**UNIT- 2 Metal cutting**:

**Syllabus:** Single and multi-point cutting; Orthogonal cutting, various force components: Chip Formation, Tool wear and tool life, Surface finish and integrity, Machinability, cutting tool materials, Cutting fluids, Coating; Turning, Drilling, Milling and finishing processes, Introduction to CNCMachining. Additive manufacturing: Rapid prototyping and rapid tooling Joining/fastening processes: Physics of welding, brazing and soldering; design considerations in welding, Solid and liquid state Joining processes; Adhesive bonding of powder metallurgy.

**Single- point cutting tool &Multi Point Cutting tool:-**

A single-point cutting tool is defined as a tool with only one main cutting edge similarly, double-point cutting tools have two cutting edges, and multi-point cutting tools have two or more main cutting edges.

The number of cutting edges in metal or [hole cutting tools](https://benchmarkabrasives.com/collections/cutting-tools-hole-saw-arbors) has a significant impact on several factors, including material removal rate (MRR), chip load, and tool cost.

In the machining process, A single-point cutting tool is used for cutting, shaping, boring, and planning because here a single cutting edge removes or cuts the whole material in one pass. Whereas, in a double point cutting tool, two cutting edges participate equally to remove material in one pass. As a result, the chip load reduces on both cutting edges.

A multi-point cutting tool has two to hundreds of cutting edges (for example, TCT blades used as [wood cutting tools](https://benchmarkabrasives.com/collections/cutting-tools-tct-blades-wood)). Double or multi-point cutting tools are primarily used for drilling, milling, reaming, and knurling applications.

Now, In the next step, we will discuss important similarities and differences between the single-point cutting tools and multi-point cutting tools.

* Both single-point and multi-point cutting tools are used for metal cutting and excess material removal. Multi-point cutters are often regarded as [aluminium cutting tools](https://benchmarkabrasives.com/collections/cutting-tools-tct-blades-for-aluminum).
* Both are utilized in traditional machining processes. However, different machining method requires a different type of cutting tools.
* Single point and multi-point cutters, both require sharp cutting edges. But, cutting-edge numbers are not similar.
* For both [types of metal cutting tools](https://benchmarkabrasives.com/blogs/news/types-of-metal-cutting-tools), geometry and material of work piece are important factors

|  |  |
| --- | --- |
| SINGLE POINT CUTTING TOOL | MULTI-POINT CUTTING TOOL |
| These tools have only one main cutting edge. | These tools have two or more main cutting edges |
| The cutting process stops completely if a cutting edge gets damaged. | The cutting process does not stop if any single cutting edge gets damaged. |
| Cutting tool contacts work piece with only one edge. | Cutting tool contacts work piece with one or more edges. |
| These tools are used to perform shaping, boring, turning, and facing. | These tools perform drilling, milling, reaming, turning & more. |
| Single Point cutting tools are mainly utilized with a lathe, planer, shaper, or slotter machines. | Multi-Point cutting tools are utilized with the grinding, milling, or more such heavy machinery. |
| Fabrication and design are simple. | Fabrication and design are difficult. |
| For a single pass, the complete chip load is borne by a single cutting edge. | Here complete chip load is distributed equally in all cutting edges. |
| Provide a good surface finish with less accuracy. | Provide an excellent surface finish with high accuracy. |
| This tool can be made from the grinder machine. | Multi-point tools cannot be made from only grinder machines. |
| Tools manufacturing and designing take less time | Tools manufacturing and designing takes more time |
| Single point cutting tools costs low. | Multi-point cutting tools cost high. |
| High cutting temperature. | Low cutting temperature. |
| Single point cutting tools have a short life span. | Multi-point cutting tools have a long life span. |
| Low material removal rate (MRR). | High material removal rate (MRR). |
| The single-point cutting tool wear rate is quite high. | The multi-point tool wear rate is comparatively low. |
| Examples of single-point cutting tools are-* Boring tool
* Slotting tool
* Planning tool
* Shaping tool
* Fly milling
* Turning tool, etc.
 | Examples of multi-point cutting tools are-* Grinding wheels
* Knurling tools
* Milling tools
* Hobs
* Broach
* Reamer, etc.
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Cutting through metal is not an easy task unless you have the right tool. So, what are the right tools to cut metal.

**Orthogonal cutting**

Orthogonal cutting uses a wedge-shaped tool in which the cutting edge is perpendicular to the direction of cutting speed. Shear plane: As the tool is forced into the material, the chip is formed by shear deformation along a plane called the shear plane, which is oriented at an angle f with the surface of the work.

**Oblique cutting**

Oblique cutting 1-cutting edge travels, making an angle with the normal of cutting edge. 2-The cutting edge may or may not clear either end of work piece. 3- chip flows, making an angle with normal of cutting edge. 4-Three mutually perpendicular forces are involved

## 1. CONTINUOUS CHIP

During the [cutting of ductile materials, a continuous chip is produced due to the presence of tool cutting edge](https://blogmech.com/weight-reduction-technology-fuel-economy-factors-light-weight-technologies-cutting-edge-technologies/) in compression and shear. These types of chips are in the form of long coils and have the same thickness throughout the length.

This type of chip is required, since it gives a good surface finish, [improving the tool life and less power](https://blogmech.com/screw-conveyor-power-calculation/) consumption. However, chip disposal is not easy and the surface finish of the finished work gets affected.

1. Smaller depth of cut.

2. High cutting speed.

3. Large rake angle.

4. Proper cutting fluid.

5. Low friction between the tool face and the chips.

## 2. DISCONTINUOUS CHIP OR SEGMENTAL CHIP

Discontinuous chips as shown in the figure are produced while [machining brittle materials such as grey cast](https://blogmech.com/manufacturing-defect-examples/) iron, bronze, and high carbon steel at low cutting speed without fluids when friction exists between the tool and chip.

## 3. CONTINUOUS CHIP WITH BUILT-UP EDGE

During the [cutting process](https://blogmech.com/laser-cladding-technology/), the interface temperature and pressure are quite high and between the tool-chip interfaces, the friction is also high. It causes the chip [material to weld](https://blogmech.com/thermit-process-thermit-welding-materials-application-of-thermit-welding/) itself to the tool face near the nose as shown in the figure. These are called “built-up edges”.

The formation of built-up edges in the continuous chips is a transient and not steady phenomenon. The [collected built-up chip material](https://blogmech.com/interview-questions-on-strength-of-materials/) will then break away, part adhering to the undesired of the chip and part to the work piece. Thus, the [process will result in a poor surface finish on the machined](https://blogmech.com/electro-chemical-grinding/) surface and accelerated wear on the tool face.

## Tool Life Definition

The Tool first one-word T is, refers to the term of the time. Ordinarily, it is expressed in minutes, for which state-of-the-art, acted through the cutting process, etc. That all maintains its cutting capability amid sharpening procedures. Moreover, it describes the length of the cutting bit which the tool might be used for.

## Factors Impacting the Tool Life

These are the following factors that affect the tool life, it is followed:

* Area of Cut
* Cutting Speed
* Essence of Cutting
* Biological Consequences of Work piece
* The ratio of Feed to Depth of Cut (f/d)
* Form and Inclinations of Tools
* Impact of Lubricant

Apart from this, the Tool material and its various parameters are the actual situations that are most imperative to choosing the quality of particleboard surface. Therefore, as a result, it is influenced by trimming speed on the length of the tool.

The connection was displayed as diminishing in the life of the tool along with extending the cutting speed.

## Meaning of the Tool Wear

As per the stable machining requirements, the tool wear has an influential effect on surface roughness.According to Rao’s deconstruction, when a profundity of cut is more diminutive than the tool proboscis’s radius. The wear dimensions are defined as:

TW = 0.5× (flank wear + nose wear)

Apart from this, it expresses the incremental destruction of cutting-edge tools. It happens due to periodic machining operations. It is called progress wear. It has another, which is known as catastrophic tool wear.

Ordinally, progressive tool wear has two types one is crater wear and flank wear. Both are types made up of surfaces. The crater wear has a rake surface, and apart from this, the flank weak has a flank surface.

In addition, which also includes numerous wears like edge wear and Noche wear, etc. its all are included under it apart from this wear.

## Causes of Tool Wear

Following are the Tool wear causes which essentially occur due:

* Vast localized pressures & tensions at the tip of the tool.
* More High temperatures (specifically along rake face).
* Keep Gliding the chip along the rake face.
* Able to move smoothly of the tool along the recently cut work piece consistency.

If you would like to comprehend “what is tool life?”.

If yes, it straightforward means that it is the most prominent element. The Tool is effectively used in the evaluation of machinability. In the duration of this period, the tool is cut very effortlessly and effectively. The process of this period has majorly affected with two successive alternates of tool and two consecutive grinding of the tool.

Apart from this, the tool is weak & life should have a too-long life of the tool. As a result, the value of the replacement and grinding is too high.

Although, the short tool life & wear will have to be uneconomical. Once in a while, several tools are not performing their job effectively and are not able to satisfy the desires. Then, as per condition, it is figured out that the tool is nearby at the end of its usual life.

These are the exhaustive signs which indicate that tools and weak life are coming to an end.

## Tool Life is Measured By

The Tool life is measured by the exhaustive signs, which indicate that the tool and weak life is coming to an endpoint.

* Low surface finish, the existence of conversation imperfections on the work piece, and size error.
* Overheating and Resurgence of the work piece. The tool interference occurs due to the contention issue.
* Decaying trimming edges.
* An impulsive huge use in power consumption.

So, you will have to use the tool material precisely. The Tool life is measured by these indicating signs very impeccably.

Ordinally, tool life and tool wear will be influenced through numerous factors, it is mentioned below:

* The properties of the tool and its material.
* Needs of the finishing with the accurate tool material on the designed product.
* The Tool geometry also affects the tool wear and tool. It is the shape of the cutting tool.
* Machining requirements like the cutting liquid used and temperature.
* Following Machining variables like Feast, cutting speed, and depth of a cut affect the tool. Moreover, the several kinds of machining processes- ongoing and sporadic cutting.

**Tool wear:-**

Today we will discuss about tool wear, is mechanism, types and mainly focus on Flank wear, Crater wear and Nose Wear. Tool wear is common phenomenon is metal cutting. Before discussing about tool wear we should learn about how a tool fails. The cutting tools fail due to following three conditions.

#### 1. Flank wear:

Flank wear is due to abrasive action of discontinuities like debris from built up edge etc. It wears out side and end flank of the tool. It is occur at tool work-piece interface. This wear predominates at low speed.

#### 2. Crater wear:

Crater wear generally occur in machining ductile material due to abrasion and diffusion of metal at face of tool. It is occur at face at a short distance from cutting edge. This wear predominates at high speed.

#### 3. Nose wear:

Nose wear are consider as separate part of wear. It wears out the tool corner. It is the matting part of flank and face which is combination effect of crater wear and flank wear. It is considered as separate wear because the tool corners are very important for proper cutting of work-piece.

Tool wear can be reduce by proper cooling and lubricate because the major cause of tool wear is friction and temperature rise due to friction. Lubricate reduce friction between chips and tool which reduce tool wear tool. It can also be reduced by using high hardness and abrasion resistance tool and high resistance to adhesion and diffusion

**Cutting fluid**

Cutting fluid is a type of coolant and lubricant designed specifically for metalworking processes, such as machining and stamping. There are various kinds of cutting fluids, which include oils, oil-water emulsions, pastes, gels, aerosols (mists), and air or other gases.

Cutting fluids are the fluids which are generally applied while the [machining](https://clubtechnical.com/material-removal-process) (or cutting) operation is taking place. The machining operation can be any i.e. [milling](https://clubtechnical.com/milling), turning, [drilling](https://clubtechnical.com/hole-making-operations) etc.

Sometimes a cutting fluid is also referred as coolant but it is wrong. A cutting fluid performs several functions and cooling the tool and work piece is just one of them.

## ****Functions or applications of cutting fluids****

As mentioned above Cutting fluids performs several functions and some of them are

* Cool the tool and work piece
* Reduce the friction
* Protect work against rusting
* Improve the surface finish
* Prevent the formation of Built-up edges (BUEs)
* Wash away the chips from the cutting zone

All the above functions are performed with the help of cooling and lubricating action of cutting fluids. It means a cutting fluid should have excellent cooling and [lubricating](https://clubtechnical.com/lubricant) properties.

## **Methods of applying cutting fluids**

Cutting fluids can be applied to the tool and work piece in the following three ways.

### Flooding

In this method tool and work piece are supplied with high volume of  the cutting fluids which are generally in liquid condition.

### Jet application

In this method the cutting fluids which may be either gas or liquid are applied with high pressure on the tool and work piece.

### Mist application

In this method the cutting fluids are mixed with a gas (generally air) and applied to tool and work piece. Mist application combines the properties of above mentioned both methods i.e. flooding and jet application.

## ****Types of cutting fluids****

## There are three basic types of cutting fluids

1. Water based emulsions
2. Straight mineral oils
3. Mineral oils with additives (Neat oils)

## Properties of cutting fluids

* It should have low viscosity
* It should be harmless to the operator
* It is have a good transparency
* It should have low surface tension
* It should have good lubricating properties
* It should not form foam
* It should be odorless
* It should be chemically inert
* It should have high thermal absorptivity
* It should be stable at high temperatures
* It should have high [flash point](https://clubtechnical.com/liquid-fuels)
* It should have high thermal conductivity

There are different cutting processes done on varying conditions. Depending on the cutting conditions and the requirements of the respective [cutting tool](https://www.mrosupply.com/machining/machining-cutting-tools/), it is important that they are of the right properties. The type of material selected for a specific application depends on what is being machined. Here is a classification of these materials.

**Carbon Tool Steel**

This is one of the inexpensive [metal cutting](https://www.mrosupply.com/tools/hand-tools/hacksaws/) tools common in low-speed machining operations. These carbon steel cutting tools are constructed with a composition of 0.6%-1.5% carbon and small amounts, less than 0.5%, of Si and Mn. To enhance the hardness, other materials such as V and Cr could also be added.

Carbon tool steels are preferred because they are abrasion resistant and can maintain the [cutting](https://www.mrosupply.com/tools/hydraulic-tools/hydraulic-cutters/) edge for a long period. However, they lose their hardness when temperatures reach 250 °C. This means that they are not good for high-temperature operations.

Common applications that use carbon steel tool include milling tools, [twist drills](https://www.mrosupply.com/machining/machining-cutting-tools/machining-drill-bits/), and forming tools.

**High-Speed Steel (HSS)**

This is another high carbon steel featuring a significant quantity of alloys like chromium and tungsten to increase their hardness and wear resistance. HSS loses its hardness when temperatures hit 650 °C. It is, therefore, advisable to use coolants to increase tool life. The following surface treatment is also used on HSS to improve the properties.

* Super-finishing to lower friction
* Chromium electroplating to lower friction
* Nitriding to increase wear resistance
* Oxidation to reduce friction

High-speed steel tools are common in broaches, single point lathe tools, and [milling cutters](https://www.mrosupply.com/machining/machining-cutting-tools/end-mills/).

**Cemented Carbide and Cement**



The cemented carbide cutting tool is created using metallurgy method. It is made from tungsten, titanium carbide and tantalum with cobalt as a binder. The most notable thing about the cemented carbide tools is that they are very hard and can be used for cutting at high speed and temperatures. For example, you can use them for cutting at temperatures of 1000 °C without losing their properties.

 For rough cuts, it is better to use high cobalt tool while low combat tools are ideal for finishing applications.

 **Ceramics**

 The common ceramic materials used in cutting tools are silicon nitride and aluminum oxide. When the ceramic material powder is compacted and inserted at very high temperatures, the resulting tools are inert and resistant to corrosion. Therefore, they have high compressive strength.

 The ceramics are stable when operating even in temperatures of up to 1800°C and are about 10 times faster than HSS. Because the friction between the chip and surface is low and heat conductivity is also low, you do not need an additional coolant.

 **Cubic Boron Nitride (CBN)**

 CBN is the second hardest material and is commonly used in hand machines. They provide high abrasion resistance and utilize abrasive in grinding wheels. They are ideal at speeds of 600-800m/min.

 **Diamond**

 This is the hardest material used in tools. It features a high melting point and thermal conductivity. Therefore, it provides excellent abrasion resistance, low thermal expansion, and low friction coefficient. It is considered ideal for machining hard materials like glass, nitrides, and carbides. Note that diamond is not ideal for machining steel.

 This post brings you the main cutting tools materials and their properties to help you pick the ideal option for your facility.

**Drilling**

Drilling is a process of producing a cylindrical hole using drill bit, in a solid material. It is a process in which a drill bit is uses to cut a hole of a circular cross-section in a solid material. The drilling is a single purpose machine for the production of holes. Drilling process is the best method of producing holes. The drill bit is rotary cutting tool, a cylindrical bar with helical flutes and radial cutting edges at one end.

Drilling operation simply consists of rotating the drill and feeding it into the work piece being drilled. The process is simple and reasonably accurate and drill is easily controlled both in cutting speed and feed rate. The is probably one of the original machining processes and it is one of the most widely machining process.

 Drill

Drill can be defined as a rotary end cutting tool which having one or more cutting lips and having one or more helical flutes for passage of chips and admission of a cutting fluid.Drills are commonly used in metal working, construction, fabrication work, wood working, etc. The high-speed steel drills are most commonly used drill bit.

**Base:** It is a solid foundation o which the column or pillar is mounted.

**Column:** It provide the solid support for the worktable.

**Worktable:** It provide the horizontal surface with the alignment connected with drill spindle and hand wheel.

**Motor:** The motor helps the spindle to rotate the pulley and gearbox.

**Hand Wheel:** It provide the feed to the drill with rack and pinion mechanism.

**Spindle:** It provide the holding and locating the cutting tool.

## **Factors for Selection of Drilling Machine:**

Some of the factors considered while selection of a drilling machine are as follows,

1. The material being drilled in a drilling machine.
2. The size of a hole.
3. Speed and Feed required during operation on drilling machine.
4. Need for coolant while working.
5. The capacity of a drilling machine.
6. The quality of a hole.
7. Method of workpiece holding and clamping on work table.

**Drilling Machine Operations:**

There are mainly various operations that can be performed in a drilling machine. The operations performed on a drilling machine are,

**Drilling:**

Drilling is an operation of predicting cylindrical hole by removing metal by rotating cutting edge of drill is known as drilling. Drilling is one of the simplest operations on a drilling machine.

**Reaming:**

Reaming is an operation of finishing a previously drilled hole for greater accuracy using a drill. The tool used for reaming operation is known as reamer.

**Boring:**The boring operation is used to perform to make a hole enlarge a previously drilled hole.

**Counter Boring:**

The counter boring is an operation of enlarging the end of a hole cylindrically like a bolt head, is known as counter boring.

**Counter Sinking:**The counter sinking is an operation of enlarging the hole cone-shaped at the end of hole, is known as counter sinking.

**Tapping:**

The operation of forming an internal thread in a previously drilled hole, is known as tapping.

**Trepanning:**The operation of producing larger holes around diameter of over 50 mm, by removing metal along the circumference, is known as trepanning.

**Spot Facing:**The operation o smoothing and squaring the surface around a hole, is known as spot facing.

**Machinability**

Machinability can be defined as the ease with which the material is machined in terms of specific energy, specific horsepower, or shear stress. In general, the larger the shear stress or specific power values, the more difficult the material is to machine and form, requiring greater forces and lower speeds.

**Milling**

A milling process refers to the complete process of cleaning, grading, and breaking down, sizing, separating, or classifying dry bulk materials. The actual milling process involves the mill that is used to break solid bulk materials into smaller pieces by grinding, cutting, or crushing

**Mechanical finishing**

Mechanical finishing is a big and important industry, it encompasses many processes that alter the surface of a manufactured item to achieve a certain property: improve appearance, adhesion or wettability, solderability, corrosion resistance, tarnish resistance, chemical resistance, wear resistance, hardness, modify electrical conductivity, remove burrs and other surface flaws, and control the surface friction. In particular, mechanical finishing is done to give the sample the desired roughness, flatness or thickness. Another common surface finishing process is Electropolishing which simultaneously can clean, smooth, deburr, passivate, and improves corrosion resistance. Electro polishing though highly desirable, is restricted to conductive materials which thermodynamic behaviour facilitates this process. Mechanical finishing though can produce better "mirror" finishes at a lower cost and it is available to all solids.

**CNC Machine:-**

The term CNC stands for 'computer numerical control', and the [CNC machining definition](https://www.thomasnet.com/articles/custom-manufacturing-fabricating/what-does-cnc-stand-for/) is that it is a subtractive manufacturing process that typically employs computerized controls and machine tools to remove layers of material from a stock piece—known as the blank or workpiece—and produces a custom-designed part. This process is suitable for a wide range of materials, including metals, [plastics](https://www.thomasnet.com/products/cnc-machined-plastics-95932844-1.html), wood, [glass](https://www.thomasnet.com/products/cnc-glass-machining-95971925-1.html), foam, and composites, and finds application in a variety of industries, such as [large CNC machining](https://www.thomasnet.com/products/large-cnc-machining-96081583-1.html), machining of parts and prototypes for telecommunications, and [CNC machining aerospace parts,](https://www.thomasnet.com/products/aircraft-aerospace-cnc-machining-96098827-1.html) which require tighter tolerances than other industries. Note there is a difference between the CNC machining definition and the CNC machine definition—one is a process and the other is a machine. A CNC machine (sometimes incorrectly referred to as a C and C machine) is a programmable machine that is capable of autonomously performing the operations of CNC machining. Subtractive manufacturing processes, such as [CNC machining](https://www.thomasnet.com/articles/top-suppliers/top-cnc-machining-services-companies/), are often presented in contrast to [additive manufacturing processes](https://www.thomasnet.com/articles/custom-manufacturing-fabricating/3d-printing-rapid-prototyping-and-additive-manufacturing), such as 3D printing, or formative manufacturing processes, such as [liquid injection molding](https://www.thomasnet.com/articles/plastics-rubber/molding-liquid-injection). While subtractive processes remove layers of material from the workpiece to produce custom shapes and designs, additive processes assemble layers of material to produce the desired form and formative processes deform and displace stock material into the desired shape. The automated nature of CNC machining enables the production of high precision and high accuracy, simple parts and cost-effectiveness when fulfilling one-off and medium-volume production runs. However, while CNC machining demonstrates certain advantages over other manufacturing processes, the degree of complexity and intricacy attainable for part design and the cost-effectiveness of producing complex parts is limited. [Evolving from the numerical control (NC) machining process](https://www.thomasnet.com/articles/custom-manufacturing-fabricating/cnc-evolution) which utilized punched tape cards, CNC machining is a manufacturing process which utilizes [computerized controls](https://www.thomasnet.com/articles/custom-manufacturing-fabricating/cnc-control-type/) to operate and manipulate machine and cutting tools to shape stock material—e.g., metal, plastic, wood, foam, composite, etc.—into custom parts and designs. While the CNC machining process offers various capabilities and operations, the fundamental principles of the process remain largely the same throughout all of them. The basic CNC machining process includes the following stages:

* Designing the CAD model
* Converting the CAD file to a CNC program
* Preparing the CNC machine
* Executing the machining operation

### CAD Model Design

### The CNC machining process begins with the creation of a 2D vector or 3D solid part CAD design either in-house or by a [CAD/CAM design service company](https://www.thomasnet.com/products/computeraided-cad-cam-designers-22080204-1.html). [Computer-aided design (CAD) software](https://news.thomasnet.com/imt/2003/05/22/the_basics_of_c_2) allows designers and manufacturers to produce a model or rendering of their parts and products along with the necessary technical specifications, such as dimensions and geometries, for producing the part or product.

Designs for CNC machined parts are restricted by the capabilities (or inabilities) of the CNC machine and tooling. For example, most CNC machine tooling is cylindrical therefore the part geometries possible via the CNC machining process are limited as the tooling creates curved corner sections. Additionally, the properties of the material being machined, tooling design, and work holding capabilities of the machine further restrict the design possibilities, such as the minimum part thicknesses, maximum part size, and inclusion and complexity of internal cavities and features.

Once the CAD design is completed, the designer exports it to a CNC-compatible file format, such as STEP or IGES.

#### **CNC Machining Tolerances Tables**

When specifying parts to a machine shop, it's important to include any necessary tolerances. Though CNC machines are very accurate, they still leave some slight variation between duplicates of the same part, generally around + or - .005 in (.127 mm), which is roughly twice the width of a human hair. To save on costs, buyers should only specify tolerances in areas of the part that will need to be especially accurate because they will come into contact with other parts. While there are standard tolerances for different levels of machining (as shown in the tables below), not all tolerances are equal. If, for example, a part absolutely cannot be larger than the measurement, it might have a specified tolerance of +0.0/-0.5 to show it can be slightly smaller, but no larger in that area.

**Additive manufacturing** (AM) or additive layer manufacturing (ALM) is the industrial production name for 3D printing, a computer controlled process that creates three dimensional objects by depositing materials, usually in layers.

**Rapid prototyping**

Rapid prototyping is the fast fabrication of a physical part, model or assembly using [3D computer aided design (CAD)](https://www.techopedia.com/definition/2063/computer-aided-design-cad). The creation of the part, model or assembly is usually completed using [additive manufacturing](https://www.twi-global.com/technical-knowledge/faqs/what-is-additive-manufacturing), or more commonly known as [3D printing](https://www.twi-global.com/technical-knowledge/faqs/what-is-3d-printing).

Where the design closely matches the proposed finished product it is said to be a high fidelity prototype, as opposed to a low fidelity [prototype](https://www.twi-global.com/technical-knowledge/faqs/what-is-prototyping), where there is a marked difference between the prototype and the final product. Rapid prototyping (RP) is a technology and apparatus for fabricating physical objects directly from parts created in CAD using [additive layer manufacturing](https://www.sciencedirect.com/topics/engineering/additive-layer-manufacturing) techniques without [manufacturing process](https://www.sciencedirect.com/topics/engineering/production-process) planning, tooling, or fixtures. Early RP machines were used to produce models and prototype parts; today, they are much more widely used, even for small runs of production-quality parts. Some RP technologies now support microscopic manufacturing, largely in microelectronics as well as in [optoelectronics](https://www.sciencedirect.com/topics/engineering/optoelectronics) fabrication. In this chapter, several major areas of rapid prototyping are introduced, including design, manufacturing, art, medical science, and [bioengineering](https://www.sciencedirect.com/topics/engineering/bioengineering). Overall objectives include (1) a general understanding of RP technology and the various machines available commercially, (2) familiarity with emerging RP and its applications in micro-manufacturing and other fields, and (3) application of basic principles and methods through case studies. Rapid prototyping is still a developing area with many new manufacturing techniques, materials, final treatments, and applications made available every month. For example, some new techniques mix additive and subtractive methods. Rapid prototyping methods are also being used to create final products. Some medical products, such as dental [implants](https://www.sciencedirect.com/topics/engineering/implants), [hearing aids](https://www.sciencedirect.com/topics/engineering/hearing-aid), [stents](https://www.sciencedirect.com/topics/engineering/stent), and parts of prosthetics are already being created through rapid prototyping.

One of the most promising rapid prototyping technologies is Biological Printing. Although not yet in the mainstream, many research labs are pioneering ways to print 3D living tissues. Generally, the process involves printing a [porous scaffold](https://www.sciencedirect.com/topics/engineering/porous-scaffold) of a [biodegradable material](https://www.sciencedirect.com/topics/engineering/biodegradable-material) using a rapid prototyping technique. Cells are deposited onto the scaffold and allowed to adhere to the internal structures. After some time, these cells lay down their own organic scaffold as the printed material slowly degrades. In some more advanced biological prints, it is possible to leave space for blood vessels, cavities, and other biological structures. Biological printing is a developing area that will have an impact on medical device design in the future.

### Rapid Tooling VS Rapid Prototyping

Rapid Tooling is any method or technology that enables rapid production of parts, which will function as a tool (primarily die or mold). In manufacturing industry, one of the most common Rapid Tooling methods - Injection Mold Tooling is utilized as Rapid Tooling channel to produce injection-molded parts quickly and inexpensively.

Rapid Prototyping refers to any method or technology that enables rapid fabrication of a physical part that could be used as a prototype or end-use functional product. Common types of Rapid Prototyping technology are as following:

* (I) Additive Manufacturing (3D printing)
* (II) Subtractive Manufacturing (CNC Machining)

For entrepreneurs or small business looking to get their ideas on the market fast, [Rapid Tooling](https://www.nicerapid.com/what-is-known-by-the-process-of-rapid-tooling-and-its-significant-advantages-a-281.html) and [**Rapid Prototyping**](https://www.nicerapid.com/top-rapid-prototyping-techniques-and-its-benefits-a-411.html)are particularly the best and quickest way for new product development in comparison to conventional manufacturing method.

### Benefits of Rapid Tooling

#### 1. Faster Time to Market

In conventional tooling method, multiple manufacturing processes and techniques might be involved in product development cycle. This may increase the time spending on each step and extend the time from design turning into a real product. Rapid Tooling involves fewer steps than conventional tooling method. Rapid Tooling enables speeding up the whole process. The faster you can get through the prototyping and molding process, the sooner you can finalize your design and get it into the customers’ hand.

#### 2. Lower Cost

The longer time spending on product development cycle, the greater the cost will be. The Rapid Tooling advantage of speed could save your business money over time.

#### 3. Variety of Material Grades

Rapid Tooling allows you to use the actual production grades of material. You can use Rapid Tooling to fabricate custom mold quickly. You can then produce as many prototypes from this mold as you can, creating parts with different material grades and test on their properties. This will allow you to have a clearer picture on which material grade performs best in real world application and allow you to make the correct material selection before launching the new product in the market.

#### 4. Designs and Functionality Testing

Rapid Tooling allows the mold to be fabricated in a short timeframe. Hence, this provides more freedom to test out the new ideas and make design adjustments. The parts can be mechanical tested such as impact and stress testing to explore the design flaws before production. This will massively prevent a lot of issues arisen during the future high volume production stage.

#### 5. Process Parameter Testing

Rapid Tooling can also be used to test the process parameter during production stage. For example, different injection speed and mold temperature for injection molding process will affect the part quality. In this way, the engineers and designers could have more measure control on the final part.

### Choosing the Best Rapid Tooling Process

Although there are a lot of advantages in Rapid Tooling process, Rapid Tooling is not always suited for all projects. One of the drawbacks of Rapid Tooling is precision. Rapid Tooling might not be as precise as conventional tooling. However, it becomes less concern nowadays thanks to the technology advancement in the 3D printing and CNC machining technology, which shows great improvement in precision and accuracy.

Before starting your project, always consult with an experienced manufacturer your requirement and expectation. Main factors that will decide whether Rapid Tooling process is appropriate for you project are as following:

* Project Budget
* Product Development Timeframe
* Part Specification & Tolerances
* Multiple Materials to be tested?
* Mold or Die to be used for large-scale production?

The upfront clear and well communication with manufacturer will help manufacturer determine which process is your best option. It will save you a lot of time and fortune with relatively ease in your project from prototyping stage to manufacturing stage.

# Physics of Welding

* Fusion welding. In fusion welding, two edges or surfaces to be joined are heated to the melting point and, where necessary, molten filler metal is added to fill the joint gap. Due to the high-temperature phase transitions inherent to these processes, a heat-affected zone (HAZ) is created in the material. Fusion welds are created by the coalescence of molten base metals mixed with molten filler metals. Heat for melting is either developed at the intended weld joint or applied to the intended joint from an external source. An example of a means of developing heat at the weld joint is the passing of current through the electrical contact resistance between the contacting surfaces of the materials to be welded. Most fusion welding processes apply heat from an external source to the weld joint to produce the weld bond. Heat is transported from the heat source to the joint by conduction, convection, and radiation. Sources of externally developed heat include electron beams, laser beams, exothermic chemical reactions (used in oxyfuel gas welding and thermite welding), and electric arcs. Electric arcs, the most widely used heat source, are the basis for the various arc welding processes. Fusion welding is used in the manufacture of many everyday items including airplanes, cars, and structures.

Solid-state welding. For solid phase welding, two clean, solid metal surfaces are brought into sufficiently close contact for a metallic bond to be formed. Solid phase welding can be accomplished at temperatures as low as room temperature.  The bonding process is based either on deformation or on diffusion and limited deformation, so that atomic movement (diffusion) creates new bonds between atoms of two surfaces. Forge welding is a solid-state welding technique known for centuries. Many metals can be forge welded, with the most common being both high and low-carbon steels. One of the most popular, ultrasonic welding, is used to connect thin sheets or wires made of metal or thermoplastic by vibrating them at high frequency and under high pressure. Another common process, explosion welding, involves the joining of materials by pushing them together under extremely high pressure. The energy from the impact plasticizes the materials, forming a weld, even though only a limited amount of heat is generated In this section we will focus on **fusion welding**, which is more common than solid-state welding. **Fusion welding** is used in the manufacture of many everyday items including airplanes, cars, and structures. By using a heat source with sufficient power it is possible to fuse through a complete section of very thick plate. The **weld pool** produced is difficult to control and the **heat affected zone (HAZ)** of such welds has a relatively coarse grain, adversely affecting the mechanical properties of the steel. The heat-affected zone (HAZ) is a ring surrounding the weld in which the temperature of the welding process, combined with the stresses of uneven heating and cooling, alter the heat-treatment properties of the alloy. The effects of welding on the material surrounding the weld can be detrimental—depending on the materials used and the heat input of the welding process used, the HAZ can be of varying size and strength. In the weld pool, heat is transported by means of [convection](https://www.nuclear-power.com/nuclear-engineering/heat-transfer/convection-convective-heat-transfer/) and [conduction](https://www.nuclear-power.com/nuclear-engineering/heat-transfer/thermal-conduction/).

Welding is a fabrication process that joins two or more parts by means of high heat, pressure or both. It melts the parts together and allows them to cool, resulting in fusion. Welding is typically used on metals and thermoplastics, but can be used on wood. Filler materials, which are extra pieces of metal, are often used to seal any gaps.

The bond created by welding can withstand all kinds of stresses, such as supporting the body of a car or plane. With welding, the two metals must be similar (i.e. you can’t weld steel to copper). The temperature must be very high to join the two pieces together, yet not too high, as this can change the characteristics of the metal and cause the weld to weaken.

No two welding projects are exactly alike. Different types of welding are used based on materials and desired outcome. There are over 30 different types of welding; however, there are four methods that are most commonly used:

1. [**Gas metal arc welding (GMAW)**](https://www.uti.edu/blog/welding/gmaw-mig-welding): Also known as MIG welding, in GMAW, an electric arc is formed between the metal and a wire electrode, which applies heat to the metal pieces. This fuses and melts the parts together, forming a permanent bond.
2. [**Shielded metal arc welding (SMAW)**](https://www.uti.edu/blog/welding/smaw-shielded-metal-arc-welding): Also known as flux shielded arc welding or sticks welding, SMAW forms the weld with a flux-coated electrode, which is a rod or metal stick held in an electrode holder connected to a power source. Electricity passes through the electrode and touches the base metal, while a gas is formed by the flux that shields the electric arc between the metal being welded and the electrode.
3. [**Flux-cored arc welding (FCAW)**](https://www.uti.edu/blog/welding/flux-core-welding): An electric arc unites a continuous filler metal electrode with the base material. As the welding process happens, the shield gas provided by the flux protects the weld pool from oxidation and other elements in the atmosphere.
4. [**Gas tungsten arc welding (GTAW)**](https://www.uti.edu/blog/welding/tig-welding-gas-tungsten-arc-welding): Also known as TIG welding, GTAW uses a non-consumable tungsten electrode in the welding process. The tungsten and weld puddle are protected and cooled with an inert shielding gas such as argon or helium, and the tungsten electrode heats up the objects in order to form a bond.

##  Brazing in Welding?

Brazing is a process in which metals are joined by melting a filler metal into the joint to create strong permanent bonds. Brazing requires a small joint spacing to allow capillary action to draw the filler metal into the joint when the parts reach the proper phase temperature above 840°F (450°C).

Brazing uses flux to strengthen and improve its mechanical properties. Fluxes used in brazing have three major functions:

* They remove any oxides that form as a result of heating the parts.
* They promote wetting which is the phenomenon whereby a liquid filler metal or flux spreads and adheres in a thin, continuous layer on a solid base metal.
* They aid in capillary action by pulling the molten alloy into the joint
* Flux flowing into a joint reduces oxides to clean the surfaces and gives rise to a capillary action that causes the filler metal to flow behind it. Fluxes are available in many forms, such as solids, powders, pastes, liquids, sheets, rings and washers.
* Flux and filler metal combinations are most convenient and easy to use. Using excessive flux in a joint may result in flux being trapped in the joint, weakening the joint or causing the joint to leak or fail.
* The American Welding Society’s classification system for brazing alloys uses the letter B to indicate that the alloy is to be used for brazing. The following letters indicate the atomic symbol of metals used to make up the alloy, such as CuZn (copper and zinc). There may be a dash followed by a letter or number to indicate a specific alloyed percentage. The letter R may be added to indicate that the braze metal is in rod form.

Unlike welding, brazing can be used to join dissimilar metals, such as gold, silver, copper and nickel. While brazed joints are strong, they are not as strong as welded joints.

## Soldering

## Soldering is a process in which metals are joined by melting a filler metal into the joint to create strong permanent bonds. Soldering may or may not have capillary attraction and is done at a temperature below 840°F, much lower than welding. This process allows for different metals to be soldered, including copper, brass and gold, just naming a few.

Like brazing, soldering uses flux to strengthen and improve its mechanical properties.

Soldering methods are grouped according to the method with which heat is applied: torch, furnace, induction, dipped or resistance. Soldering alloys are usually identified by their major alloying elements. The below chart lists the major types of solder and the materials they will join.

While soldering may seem similar to welding, it serves a different purpose. Typically, a solder is soft and comes in tubes and reels. It’s often used in electronic devices, as it allows the parts to connect electronically. In general, a soldered bond isn’t as strong as one that has been brazed or welded—however, it allows for pieces to conduct electricity.

## Soldering vs Welding

Soldering is classified by the [American Welding Society](http://www.aws.org/) (AWS) as liquid-solid phase bonding processes. Liquid means that the filler metal is melted and solid means that the base material or materials are not melted.

Unlike welding, soldering does not involve melting the work pieces. The main difference between soldering and welding is the heat source. Soldering is applied via torch, furnace, induction, dipped or resistance as heat sources taking place at a temperature below 840°F (450°C), whereas arc welding uses electricity as a heat source reaching temperatures of roughly 10,000 degrees Fahrenheit.

## Brazing vs Welding

Brazing is also classified by the AWS as liquid-solid phase bonding processes. Liquid means that the filler metal is melted, and solid means that the base material or materials are not melted.

Unlike welding, brazing does not involve melting the work pieces. The main difference between brazing and arc welding is the heat source. Brazing is applied via torch, furnace, induction, dipped, or resistance as heat sources occurring at a temperature above 840°F (450°C) whereas arc welding uses electricity as a heat source reaching temperatures of roughly 10,000 degrees Fahrenheit.

## Brazing vs Soldering

The only difference between soldering and brazing is the temperature at which each process takes place. Soldering takes place at a temperature below 840°F (450°C), and brazing occurs at a temperature above 840°F (450°C).

## Advantages of Brazing and Soldering

Some advantages of brazing and soldering as compared to other methods of joining include the following:

* Low temperature
* May be permanently or temporarily joined
* Dissimilar materials can be joined
* Speed of joining
* Less chance of damaging parts
* Slow rate of heating and cooling
* Parts of varying thicknesses can be joined
* Easy realignment

Brazing and soldering are processes that have many great advantages, but are often overlooked when a joining process is being selected. The ability to join many different materials with a limited variety of fluxes and filler metals reduces the need for a large inventory of materials, which can result in great cost savings for a small business, home shop or farm.