may be over 50 technologies and at least 300 companies making pressure sensors worldwide.

There is also a category of pressure sensors that are designed to measure in a dynamic mode for capturing very high speed changes in pressure. Example applications for this type of sensor would be in the measuring of combustion pressure in an engine cylinder or in a gas turbine. These sensors are commonly manufactured out of piezoelectric materials such as quartz.

Some pressure sensors, such as those found in some traffic enforcement cameras, function in a binary (on/off) manner, i.e., when pressure is applied to a pressure sensor, the sensor acts to complete or break an electrical circuit. These types of sensors are also known as a pressure switch.

Types of pressure measurements



silicon piezoresistive pressure sensors

Pressure sensors can be classified in terms of pressure ranges they measure, temperature ranges of operation, and most importantly the type of pressure they measure. In terms of pressure type, pressure sensors can be divided into five categories:

- **Absolute pressure sensor**

This sensor measures the pressure relative to perfect vacuum pressure (0 PSI or no pressure). Atmospheric pressure, is 101.325 kPa (14.7 PSI) at sea level with reference to vacuum.

- **Gauge pressure sensor**

This sensor is used in different applications because it can be calibrated to measure the pressure relative to a given atmospheric pressure at a given location. A tire pressure gauge is an example of gauge pressure indication. When the tire pressure gauge reads 0 PSI, there is really 14.7 PSI (atmospheric pressure) in the tire.

- **Vacuum pressure sensor**

This sensor is used to measure pressure less than the atmospheric pressure at a given location. This has the potential to cause some confusion as industry may refer to a vacuum sensor as one which is referenced to either atmospheric pressure (i.e. measure Negative gauge pressure) or relative to absolute vacuum.

- **Differential pressure sensor**

This sensor measures the difference between two or more pressures introduced as inputs to the sensing unit, for example, measuring the pressure drop across an oil filter. Differential pressure is also used to measure flow or level in pressurized vessels.

- **Sealed pressure sensor**

This sensor is the same as the gauge pressure sensor except that it is previously calibrated by manufacturers to measure pressure relative to sea level pressure.

Pressure-sensing technology

There are two basic categories of analog pressure sensors.

Force collector types These types of electronic pressure sensors generally use a force collector (such a diaphragm, piston, bourdon tube, or bellows) to measure strain (or deflection) due to applied force (pressure) over an area.

- ***Piezoresistive strain gauge***

  Uses the piezoresistive effect of bonded or formed strain gauges to detect strain due to applied pressure. Common technology types are Silicon (Monocrystalline), Polysilicon Thin Film, Bonded Metal Foil, Thick Film, and Sputtered Thin Film. Generally, the strain gauges are connected to form a Wheatstone bridge circuit to maximize the output of the sensor. This is the most commonly employed sensing technology for general purpose pressure measurement. Generally, these technologies are suited to measure absolute, gauge, vacuum, and differential pressures.

- ***Capacitive***

  Uses a diaphragm and pressure cavity to create a variable capacitor to detect strain due to applied pressure. Common technologies use metal, ceramic, and silicon diaphragms. Generally, these technologies are most applied to low pressures (Absolute, Differential and Gauge)

- ***Electromagnetic***

  Measures the displacement of a diaphragm by means of changes in inductance (reluctance), LVDT, Hall Effect, or by eddy current principle.

- ***Piezoelectric***

  Uses the piezoelectric effect in certain materials such as quartz to measure the strain upon the sensing mechanism due to pressure. This technology is commonly employed for the measurement of highly dynamic pressures.

- ***Optical***

  Uses the physical change of an optical fiber to detect strain due to applied pressure. A common example of this type utilizes Fiber Bragg Gratings. This technology is employed in challenging applications where the measurement may be highly remote, under high temperature, or may benefit from technologies inherently immune to electromagnetic interference.

- ***Potentiometric***

  Uses the motion of a wiper along a resistive mechanism to detect the strain caused by applied pressure.

Other types

These types of electronic pressure sensors use other properties (such as density) to infer pressure of a gas, or liquid.

- ***Resonant***

  Uses the changes in resonant frequency in a sensing mechanism to measure stress, or changes in gas density, caused by applied pressure. This technology may be used in conjunction with a force collector, such as those in the category above. Alternatively, resonant technology may be employed by expose the resonating element itself to the media, whereby the resonant frequency is dependent upon the density of the media. Sensors have been made out of vibrating wire, vibrating cylinders, quartz, and silicon MEMS. Generally, this technology is considered to provide very stable readings over time.

- ***Thermal***

  Uses the changes in thermal conductivity of a gas due to density changes to measure pressure. A common example of this type is the Pirani gauge.

- ***Ionization***

  Measures the flow of charged gas particles (ions) which varies due to density changes to measure pressure. Common examples are the Hot and Cold Cathode gages.

- ***Others***

  There are numerous other ways to derive pressure from its density (speed of sound, mass, index of refraction) among others.

Applications

There are many applications for pressure sensors:

- **Pressure sensing**

This is the direct use of pressure sensors to measure pressure. This is useful in weather instrumentation, aircraft, cars, and any other machinery that has pressure functionality implemented.

- **Altitude sensing**

This is useful in aircraft, rockets, satellites, weather balloons, and many other applications. All these applications make use of the relationship between changes in pressure relative to the altitude. This relationship is governed by the following equation:

$$h = (1 - (P/P_{\text{ref}})^{0.190284}) \times 145366.45\text{ft}$$

This equation is calibrated for an altimeter, up to 36,090 feet (11,000 m). Outside that range, an error will be introduced which can be calculated differently for each different pressure sensor. These error calculations will factor in the error introduced by the change in temperature as we go up.

Barometric pressure sensors can have an altitude resolution of less than 1 meter, which is significantly better than GPS systems (about 20 meters altitude resolution). In navigation applications altimeters are used to distinguish between stacked road levels for car navigation and floor levels in buildings for pedestrian navigation.

- **Flow sensing**

This is the use of pressure sensors in conjunction with the venturi effect to measure flow. Differential pressure is measured between two segments of a venturi tube that have a different aperture. The pressure difference between the two segments is directly proportional to the flow rate through the venturi tube. A low pressure sensor is almost always required as the pressure difference is relatively small.

- **Level / depth sensing**

A pressure sensor may also be used to calculate the level of a fluid. This technique is commonly employed to measure the depth of a submerged body (such as a diver or submarine), or level of contents in a tank (such as in a water tower). For most practical purposes, fluid level is directly proportional to pressure. In the case of fresh water where the contents are under atmospheric pressure, 1psi = 27.7 inH20 / 1Pa = 9.81 mmH20. The basic equation for such a measurement is

$$P = pgh$$

where *P* = pressure, *p* = density of the fluid, *g* = standard gravity, *h* = height of fluid column above pressure sensor

- **Leak testing**

A pressure sensor may be used to sense the decay of pressure due to a system leak. This is commonly done by either comparison to a known leak using differential pressure, or by means of utilizing the pressure sensor to measure pressure change over time.

Chapter 7

Riveting Machines

Impact riveting machine

Radial riveting machine

Riveting machines are used to automatically set (squeeze) rivets in order to join materials together. The riveting machine offers greater consistency, productivity, and lower cost when compared to manual riveting.

Types

Automatic feed riveting machines include a hopper and feed track which automatically delivers and presents the rivet to the setting tools which overcomes the need for the operator to position the rivet. The downward force required to deform the rivet with an automatic riveting machine is created by a motor and flywheel combination, pneumatic cylinder, or hydraulic cylinder. Manual feed riveting machines usually have a mechanical lever to deliver the setting force from a foot pedal or hand lever.

Riveting machines can be sub-divided into two broad groups — impact riveting machines and orbital (or radial) riveting machines.

Impact riveting

Impact riveting machines set the rivet by driving the rivet downwards, through the materials to be joined and on into a forming tool (known as a rollset). This action causes the end of the rivet to roll over in the rollset which causes the end of the rivet to flare out and thus join the materials together. Impact riveting machines are very fast and a cycle time of 0.5 seconds is typical.

Example of a 4-step orbital rivet

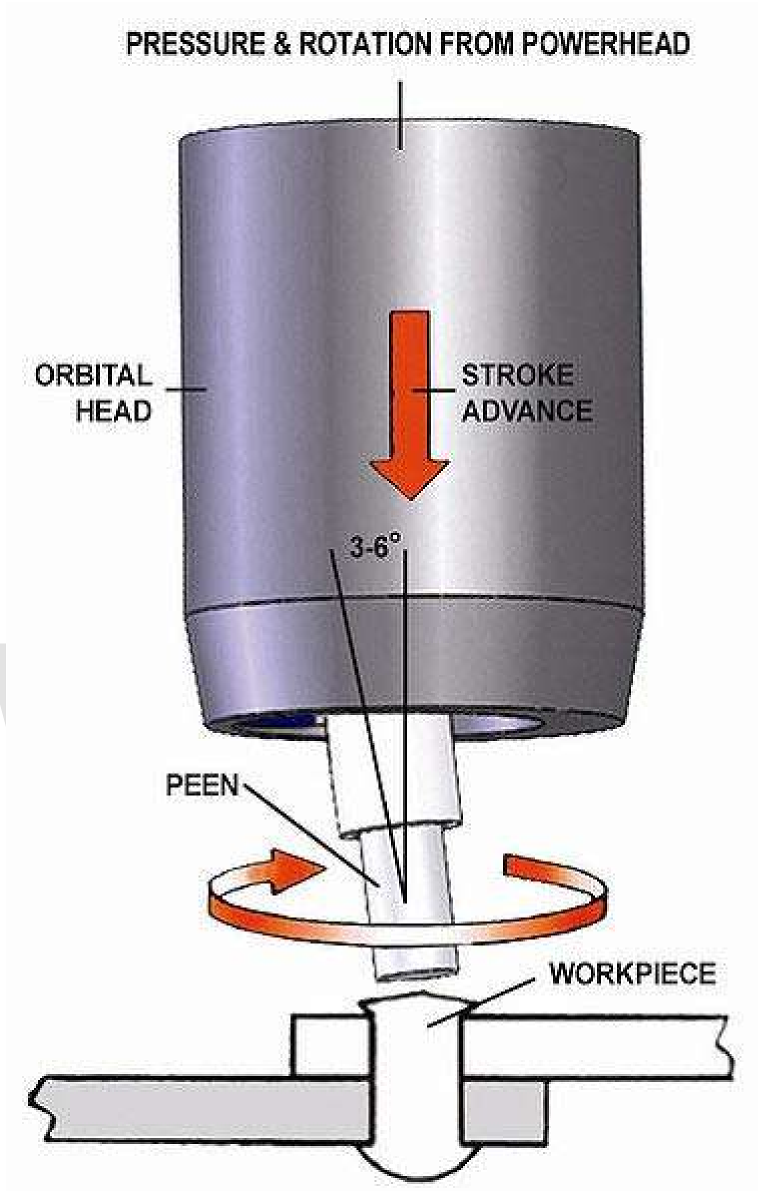


Diagram of how a orbital riveting works

Example of Rollerform process

Orbital riveting

Orbital riveting machines have a spinning forming tool (known as a peen) which is gradually lowered into the rivet which spreads the material of the rivet into a desired shape depending upon the design of the tool. Orbital forming machines offer the user more control over the riveting cycle but the trade off is in cycle time which can be 2 or 3 seconds.

There are different types of riveting machines. Each type of machine has unique features and benefits. The orbital riveting process is different from impact riveting and spiralform riveting. Orbital riveting requires less downward force than impact or spiral riveting. Also, orbital riveting tooling typically lasts longer.

Orbital riveting machines are used in a wide range of applications including brake linings for commercial vehicles, aircraft, and locomotives, textile and leather goods, metal brackets, window and door furniture, latches and even mobile phones. Many materials can be riveted together using orbital riveting machines including delicate and brittle materials, and sensitive electrical or electronic components.

The orbital riveting process uses a forming tool mounted at a 3 or 6° angle. The forming tool contacts the material and then presses it while rotating until the final form is achieved. The final form often has height and/or diameter specifications.

Pneumatic orbital riveting machines typically provide downward force in the 1,000–7,500 lb (450–3,400 kg) range. Hydraulic orbital riveting machines typically provide downward force in the 6,000–50,000 pounds (2,700–23,000 kg) range.

Radial (Spiralform) riveting

Radial riveting is subtly different from orbital forming. Radial riveting lightly peens (hammers) the rivet head into the desired shape whereas orbital forming spreads the rivet head in one, continuous contact, motion. While orbital forming is the superior process in most applications, spiralform riveting can produce better results when very small rivets are involved.

Rollerform riveting

Rollerforming is a subset of orbital forming. Rollerforming uses the same powerhead as orbital forming but instead of a peen has multiple wheels that circle the workpiece and combine two similar or non-similar materials together with a seamless and smooth gentle bonding via downward pressure as the rollers move downward or inward on the piece.

Automatic drilling and riveting machine

These machines take the automation one step farther by clamping the material and drilling or countersinking the hole in addition to riveting. They are commonly used in the aerospace industry because of the large number of holes and rivets required to assemble the aircraft skin.

Applications

Riveting machines are used in a wide range of applications including brake linings for commercial vehicles, aircraft, and locomotives, textile and leather goods, metal brackets, window and door furniture, latches and even mobile phones. Many materials can be riveted together using riveting machines including delicate and brittle materials, and sensitive electrical or electronic components.

Chapter 8

Crusher

A **crusher** is a machine designed to reduce large rocks into smaller rocks, gravel, or rock dust. Crushers may be used to reduce the size, or change the form, of waste materials so they can be more easily disposed of or recycled, or to reduce the size of a solid mix of raw materials (as in rock ore), so that pieces of different composition can be differentiated. Crushing is the process of transferring a force amplified by mechanical advantage through a material made of molecules that bond together more strongly, and resist deformation more, than those in the material being crushed do. Crushing devices hold material between two parallel or tangent solid surfaces, and apply sufficient force to bring the surfaces together to generate enough energy within the material being crushed so that its molecules separate from (fracturing), or change alignment in relation to (deformation), each other. The earliest crushers were hand-held stones, where the weight of the stone provided a boost to muscle power, used against a stone anvil. Querns and mortars are types of these crushing devices.

Industrial use

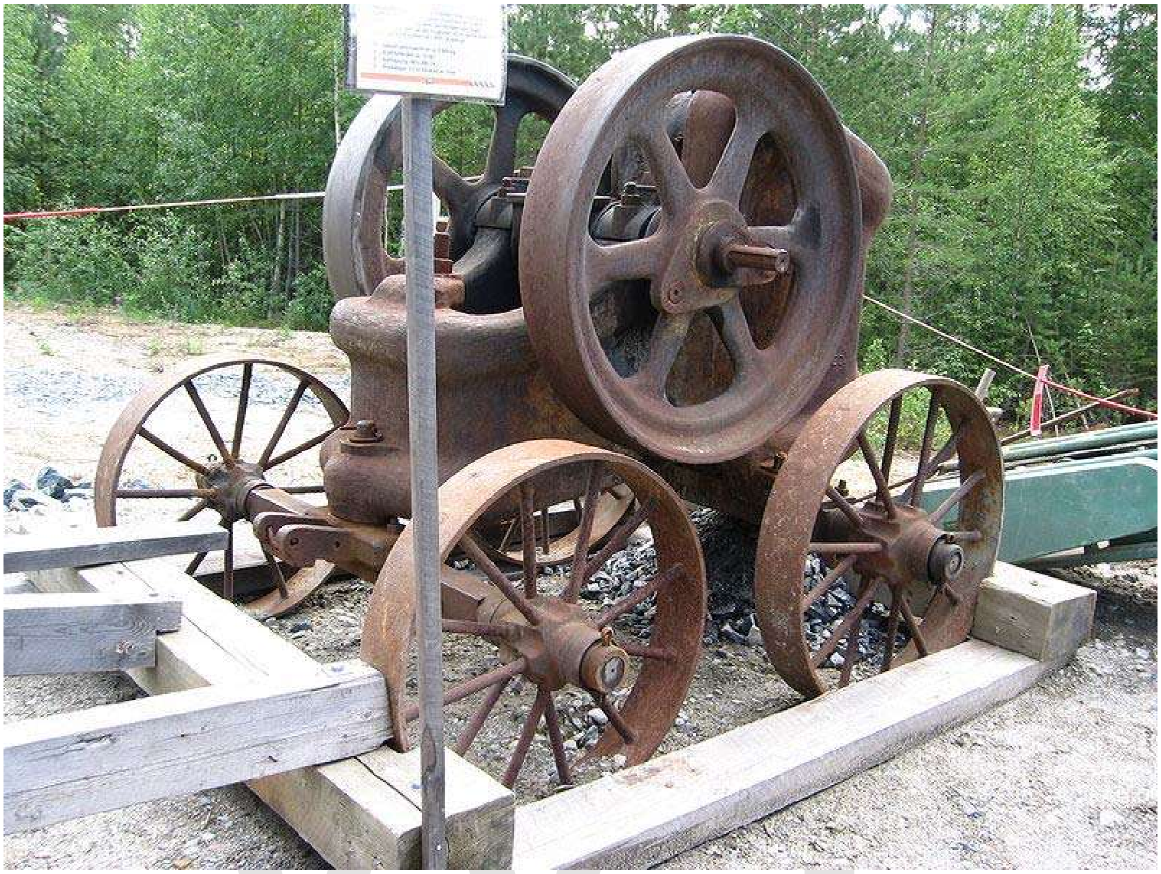
In industry, crushers are machines which use a metal surface to break or compress materials. Mining operations use crushers, commonly classified by the degree to which they fragment the starting material, with primary and secondary crushers handling coarse materials, and tertiary and quaternary crushers reducing ore particles to finer gradations. Each crusher is designed to work with a certain maximum size of raw material, and often delivers its output to a screening machine which sorts and directs the product for further processing. Typically, crushing stages are followed by milling stages if the materials need to be further reduced. Crushers are used to reduce particle size enough so that the material can be processed into finer particles in a grinder. A typical circuit at a mine might consist of a crusher followed by a SAG mill followed by a ball mill. In this context, the SAG mill and ball mill are considered grinders rather than crushers.

In operation, the raw material (of various sizes) is usually delivered to the primary crusher's hopper by dump trucks, excavators or wheeled front-end loaders. A feeder device such as a conveyor or vibrating grid controls the rate at which this material enters the crusher, and often contains a preliminary screening device which allows smaller material to bypass the crusher itself, thus improving efficiency. Primary crushing reduces the large pieces to a size which can be handled by the downstream machinery.

Some crushers are mobile and can crush rocks (as large as 16 inches. In a mobile operation, these crushed rocks are directly combined with concrete and asphalt which are then deposited on to a road surface. This removes the need for hauling over-sized material to a stationary crusher and then back to the road surface.

Types of crushers

Cornish stamps used in the 19th century for breaking tin ore



A portable rock crusher from the early 20th century

The entrance bin of a mine rock crusher

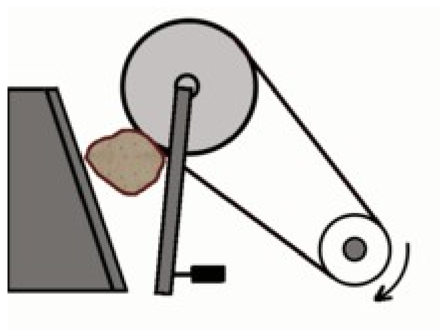
Mobile crusher

The following table describes typical uses of commonly used crushers:

Type	Hardness	Abrasion limit	Moisture content	Reduction ratio	Main use
Jaw crushers	Soft to very hard	No limit	Dry to slightly wet, not sticky	3/1 to 5/1	Quarried materials, sand & gravel, recycling
Gyratory crushers	Soft to very hard	Abrasive	Dry to slightly wet, not sticky	4/1 to 7/1	Quarried materials
Cone crushers	Medium hard to very hard	Abrasive	Dry or wet, not sticky	3/1 to 5/1	Sand & gravel
Horizontal shaft impactors	Soft to medium hard	Slightly abrasive	Dry or wet, not sticky	10/1 to 25/1	Quarried materials, sand & gravel, recycling

Vertical shaft impactors (shoe and anvil)	Medium hard to very hard	Slightly abrasive	Dry or wet, not sticky	6/1 to 8/1	Sand & gravel, recycling
Vertical shaft impactors (autogenous)	Soft to very hard	No limit	Dry or wet, not sticky	2/1 to 5/1	Quarried materials, sand & gravel

Jaw crusher



Operation of a jaw crusher

A jaw or toggle crusher consists of a set of vertical jaws, one jaw being fixed and the other being moved back and forth relative to it by a cam or pitman mechanism. The jaws are farther apart at the top than at the bottom, forming a tapered chute so that the material is crushed progressively smaller and smaller as it travels downward until it is small enough to escape from the bottom opening. The movement of the jaw can be quite small, since complete crushing is not performed in one stroke. The inertia required to crush the material is provided by a weighted flywheel that moves a shaft creating an eccentric motion that causes the closing of the gap.

Single and double toggle jaw crushers are constructed of heavy duty fabricated plate frames with reinforcing ribs throughout. The crushers components are of high strength design to accept high power draw. Manganese steel is used for both fixed and movable jaw faces. Heavy flywheels allow crushing peaks on tough materials. Double Toggle jaw crushers may feature hydraulic toggle adjusting mechanisms.

Gyratory crusher

Ruffner Red Ore Mine gyratory crusher

A gyratory crusher is similar in basic concept to a jaw crusher, consisting of a concave surface and a conical head; both surfaces are typically lined with manganese steel surfaces. The inner cone has a slight circular movement, but does not rotate; the movement is generated by an eccentric arrangement. As with the jaw crusher, material travels downward between the two surfaces being progressively crushed until it is small enough to fall out through the gap between the two surfaces.

A gyratory crusher is one of the main types of primary crushers in a mine or ore processing plant. Gyratory crushers are designated in size either by the gape and mantle diameter or by the size of the receiving opening. Gyratory crushers can be used for primary or secondary crushing. The crushing action is caused by the closing of the gap between the mantle line (movable) mounted on the central vertical spindle and the concave liners (fixed) mounted on the main frame of the crusher. The gap is opened and closed by an eccentric on the bottom of the spindle that causes the central vertical spindle to gyrate. The vertical spindle is free to rotate around its own axis. The crusher illustrated is a short-shaft suspended spindle type, meaning that the main shaft is suspended at the top and that the eccentric is mounted above the gear. The short-shaft design has superseded the long-shaft design in which the eccentric is mounted below the gear.

Cone crusher

A cone crusher is similar in operation to a gyratory crusher, with less steepness in the crushing chamber and more of a parallel zone between crushing zones. A cone crusher breaks rock by squeezing the rock between an eccentrically gyrating spindle, which is covered by a wear resistant mantle, and the enclosing concave hopper, covered by a manganese concave or a bowl liner. As rock enters the top of the cone crusher, it becomes wedged and squeezed between the mantle and the bowl liner or concave. Large pieces of ore are broken once, and then fall to a lower position (because they are now smaller) where they are broken again. This process continues until the pieces are small enough to fall through the narrow opening at the bottom of the crusher.

A cone crusher is suitable for crushing a variety of mid-hard and above mid-hard ores and rocks. It has the advantage of reliable construction, high productivity, easy adjustment and lower operational costs. The spring release system of a cone crusher acts an overload protection that allows tramp to pass through the crushing chamber without damage to the crusher.

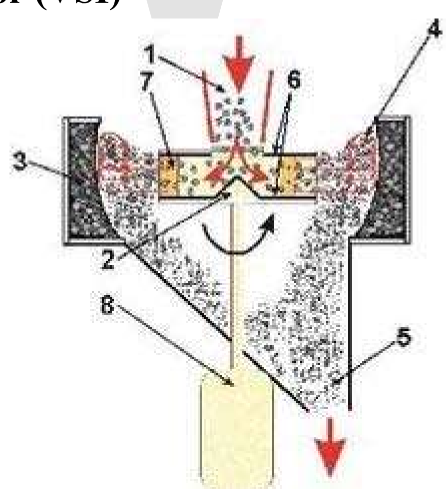
Impact crushers

Impact crushers involve the use of impact rather than pressure to crush material. The material is contained within a cage, with openings on the bottom, end, or side of the desired size to allow pulverized material to escape. This type of crusher is usually used with soft and non-abrasive material such as coal, seeds, limestone, gypsum or soft metallic ores. There are two types of impact crushers: horizontal shaft impactor and vertical shaft impactor.

Horizontal shaft impactor (HSI)

The HSI crushers break rock by impacting the rock with hammers that fixed upon the outer edge of a spinning rotor. The practical use of HSI crushers is limited to soft materials and non abrasive materials, such as limestone, phosphate, gypsum, weathered shales.

Vertical shaft impactor (VSI)



Scheme of a VSI crusher with air-cushion support

VSI crushers use a different approach involving a high speed rotor with wear resistant tips and a crushing chamber designed to 'throw' the rock against. The VSI crushers utilize velocity rather than surface force as the predominant force to break rock. In its natural state, rock has a jagged and uneven surface. Applying surface force (pressure) results in unpredictable and typically non-cubicle resulting particles. Utilizing velocity rather than surface force allows the breaking force to be applied evenly both across the surface of the rock as well as through the mass of the rock. Rock, regardless of size, has natural fissures (faults) throughout its structure. As rock is 'thrown' by a VSI Rotor against a solid anvil, it fractures and breaks along these fissures. Final particle size can be controlled by 1) the velocity at which the rock is thrown against the anvil and 2) the distance between the end of the rotor and the impact point on the anvil. The product resulting from VSI Crushing is generally of a consistent cubicle shape such as that required by modern SUPERPAVE highway asphalt applications. Using this method also allows materials with much higher abrasiveness to be crushed than is capable with an HSI and most other crushing methods.

VSI crushers generally utilize a high speed spinning rotor at the center of the crushing chamber and an outer impact surface of either abrasive resistant metal anvils or crushed rock. Utilizing cast metal surfaces 'anvils' is traditionally referred to as a "Shoe and Anvil VSI". Utilizing crushed rock on the outer walls of the crusher for new rock to be crushed against is traditionally referred to as "rock on rock VSI". VSI crushers can be used in static plant set-up or in mobile tracked equipment.

Technology

VSI crusher

For the most part advances in crusher design have moved slowly. Jaw crushers have remained virtually unchanged for sixty years. More reliability and higher production have been added to basic cone crusher designs that have also remained largely unchanged. Increases in rotating speed, have provided the largest variation. For instance, a 48 inch (120 cm) cone crusher manufactured in 1960 may be able to produce 170 tons/h of crushed rock, whereas the same size cone manufactured today may produce 300 tons/h. These production improvements come from speed increases and better crushing chamber designs.

The largest advance in cone crusher reliability has been seen in the use of hydraulics to protect crushers from being damaged when uncrushable objects enter the crushing chamber. Foreign objects, such as steel, can cause extensive damage to a cone crusher, and additional costs in lost production. The advance of hydraulic relief systems has greatly reduced downtime and improved the life of these machines.

Chapter 9

Hammer Drill

Hammer drill

A **hammer drill**, also known as a "rotary hammer", "roto-hammer" or "impact drill", is a rotary drill with a hammering action. The hammering action provides a short, rapid hammer thrust to pulverize relatively brittle material and provide quicker drilling with less effort. Lower power units are usually titled as "hammer drills." Higher power units, usually labeled "rotary hammers," tend to be larger and provide bigger impact forces. Modern units allow the hammer and rotation functions to be used separately or in combination, i.e., hammer mode, drill mode, or both. When used in the hammer mode, the tool provides a drilling function similar to a jackhammer. The definitive origin of the first hammer drill is a matter of discussion. Hilti had a rotary hammer on the market in 1967 and the Milwaukee Electric Tool Corporation claims that in 1935, it was selling a lightweight 3/4-inch electric hammer drill .

Hammer drills are well suited for drilling holes in masonry or stone. They are also used to drill holes in concrete footings to pin concrete wall forms and to drill holes in concrete floors to pin wall framing. The hammering action helps to break up the masonry so that it can be removed by the drill bit's flutes.

Types of hammer drills

There are two main types of hammer drill, percussion and rotary hammer. With percussion drills the chuck has a mechanism whereby the entire chuck and bit move forward and backwards on the axis of rotation, the motion is tied to the rotation of the chuck. Typically this type of drill can be used with and without the hammer action but it is not possible to use the hammer action alone as it is the rotation which causes the hammer motion. The second type uses a different type of chuck which allows the bit to move forwards and backwards independently and is usually powered pneumatically. As such this type of drill can be used in hammer-only mode which has certain advantages when dealing with very hard substances.

Use

A hammer drill has a specially designed clutch that allows it to not only spin the drill bit, but also to punch it in and out (along the axis of the bit). The actual distance the bit travels in and out and the force of its blow are both very small, and the hammering action is very rapid—thousands of "BPM" (blows per minute) or "IPM" (impacts per minute). Although each blow is of relatively low force, these thousands of blows per minute are more than adequate to break up concrete or brick, using the masonry drill bit's carbide wedge to pulverize it for the spiral flutes to whisk away. For this reason, a hammer drill drills much faster than a regular drill through concrete or brick.

Hammer drills almost always have a lever or switch that locks off the special "hammer clutch," turning the tool into a conventional drill for wood or metal work. Hammer drills are more expensive and more bulky than regular drills, but are preferable for applications where the material to be drilled—concrete block or wood studs—is unknown. For example, an electrician would use a hammer drill for attaching items (such as an electrical box) to either wood studs (if used as a conventional power drill) or masonry walls (if used as a hammer drill).

Rotary hammers

Ramset 342 Dyna Drill and Chipping Hammer, shown with chipping chisel.

Rotary hammers are similar in that they also pound the drill bit in and out while it is spinning. However, they use a piston mechanism instead of a special clutch. This causes them to deliver a much more powerful hammer blow. One can drill bigger holes much faster. Rotary hammers have such force, in fact, that the usual masonry bits are no longer adequate. Their smooth shanks would be pounded loose from the tool's chuck in a few seconds. Therefore, they require special bits which can lock into the rotary hammer and continue on spinning while smashing away.

A number of "special shanks" have been developed by various manufacturers. Over the years a fair number of these proprietary systems evolved, but the remaining shanks in use today are: SDS, SDS-MAX, and SPLINE SHANK.

Rotary hammer drills have an oil filled gearbox, which allows them to operate durably despite the large forces and shocks they receive and the grit-filled environments where they are often used.

Apart from their main function of drilling concrete, the rotary action can be switched off and use is made of just the percussive force. Chisel and point accessories are used for small chipping jobs.

The type of work they do means that they need to have a clutch which cuts in when the drill bit jams. This stops the violent wrenching motion that a drill without a clutch would cause when stopped suddenly from full speed, saving both drill and operator from damage.

Jams are most often caused by hitting reinforcing steel or by a worn bit. In both cases the drill must be disengaged from the bit and the jammed bit backed out of the hole with vise grips or monkey wrench.

Worn masonry drill bit

A worn drill bit will still drill a horizontal hole, although of a slightly smaller diameter than one created when it was new. When a drill like this is used to drill holes down into a concrete slab, the flutes are so worn that they can no longer lift the dust out of the hole; the concrete dust packs up in the hole and jams the bit.

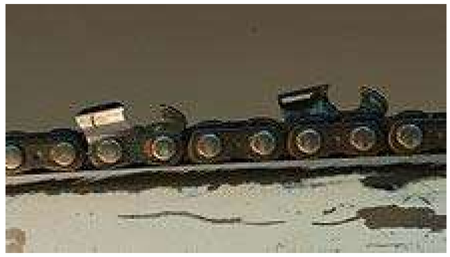
Chapter 10

Chainsaw

An arborist using a chainsaw to fell a eucalyptus tree

A **chainsaw** (or **chain saw**) is a portable mechanical saw, powered by electricity, compressed air, hydraulic power, or most commonly a two-stroke engine. It is used in activities such as tree felling, limbing, bucking, pruning, by tree surgeons to fell trees and remove branches and foliage, to fell snags and assist in cutting firebreaks in wildland fire suppression, and to harvest firewood. Chainsaws with specially designed bar and chain combinations have been developed as tools for use in chainsaw art. Specialist chainsaws are used for cutting concrete.

Construction



Chainsaw chain

A chainsaw consists of several parts.

- Engine — almost always a two-stroke gasoline (petrol) internal combustion engine, usually with a cylinder volume of 30-120 cm3 or electric motor.
- Drive mechanism — typically a clutch and sprocket.
- Guide bar — an elongated bar with a round end of wear-resistant alloy steel typically 16 to 36 inches in length. An edge slot guides the cutting chain.
- Cutting chain — Usually each segment in this chain (which is constructed from riveted metal sections similar to a bicycle chain, but without rollers) features small sharp blades called teeth. Each tooth takes the form of a folded tab of chromium plate steel with a sharp angular or curved corner and two cutting edges on the top plate and side plate. Left-handed and right-handed teeth are alternated in the chain. Chains come in varying pitch and gauge; the pitch of a chain is defined as half of the length spanned by any three consecutive rivets (e.g., 0.325 inch), while the gauge is the thickness of drive link where it fits into the guide bar (e.g., 0.05 inch). Conventional "full complement" chain has one tooth per drive link. Built into each tooth is a depth gauge or "raker" which rides ahead of the tooth and limits the depth of cut, typically to around 0.025". Depth gauges are critical to safe chain operation. If left too high they will cause very slow cutting, if filed too low they will make the saw dangerous and hard to control.

The underside of each link features a small metal finger called a "drive link" which locates the chain on the bar, helps to carry lubricating oil around the bar, and engages with the engine's drive sprocket inside the body of the saw. The engine drives the chain around the track by a centrifugal clutch, engaging the chain under power but allowing it to stop as the engine idles.

Dramatic improvements, chainsaw safety devices and overall design have taken place since the chainsaw's invention, saving many lives and preventing countless serious injuries. These include chainbrake systems, better chain design and anti-vibration systems.

As chainsaw carving has become more popular, chainsaw manufacturers are making special short, narrow-tipped bars for carving. These are called "quarter tipped," "nickel tipped" or "dime tipped" bars, based on the size of the round tip. Echo sponsors a carving series, as well as carvers such as former Runaways singer Cherie Currie. RedMax specifically built the G3200 CV chainsaw for carving applications.

Maintenance

Logging near Apiary, Oregon

Most chainsaws require two sources of lubrication. Like most two-stroke engines, the engine is lubricated by its fuel, which contains about 2–5% oil (depending on the oil used) dissolved in the fuel. Separate *chain oil* or *bar oil* is used for the external lubrication of the bar and chain. The chain oil is depleted quickly because it tends to be thrown off the chain by centrifugal force, and it is soaked up by sawdust. The chain oil reservoir is usually topped up at the same time as refuelling, and the reservoir is large enough so that the saw runs out of fuel and stops before the chain oil runs dry. Failing to keep the chain oil topped up, or using an oil of incorrect viscosity, is a common source of damage to saws, and tends to lead to rapid wear of the bar, or the chain jamming or coming off the bar.

In addition to being quite thick, chain oil is particularly sticky (due to "tackifier" additives) to reduce the amount thrown off the chain. Although motor oil is a common emergency substitute, it is lost even faster and so leaves the chain underlubricated.

Chains must be kept sharp to perform well. They become blunt rapidly if they touch soil, metal or stones. When blunt, they tend to produce powdery sawdust, rather than the longer, clean shavings characteristic of a sharp chain; a sharp saw also needs very little force from the operator to push it into the cut. Special hardened chains (made with tungsten carbide) are used for applications where soil is likely to contaminate the cut, such as for cutting through roots.

The air intake filter tends to clog up with sawdust. This must be cleaned from time to time, but is not a problem during normal operation.

Safety

A chainsaw operator wearing full safety gear using a gasoline-driven chain saw

Despite safety features and protective clothing, injuries can still arise from chainsaw use, from the large forces involved in the work, from the fast-moving, sharp chain, or from the vibration and noise of the machinery.

A common accident arises from *kickback*, when a chain tooth at the tip of the guide bar catches on wood without cutting through it. This throws the bar (with its moving chain) in an upward arc toward the operator, often causing serious injury or even death.

Another dangerous situation occurs when heavy timber begins to fall or shift before a cut is complete – the chainsaw operator may be trapped or crushed. Similarly, timber falling in an unplanned direction may harm the operator or other workers, or an operator working at a height may fall or be injured by falling timber.

Like other hand-held machinery, the operation of chainsaws can cause vibration white finger, tinnitus or industrial deafness.

The risks associated with chainsaw use mean that protective clothing and hearing protectors are normally worn while operating them, and many jurisdictions require that operators be certified or licensed to work with chainsaws. Injury can also result if the chain breaks during operation due to poor maintenance or attempting to cut inappropriate materials.

Gasoline-powered chainsaws expose operators to harmful carbon monoxide (CO) gas, especially indoors or in partially enclosed outdoor areas.

Working techniques

Chainsaw training is designed to provide working technical knowledge and skills to safely operate the equipment.

- **Sizeup -** This is scouting and planning safe cuts, before starting the saw.
- **Felling -** The aim is for the tree to fall safely for limbing and cross cutting the log. It includes considerations for lean, bend, wind, branches, obstacles, snow load and tree damage. The goal is to avoid letting the tree fall on another tree or obstacle. After clearing the tree's base undergrowth for the retreat path and the felling direction; felling is properly done with three main cuts. To control the fall, the top and bottom cuts are made to form a wedged 45 degree hinge in the directional cut line. From the opposite side of the wedge, the felling cut is made horizontally and slightly above the bottom cut. When the hinge is properly set, the felling cut will begin the fall in the desired direction. A sitback is when a tree moves back opposite the intended direction. Placing a wedge in the felling cut can prevent a sitback from pinching the saw.
- **Limbing -** This is cutting the branches off the log. The operator must be able to properly reach the cut to avoid kickback.

- **Bucking -** This is cross cutting the felled log into sections. Setup is made to avoid binding the chainsaw within the changing log tensions and compressions. Safe bucking is started at the log highside and then sections worked offside, toward the butt end. The offside log falls and allows for gravity to help prevent binds. Watching the log's kerf movement while cutting, helps to indicate binds. Additional equipment (lifts, bars, wedges and winches) and special cutting techniques can help prevent binds.

- **Binds -** This is when the chainsaw is at risk or is stuck in the log compression. A log binded chainsaw is not safe, and must be carefully removed to prevent equipment damage.
  - Top bind — The tension area on log bottom, compression on top.
  - Bottom bind — The tension area on log top, compression on bottom.
  - Side bind — Sideways pressure exerted on log.
  - End bind — Weight compresses the log’s entire cross section.

- **Brushing and Slashing -** This is quickly clearing small trees and branches under 5 inches diameter. A hand piler may follow along to move out debris.

History

Electric chainsaw

The origin is debated, but the first chainsaw-like tool was probably made around 1830 by the German orthopaedist Bernard Heine. This instrument, the osteotome, had links of a chain carrying small cutting teeth with the edges set at an angle; the chain was moved around a guiding blade by turning the handle of a sprocket wheel. As the name implies, this was used to cut bone.

Two important contributors to the *modern* chainsaw are Joseph Buford Cox and Andreas Stihl; the latter patented and developed a chainsaw in 1926 and a gasoline-powered chainsaw in 1929, and founded a company to mass-produce them. In 1927, Emil Lerp, the founder of Dolmar, developed the world's first gasoline-powered chainsaw and mass-produced them.

McCulloch and Industrial Equipment Corp in North America started to produce chainsaws. The early models were heavy, two-person devices with long bars. Often chainsaws were so heavy that they had wheels like dragsaws. Other outfits used driven lines from a wheeled power unit to drive the cutting bar.

After World War II, improvements in aluminum and engine design lightened chainsaws to the point where one person could carry them. In some areas the skidder (chainsaw) crews have been replaced by the feller buncher and harvester.

Chainsaws have almost entirely replaced simple man-powered saws in forestry. They come in many sizes, from small electric saws intended for home and garden use, to large "lumberjack" saws. Members of military engineer units are trained to use chainsaws.

Cutting stone, concrete and brick

A chainsaw cutting concrete

Special chainsaws are used to cut concrete, brick and natural stone. These use similar chains to ordinary chainsaws, but with cutting edges embedded with diamond grit. They may be gasoline or hydraulically driven, and the chain is lubricated with water, because of high friction and to remove stone-dust. The machine is used in construction, for example in cutting deep square holes in walls or floors, in stone sculpture for removing large chunks of stone during pre-carving, by fire departments for gaining access to buildings and in restoration of buildings and monuments, for removing parts with minimal damage to the surrounding structure.

Because the material to be cut is non-fibrous, there is much less chance of kickback. Therefore the most-used method of cutting is plunge-cutting, by pushing the tip of the blade into the material. With this method square cuts as small as the blade width can be achieved. Pushback can occur if a block shifts when nearly cut through, and pinches the blade, but overall the machine is less dangerous than a wood-cutting chainsaw.

Chapter 11

Circular Saw

This miter saw uses a circular saw mounted to cut at an angle

The **circular saw** is a metal disc or blade sometimes with saw teeth on the edge as well as the machine that causes the disk to spin. It is a tool for cutting wood or other materials and may be hand-held or table-mounted. It can also be used to make narrow slots (dados). Most of these saws are designed with a blade to cut wood but may also be equipped with a blade designed to cut masonry, plastic, or metal. There are also purpose-made circular saws specially designed for particular materials. While today circular saws are almost exclusively powered by electricity, larger ones, such as those in "saw mills", were traditionally powered by water turning a large wheel.

Circular saw for woodworking

Process

Typically, the material to be cut is securely clamped or held in a vise, and the saw is advanced slowly across it. In variants such as the table saw, the saw is fixed and the material to be cut is slowly moved into the saw blade. As each tooth in the blade strikes the material, it makes a small chip. The teeth guide the chip out of the workpiece, preventing it from binding the blade.

Characteristics

- Cutting is by teeth on the edge of a thin blade
- The cut has narrow kerf and good surface finish
- Cuts are straight and relatively accurate
- The saw usually leaves burrs on the cut edge
- Saw setting should be done geometrically.

Invention

Various claims have been made as to who invented the circular saw:

- A common claim is for a little known sailmaker named Samuel Miller of Southampton, England who obtained a patent in 1777 for a saw windmill. However the specification for this only mentions the form of the saw incidentally, probably indicating that it was not his invention.
- Gervinus of Germany is often credited with inventing the circular saw in 1780
- Walter Taylor of Southampton had the blockmaking contract for Portsmouth Dockyard. In about 1762 he built a saw mill where he roughed out the blocks. This was replaced by another mill in 1781. Descriptions of his machinery there in the 1790s show that he had circular saws. Taylor patented two other improvements to blockmaking but not the circular saw. This suggests either that he did not invent it or that he published his invention without patenting it (which would mean it was no longer patentable).
- Another claim is that it originated in Holland in the sixteenth or seventeenth century. This may be correct, but nothing more precise is known.
- The use of a large circular saw in a saw mill is said to have been invented in 1813 by Tabitha Babbit, a Shaker spinster, who sought to ease the labour of the male sawyers in her community.
- The Barringer, Manners and Wallis factory in Rock Valley Mansfield, Nottinghamshire also claims to be the site of the invention.

Types of circular saw

Allis-Chalmers B with a portable sawmill setup

In addition to hand-held circular saws, different saws that use circular saw blades include:

- Miter saws (or Chop saw or Cut-off saw)
- Radial arm saws
- Saw mills
- Table saws
- Panel saws
- Biscuit joiners
- Pendulum saw
- Brushcutter
- Cold saws
- Flip Over Saws (the Combination of a Compound Miter and Table saw)

Sawmill blades

Portable sawmill circular saw blade about 2 foot diameter.

Originally, circular saws in mills had smaller blades and were used to resaw lumber after it passed through an "up and down" (muley or sash) saw leaving both vertical and circular saw marks on different sides of the same piece. These saws made it more efficient to cut small pieces such as lath. After 1813 or 1822 saw mills use large circular saws, up to nine feet (2.97 m) in diameter. Large saws demand more power than up-and-down saws and did not become practical for sawing timbers until they were powered by steam engines. They are either left or right-handed, depending on which side of the blade the plank falls away from. Benching determines which hand the saw is. Saws of this size typically have a shear pin hole, off axis, that breaks if the saw is overloaded and allows the saw to spin free. The most common version is the ITCO (insert tooth cut-off) which has replaceable teeth. Sawmill blades are also used as an alternative to a radial arm saw.

Cordwood saws

Cordwood saws, also called buzz saws in some locales, use blade of a similar size to sawmills. Where a sawmill rips (cuts with the grain) a cordwood saw crosscuts (cuts across the grain). Cordwood saws can have a blade from 20 to more than 36 inches (910 mm) diameter depending on the power source and intended purpose. Buzz saws are used to cut long logs (cordwood) and slabs (sawmill waste) into pieces suitable for home heating (firewood).

Most cordwood saws consist of a frame, blade, mandrel, cradle, and power source. The cradle is a tilting or sliding guide that holds logs during the cutting process. Some cordwood saws are run from a belt from a farm tractor power takeoff pulley. Others are equipped with small gasoline engines or even large electric motors as power sources. The mandrel is a shaft and set of bearings that support and transfer power to the blade. The frame is a structure that supports the cradle and blade at a convenient working height.

Cordwood saws were once very popular in rural America. They were used to cut smaller wood into firewood in an era when hand powered saws were the only other option. Logs too large for a cordwood saw were still cut by hand. Chainsaws have largely replaced cordwood saws for firewood preparation today. Still, some commercial firewood processors and others use cordwood saws to save wear and tear on their chainsaws. Most people consider cordwood saws unsafe and outdated technology.

Hand-held circular saws

The term circular saw is most commonly used to refer to a hand-held electric circular saw designed for cutting wood, which may be used less optimally for cutting other materials with the exchange of specific blades. Circular saws can be either left or right-handed, depending on the side of the blade where the motor sits and which hand the operator uses when holding a saw.

Blades for timber are almost universally tungsten carbide tipped (TCT). High speed steel (HSS) blades are also available. The saw base can be adjusted for depth of cut. Adjusting the depth of cut helps minimize kickback. The saw base can also be adjusted to tilt up to 50 degrees in relation to the blade.

The saw can be designed for the blade to mount directly to the motor's driveshaft (known colloquially as a sidewinder), or be driven indirectly by a perpendicularly-mounted motor via worm gears, garnering considerably higher torque (Worm-drive saws).

The worm-drive portable circular saw was invented in 1923 by Edmond Michel. In 1924 Michel formed a partnership with Joseph Sullivan, and together they started the Michel

Electric Handsaw Company, with the sole purpose of manufacturing and marketing the saw invented by Michel. The company later renamed itself Skilsaw Inc., which today is a subsidiary of Robert Bosch GmbH. Portable circular saws are often still called Skilsaws or Skil saws. Its successor is still sold by Skil as the model 77. To get around the Skil patents, Art Emmons of Porter-Cable invented the direct-drive sidewinder saw in 1928. Recently smaller cordless circular saws with rechargeable batteries have become popular.

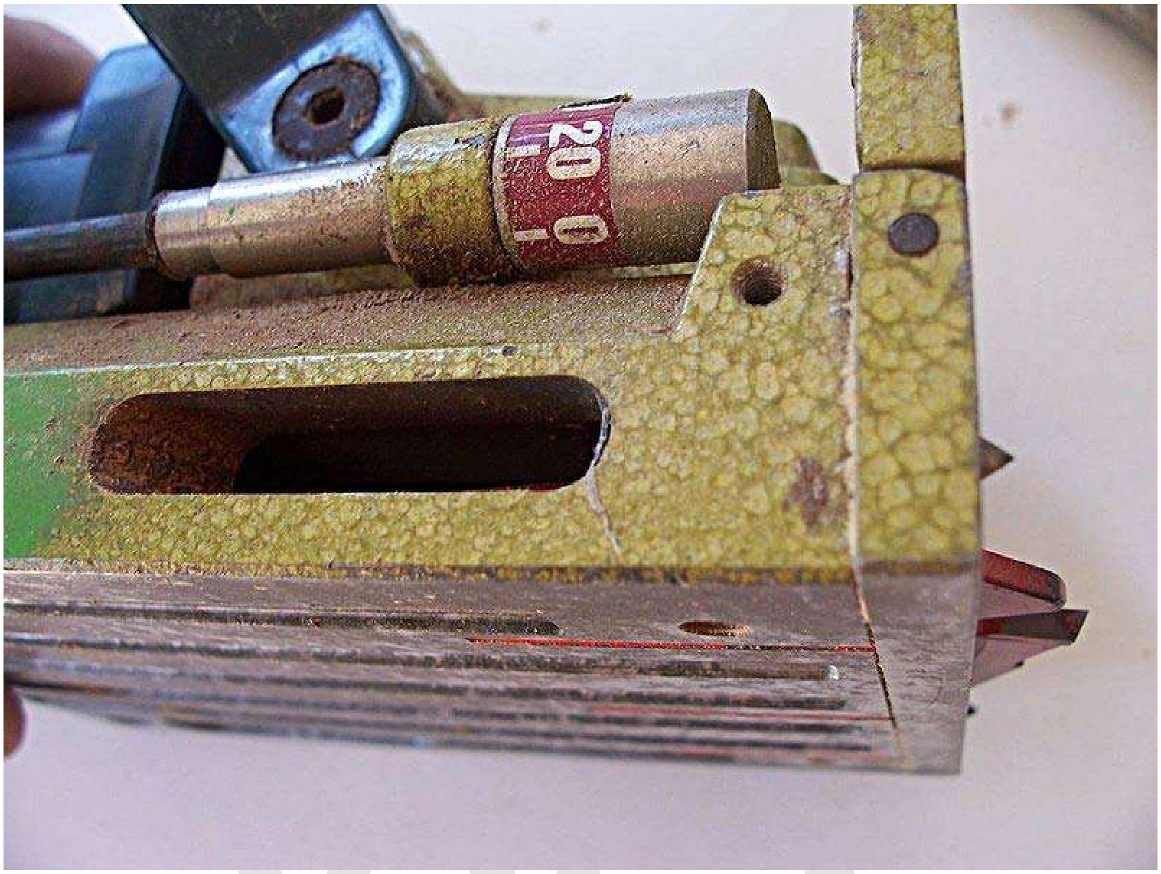
Cold saw

Cold saw(ing) machines are circular saws that are used in many metal cutting operations. The saw blades used are quite large in diameter and operate at low rotational speeds, and linear feeds. There are three common types of blades used in circular saws; solid-tooth, segmental tooth, and the carbide inserted-tooth. The circular saw is typically fed into the workpiece horizontally, and as the saw advances into the material, it severs the material by producing narrow slots. The material is usually held in place during the cutting operation by means of a vice. The chips produced by cutting are carried away from the material by both the teeth of the blade as well as the coolant or other cutting fluid used.

Chapter 12

Biscuit Joiner

Lamello Top biscuit joiner



Lamello Top biscuit joiner with blade extended

Edges of 16mm Medium-density fibreboard with a #0 biscuit, set up to make a right angle joint.

A **biscuit joiner** or sometimes **plate joiner** is a woodworking tool used to join two pieces of wood together. A biscuit joiner uses a small 100mm (4") diameter tungsten carbide tipped circular saw blade to cut a crescent shaped hole (called the mouth) in the opposite edges of two pieces of wood or wood composite panels. An oval-shaped, highly-dried and compressed wooden biscuit (usually beech) is covered with glue, or glue is applied in the slot. The biscuit is immediately placed in the slot, and the two boards are clamped together. The wet glue expands the biscuit, further improving a bond that is often stronger than the wood itself.

History

The biscuit joining system is a recent development, having been invented in 1956 in Liestal, Switzerland by Hermann Steiner. Steiner opened his carpenters shop in 1944 and in the middle of the 50's, while looking for a simple means of joining the recently introduced chipboard, invented almost by accident the now world-famous Lamello Joining System. In the succeeding years there followed further developments such as the circular saw and the first stationary biscuit (plate) joining machine in 1956 followed by the first portable biscuit joiner for Lamello grooves in 1968. In 1969 the family operation was incorporated by the name of Lamello AG.

American Tool Manufacturer Porter Cable produces a Biscuit Joiner with interchangeable blades, enabling the user to cut both 4" and 2" biscuit slots.

Tool Manufacturer Festool now manufactures a similar tool, called the Domino, which uses a rotary blade. The blade cuts a domino shaped mortise which provides a surface area larger than typical biscuit slots for greater bond strength. The cutter is capable of accommodating a variety of domino sizes. This system essentially creates loose mortise and tenon joints.

Production

Biscuits are predominantly used in joining sheet goods such as plywood, particle board and medium-density fibreboard. They are sometimes used with solid wood, replacing mortise and tenon joints as they are easier to make and almost as strong. They are also used to align pieces of wood when joined edge-to-edge in making wider panels. It is important to use the same face when cutting the slots, so the boards are perfectly flush.

Biscuits are also used to align edges of workpieces, such as when forming a 90 degree angle with your materials. The biscuit provides a quick means of getting a perfectly flush joint, while at the same time reinforcing the joint.

Typically, the machine will have an adjustable fence, so it can be set on an angle for joining mitered pieces.

Also, there are other types of specialty biscuits available, from metal connectors, used for removable panels, to hinges, making these portable machines even more flexible.

Usage

The workpieces are brought together and the user marks the location for the biscuits. Precise measurement is not required, as the biscuits are hidden when the pieces are assembled, so a quick pencil stroke that marks both pieces where they align is all that is required. The parts are separated and the machine is used to cut the slots in each piece. The machine has reference marks on the center line of the blade for easy alignment to the marks on the materials being joined.

The body of the machine with the blade is spring loaded and in the normal position the blade is retracted. The operator aligns the machine and uses a firm pressure to push the body forward against the base plate to make the cut. The waste material is blown out of the slot on the right of the base plate.

Because the slots are slightly longer than the biscuits, it is still possible to slide the panels sideways after the joint is assembled (before the glue sets). This fact makes the biscuit joiner easy to use, because it does not require extreme accuracy or jigs to achieve perfect joints.

The depth of the cut can be altered by an adjustable stop, the smaller base can be rotated through 90 deg. and accessories are provided for altering the offset of the base to the blade (for use with thicker or thinner materials as required). Some models allow slots to be cut at angles other than 90 deg. to the joining face, for example 45 deg., which greatly speeds up the assembly of things like cabinets.

The sizes of standard biscuits

Size	Metric Biscuits † in mm (L x W x T)	Inch Biscuits † in inches (L x W x T)	Notes
#H9	38 x 12 x 3 mm‡		Uses a smaller cutter wheel 3 mm wide.
#0	47 x 15 x 4 mm‡	1-1/8" x 5/8" x 19/128"	Standard cutter width is 4 mm or 5/32".
#10	53 x 19 x 4 mm‡	2-1/8" x 3/4" x 19/128"	
#20	56 x 23 x 4 mm‡	2-3/8" x 1" x 19/128"	One source uses 2-1/4" for length.
S6	85 x 30 x 4 mm‡		

† Biscuits may also be referred to as plates (as per the Lamello website).
‡ These data require clarification because the standard cutter width is 4 mm thus requiring the biscuit to be thinner. It is more likely that the thickness is 3.75 mm which would correspond well to the typical inch thickness (19/128" = 3.77 mm).

Note: The mm sizes were taken verbatim from the Lamello website. The inch sizes were taken verbatim from an article on plate joinery published in The Woodworker's Gazette several years ago. In general, the sizes appear to be consistent with each other given the typical tolerances used in woodworking. The usual caveats in dealing with tools and materials destined for US or European use are to be observed, of course. The most commonly used inch sizes used are #0, #10 and #20 hence their exclusive listing.

The sizes of Porter Cable biscuits

Size	Metric Biscuits in mm (W x L)	Inch Biscuits in inches (W x L)	Notes
#FF	13 x 30 mm	1/2" x 1-13/64"	FF = Face Frame for 1-1/2" width, and up.
#0	16 x 47 mm	5/8" x 1-21/32"	
#10	20 x 52 mm	25/32" x 2-3/64"	
#20	24 x 54 mm	15/16" x 2-9/32"	

Note: The sizes were taken verbatim from the Porter-Cable website.

Chapter 13

Router (Woodworking)

A "D-handle" fixed-base router

Makita plunge router.

Makita laminate trimmer

A **router** is a woodworking tool used to rout out (hollow out) an area in the face of a piece of wood. It was a tool particularly used by pattern makers and staircase makers and consisted of a broad-based wooden hand plane with a narrow blade projecting well beyond its base plate gaining it the nickname **Old Woman's Tooth**. Although the original hand tool has a few advantages over the power tool equivalent and retains favour with some workers, since about 1960, it has all but been replaced by the modern *spindle router*, which was designed for the same work, although the first electric hand routers appeared in the years just after World War I. Further refinement produced the plunge router, invented by ELU (now part of DeWalt) in Germany in the late 1940s. This is even better adapted for many types of work. Today, traditional hand-powered routers are often called router planes. Some workers consider it to be the single most versatile woodworking power tool. Modern routers are often used in place of traditional moulding planes or spindle moulder machines for edge decoration (moulding) of timber. Related to the router is a smaller, lighter version designed specifically for trimming laminates. It can be used for smaller general routing work. For example, with an appropriate jig it can be used for recessing door hinges and recessing lock faceplates.

Process

Routing is a high speed process of cutting, trimming, and shaping wood, metal, plastic, and a variety of other materials.

Process characteristics

- usually routing is limited to soft metals (aluminum etc.) and rigid nonmetals.
- Specially designed cutters are used for a variety of patterns, cuts, and edging.
- Both hand controlled and machine controlled/aided routers are common today.

Workpiece geometry

Routing is a shaping process used to produce finished edges and shapes. Some materials that prove difficult to shape with other processes, such as fiber-glass, Kevlar, and graphite, can be shaped and finished neatly via various routing techniques. Apart from finished edges and shaping, cutaways, holes, and contours can also be shaped using routers.

Tools and equipment

- The set up includes an air or electric driven router, a cutting bit or tool, and a guide template. Also the router can be fixed to a table or connected to radial arms which can be controlled easier.
- In general there are three types of cutting bits or tools.
    1. Fluted cutters (used for edging and trimming)
    2. Profile cutters (used for shaping and trimming)
    3. Helical cutters (used on easily machined materials, for drilling, shaping, trimming)
- Safety glasses and ear protection should be worn at all times when using a router.

Moulding

The spindle router is positioned at the finer end of the scale of work done by a moulding spindle. That is to say it is able to cut grooves, edge moulding, and chamfer or radius the edge of a piece of wood. It is also possible to use it for cutting some joints. The shape of cut that is created is determined by the size and shape of the bit (cutter) held in the collet and the depth by the depth adjustment of the sole plate.

Variety of routers

There are a variety of router styles, some are plunge, some are D handled, some are double knob handled. Some have variable speed controls. Some have a soft start feature, meaning they build up speed gradually. This is nice for routers with a large cutter. Holding a 3 horse router and turning it on is somewhat dangerous, due to the torque of the motor. Holding it with two hands is a must. For routers with a toggle type on / off switch it is important to check to verify the switch is in the off position, prior to plugging it in.

The purpose of multiple handle arrangements is depending on the bit, control is easier with different configurations. For example when shaping the edge of a fine table top, many users prefer a D handle, with variable speed, as it seems to permit better control and burning the wood can be minimized.

Uses for routers are many. With the help of the multitude of jigs and various bits, they are capable of producing dovetails, mortises, and tenons, moldings of infinite varieties, dados, rabbets, raised panel doors and frames, cutting circles, and so much more.

Features of the modern spindle router

template guide bushing secured in the base around the router cutter

The tool usually consists of a base housing a vertically mounted universal electric motor with a collet on the end of its shaft. The bit is height-adjustable to allow protrusion through an opening in a flat sole plate, usually via adjusting the motor-mounting height (the mechanism of adjustment is widely varied among manufacturers). Control of the router is derived from a handle or knob on each side of the device, or by the more recently developed "D-handle".

There are two standard types of router—plunge and fixed. When using a **plunge-base router**, the sole of the base is placed on the face of the work with the cutting bit raised above the work, then the motor is turned on and the cutter is lowered into the work. With a **fixed-base router**, the cut depth is set before the tool is turned on. The sole plate is then either rested flat on the workpiece overhanging the edge so that the cutting bit is not contacting the work (and then entering the work from the side once the motor is turned on), or the sole plate is placed at an angle with the bit above the work and the bit is "rocked" over into the work once the motor is turned on. In each case, the bit cuts its way in, but the plunge router does it in a more refined way, although the bit used must be shaped so it bores into the wood when lowered.

The baseplate (sole plate) is generally circular (though this, too, varies by individual models) and may be used in conjunction with a fence attached to the base, which then braces the router against the edge of the work, or via a straightedge clamped across the work to obtain a straight cut. Other means of guiding the machine include the template guide bushing secured in the base around the router cutter, or router cutters with built-in guide bearings. Both of these run against a straight edge or shaped template. Without this, the varying reaction of the wood against the torque of the tool makes it impossible to control with the precision normally required.

Table mounted router

A router may be mounted upside down in a **router table** or bench. The router's base plate is mounted to the underside of the table, with a hole allowing the bit to protrude above the table top. This allows the work to be passed over the router, rather than passing the router over the work. This has benefits when working with smaller objects and makes some router operations safer to execute. A router table may be fitted with a fence, fingerboards and other work-guiding accessories to make the operation safer and more accurate.

A simple router table consists of a rigid top with the router bolted or screwed directly to the underside. More complex solutions can be developed to allow the router to be easily removed from the table, and there is a wide range of commercially available systems.

In this mode, the router can perform tasks similar to a spindle moulder. For smaller, lighter jobs, the router used in this way can be more convenient than the spindle moulder, with the task of set up being somewhat faster. There is also a much wider range of bit profiles available for the router, although the size is limited.

The router table is usually oriented so that the router bit is vertical and the table over which the work is passed is horizontal. Variations on this include the horizontal router table, in which the table remains horizontal but the router is mounted vertically above the table, so that the router bit cuts from the side. This is an alternative for edge operations, such as panel raising and slot cutting.

Available cutters

Profiles made in wood by several common router bits.

Two typical router bits: (top) a ¼-inch shaft Roman Ogee with bearing, (bottom) 1/4-inch shaft dovetail bit.

Router bits come in hundreds of varieties to create either decorative effects or joinery aids. Generally, they are classified as either high-speed steel (HSS) or carbide-tipped, however some recent innovations such as solid carbide bits provide even more variety for specialized tasks.

Aside from the materials they are made of, bits can be classified as edge bits or non-edge bits, and whether the bit is designed to be *anti-kickback*. Edge bits have a small wheel bearing to act as a fence against the work in making edge moldings. These bearings can be changed by using commercially available bearing kits. Changing the bearing, in effect, changes the diameter of the cutting edge. This is especially important with rabbeting bits. Non-edge bits require the use of a fence, either on a router table or attached to the work or router. Anti-kickback bits employ added non-cutting bit material around the circumference of the bit's shoulders which serves to limit feed-rate. This reduces the chance that the workpiece is pushed too deeply into the bit (which would result in significant kickback from the cutting edge being unable to compensate).

Bits also differ by the diameter of their shank, with ½ inch, 12 mm, 10 mm, 3/8 inch, 8 mm and ¼ inch and 6 mm shanks (ordered from thickest to thinnest) being the most common. Half-inch bits cost more but, being stiffer, are less prone to vibration (giving smoother cuts) and are less likely to break than the smaller sizes. The bit shank and router collet sizes must match. Many routers come with removable collets for the popular shank sizes (in the USA ½ in and 1/4 in, in Great Britain ½ in, 8 mm and 1/4 in, and metric sizes in Europe—although in the United States the 3/8-inch and 8 mm sizes are often only available for extra cost).

Many modern routers allow the speed of the bit's rotation to be varied. A slower rotation allows bits of larger cutting diameter to be used safely. Typical speeds range from 8,000 to 30,000 rpm.

Router Bits can be made to match any imaginable profile. Companies that manufacture custom router bits can be found on the Internet. Custom router bits are especially beneficial for home restoration projects, where the original trim and molding of the home is often out of production.

Versatility

The router was described as "the most versatile tool in the world" by Jeremy Broun in his book, *The Incredible Router*. Hylton and Matlack also describe the router as a versatile tool: "You can use it in just about every aspect of a job but assembly ... used creatively, it will do almost any kind of cutting or shaping of wood." However, custom baseplates, templates, or **jigs**—tools that help guide the router or the workpiece through a controlled motion—are typically needed for more complex cuts.

CNC router

A CNC wood router is a table with a gantry to which the router or spindle mounts. Tables use CAM programming to move the router along three axes (X-Y-Z). Most table routers have a three motor drive system utilizing either servo or stepper motor. More advanced routers use a 4 motor system for added speed and accuracy.

Similar tools

A tool similar to a router, but designed to hold smaller cutting bits—thereby making it easier to handle for small jobs—is a laminate trimmer.

A related tool, called a *spindle moulder* (UK) or shaper (North America), is used to hold *larger* cutter heads and can be used for deeper or larger-diameter cuts. Another related machine is the pin router, a larger static version of the hand electric router but normally with a much more powerful motor and other features such as automatic template copying.

Some profile cutters use a cutting head reminiscent of a spindle router. These should not be confused with profile cutters used for steel plate which use a flame as the cutting method.

Chapter 14

Airbrush

Paasche F#1 Single-action external mix airbrush

An **airbrush** is a small, air-operated tool that sprays various media including ink and dye, but most often paint by a process of nebulization. Spray guns developed from the airbrush and are still considered a type of airbrush.

History

The first airbrush, depending on your definition, was patented in 1876 (Patent Number 182,389) by Francis Edgar Stanley of Newton, Massachusetts. Stanley and his twin brother later invented a process for continuously coating photographic plates (Stanley Dry Plate Company) but are perhaps best known for their Stanley Steamer. No artistic images that used this 'paint distributor / atomiser' exist or are as yet known.

The first instrument to be named the "airbrush" was developed by Abner Peeler "for the painting of watercolors and other artistic purposes" and used a hand-operated compressor. It was rather crude, being based on a number of spare parts in a jeweller's workshop such as old screwdrivers and welding torches. It took 4 years of further development before a truly practical device was developed. This was marketed by Liberty Walkup, who taught airbrush technique to American Impressionist master Wilson Irvine at the Air Brush School in Rockford, Illinois. The first certain 'atomising' type airbrush was invented by Charles Burdick in 1893 and presented by Thayer and Chandler art materials company at the World Columbian Exposition in Chicago. This device was essentially the same as a modern airbrush, resembling a pen and working in a different manner than Peeler's device. Aerograph, Burdick's original company, still makes and sells airbrushes in England. Thayer and Chandler were acquired by Badger Air-Brush Co. in 2000. Badger Air-Brush continues the Thayer and Chandler tradition of manufacturing quality airbrush guns, tools and compressors out of Franklin Park, Illinois.

For more a detailed academic study, the University of Wales Library holds a detailed PhD on Airbrush History. The Franklin Institute in Philadelphia, The Public Library in Rockford Illinois and the Conservation Department of New York University retain copies. This was authored by Dr. Andy Penaluna, now Professor of Creative Entrepreneurship at Swansea Metropolitan University. Professor Penaluna has also advised the International Museum of Photography at George Eastman House, Rochester, New York.

Design

An airbrush works by passing a stream of fast moving (compressed) air through a venturi, which creates a local reduction in air pressure (suction) that allows paint to be pulled from an interconnected reservoir at normal atmospheric pressure. The high velocity of the air atomizes the paint into very tiny droplets as it blows past a very fine paint-metering component. The paint is carried onto paper or other surface. The operator controls the amount of paint using a variable trigger which opens more or less a very fine tapered needle that is the control element of the paint-metering component. An extremely fine degree of atomization is what allows an artist to create such smooth blending effects using the airbrush.

The technique allows for the blending of two or more colors in a seamless way, with one color slowly becoming another color. Freehand airbrushed images, without the aid of stencils or friskets, have a floating quality, with softly defined edges between colors, and between foreground and background colors. A well skilled airbrush artist can produce paintings of photographic realism or can simulate almost any painting medium. Painting at this skill level involves supplementary tools, such as masks and friskets, and very careful planning.

Some airbrushes use pressures as low as 20 psi (1.38 bar) while others use pressures in the region of 30-35 psi (2-2.4 bar). Larger "spray guns" as used for automobile spray-painting need 100 psi (6.8 bar) or more to adequately atomize a thicker paint using less solvent. They are capable of delivering a heavier coating more rapidly over a wide area. Even with small artist airbrushes using acrylic paint, artists must be careful not to breathe in the atomized paint, which floats in the air for minutes and can go deep into the lungs. With commercial spray guns for automobiles, it is vital that the painter have a clean air source to breathe, because automotive paint is far more harmful to the lungs than acrylic. Certain spray guns, called High-Volume Low-Pressure (HVLP) spray guns, are designed to deliver the same high volumes of paint without requiring such high pressures.

Types

Aerograph Super 63, a gravity fed, double action, internal mix airbrush

Airbrushes are usually classified by three characteristics. The first characteristic is the action performed by the user to trigger the paint flow while the second is the mechanism for feeding the paint into the airbrush and the third is the point at which the paint and air mix.

Trigger

The simplest airbrushes work with a *single action* mechanism where the depression of a single "trigger" results in paint and air flowing into the airbrush body and the atomized paint being expelled onto the target surface. Cheaper airbrushes and spray guns tend to be of this type.

Dual action or *double action* airbrushes separate the function for air and paint flow so that the user can control the volume of airflow and the concentration of paintflow through two independent mechanisms. This allows for greater control and a wider variety of artistic effects. This type of airbrush is more complicated in design than single action airbrushes which tends to be reflected in its cost.

Feed system

Paint can be fed by gravity from a paint reservoir sitting atop the airbrush (called *gravity feed*) or siphoned from a reservoir mounted below (*bottom feed*) or on the side (*side feed*). Each feed type carries unique advantages. Gravity feed instruments require less air pressure for suction as the gravity pulls the paint into the mixing chamber. Typically instruments with the finest mist atomization and detail requirements use this method. Side- and bottom-feed instruments allow the artist to see over the top, with the former sometimes offering left-handed and right-handed options to suit the artist. A bottom feed airbrush typically holds a larger capacity of paint than the other types, and is often preferable for larger scale work such as automotive applications and tee-shirt design.

Mix point

With an *internal mix* airbrush the paint and air mix inside the airbrush (in the tip) creating a finer atomized "mist" of paint. With *external mix* the air leaves the airbrush before it comes into contact with the paint which creates a coarser stippled effect. External mix airbrushes are cheaper and more suited for covering larger areas with more viscous paints or varnishes.

Spray guns

The airbrush led to the development of the spray gun; a similar device, that typically delivers a higher volume of paint and for painting larger areas.

The first paint spraying machine was developed in 1887. Equipment by De Vilbiss and Binks is typical of modern sprayguns.

The addition of a simple pistol grip adapter to an aerosol paint spray can creates a cheap alternative to a spray gun.

Technique

Airbrush technique is the freehand manipulation of the airbrush, medium, air pressure and distance from the surface being sprayed in order to produce a certain predictable result on a consistent basis with or without shields or stencils. Airbrush technique will differ with the type of airbrush being used (single action or dual/double action).

Double action airbrush technique involves depressing the trigger on the top of the airbrush with the index finger to release air only, and drawing it back gradually to the paint release threshold. The most important procedural dynamic is to always begin with air only and end with air only. By observing this rule, precise control of paint volume and line width and character can be achieved. The single most important airbrush stroke consistently utilized by professionals is the dagger stroke. This describes a stroke which begins wide and ends as a narrow line, created by starting with the brush far from the support and moving it evenly closer as the line is drawn.

Single action airbrush technique derives its name from the fact that only one action is required for operation. The single action of depressing the trigger releases a fixed ratio of paint to air. Achieving different line widths requires either changing the tip and nozzle combination or else adjusting the spray volume manually between spray width changes. The most important aspect of proper single action airbrush technique is to keep the hand moving before the trigger is depressed and after the trigger is released. This avoids the "bar bell" line.

Use

Art and illustration

Since the inception of airbrush technology, commercial artists and illustrators realized airbrushes allowed them to create highly rendered images and a high level of realism. Artists often use the airbrush in combination with cut stencils or items held freehand to block in controlled manner the flow of paint onto the paper (or digital alternatives) with fantasy and science fiction artists. Airbrush images can be found today in advertising, publishing (e.g., book covers), comic books and graphic novels.

Photo retouching

Yezhov is clearly visible to Stalin's left. The photo was later altered by censors.

Airbrushing has long been used to alter photographs in the pre-digital era. In skilled hands it can be used to help hide signs that an image has been extensively retouched or "doctored".

As a result of Stalin's purges, and later destalinization, many photographs of officials from the periods show extensive airbrushing, often entire people have been removed. The term "airbrushed out" has come to mean rewriting history to pretend that something was never there. In contemporary academic discourse, the process of removing components from an image is formally known as *object removal.*

The term "airbrushed" or "airbrushed photo" has also been used to describe glamour photos in which a model's imperfections have been removed, or in which their attributes have been enhanced. The term has often been applied in a pejorative manner to describe images of unrealistic female perfection and has been particularly common in reference to pictures in Playboy, and later Maxim.

Using today's digital imaging technology, this kind of picture editing is now usually done with a raster image editor, which is capable of even more subtle work in the hands of a skilled touch-up artist. This technique is still called airbrushing or photoshopping.

Murals

Airbrushes are also suitable for painting murals.

Hobby

Airbrushes are commonly used by scale modeling enthusiasts because finer coats can be laid down, as well as opaque effects, like weathering, adding stains etc. The fine atomization of paint in modern airbrushes also makes it possible to accurately reproduce soft-edged mottled camouflage schemes, which are very hard to do convincingly by hand-brushing. (Luftwaffe aircraft are a good example of this)

Many Radio Control hobbyists also use the airbrush to create works of art on the lexan bodies. The paint jobs range from a basic one-color paint job to fine detailed works of art.

Airbrush makeup application

Though the earliest record of this type of cosmetic application dates back to the 1925 film version of Ben-Hur, it has recently been re-popularized by the advent of Hi-Definition Television and Digital Photography, wherein the camera sees more detail than ever before. Liquid Foundations that are high in coverage but thin in texture are applied with the airbrush for full coverage without a heavy build-up of product. It is also a highly popular technique for Special F/X Makeup.

Temporary airbrush tattoos (TATs)

Temporary tattoo

Airbrushes can also be used to apply temporary airbrush tattoos. An artist sprays ink onto the skin through a stencil. Often, the resulting design mirrors the look of a permanent tattoo, without any pain or discomfort. In the past, TATs might only last a week, but now, the best inks can last up to two weeks or longer.

Airbrush tanning

Airbrushes are used to apply special tanning solutions as a form of sunless tanning that simulates the appearance of a natural sun tan. It is promoted as a safer and healthier alternative to the damaging effects of long term exposure to the sun. It is often performed by companies also offering other sun tanning alternatives like sun beds.

Finger nail art

Airbrushes are also used to apply images onto human finger nails as well as synthetic ones that are later glued to the person's actual finger nail.

Clothing

T-shirt airbrushing is popular—many t-shirt airbrush shops offer to paint any textile that will hold paint, including jeans, denim jackets, leather apparel, pillow cases, and hoodies.

One well known producer of airbrushed clothing is Marc Ecko. He used to airbrush t-shirts when he started his clothing company.

Automotive

Airbrushes are used to spray murals, graphics, and other artwork on automobiles, motorcycles and helmets. This artform has been around since at least the fifties, but more recently it has seen an increase in popularity thanks to such shows as *Rides* and *American Chopper*. Most professionals prefer to use automotive grade bases through top of the line gravity fed airbrushes. The cost to hire a professional artist will vary from a few hundred to several thousand dollars, depending on location, skill level and reputation.

Street artists

Many street artists use airbrushing to create names and pictures for tourists, such as around Jackson Square in New Orleans. In the mid-seventies, Panama City Beach, Florida was the airbrush capital of the world, with hundreds of artists painting custom designs on T-shirts.

Safety

When inhaled, finely dispersed paint and solvents can produce serious health hazards. Regulatory provisions such as OSHA dictate strict requirements to prevent unsafe use in work environments.