

CASTING AND WELDING TECHNOLOGY

Casting Processes

The casting process involves pouring of liquid metal into a mold cavity and allowing it to solidify to obtain the final casting. The flow of molten metal into the mold cavity depends on several factors like minimum section thickness of the part, presence of corners, non-uniform cross-section of the cast, and so on. The casting processes can be broadly classified into expendable mold casting and permanent mold casting processes.

Expendable Mold Casting

Expendable mold casting is a generic classification that includes sand, plastic, shell, plaster, and investment (lost-wax technique) molds. All these methods use temporary, non-reusable molds. After the molten metal in the mold cavity solidifies, the mold is broken to take out the solidified cast. Expendable mold casting processes are suitable for very complex shaped parts and materials with high melting point temperature. However, the rate of production is often limited by the time to make mold rather than the casting itself. The following are a few examples of expendable mold casting processes.

A. *Sand Casting*

Sand casting is widely used for centuries because of the simplicity of the process. The sand casting process involves the following basic steps: (a) place a wooden or metallic pattern in sand to create a mold, (b) fit in the pattern and sand in a gating system, (c) remove the pattern, (d) fill the mold cavity with molten metal, (e) allow the metal to cool, and (f) break the sand mold and remove the casting. The sand casting process is usually economical for small batch size production. The quality of the sand casting depends on the quality and uniformity of green sand material that is used for making the mold. The molten metal is poured through the pouring cup and it fills the mold cavity after passing through downsprue, runner and gate. The core refers to loose pieces which are placed inside the mold cavity to create internal holes or open section. The riser serves as a reservoir of excess molten metal that facilitates additional filling of mold cavity to compensate for volumetric shrinkage during solidification. Sand castings process provides several advantages. It can be employed

for all types of metal. The tooling cost is low and can be used to cast very complex shapes. However, sand castings offer poor dimensional accuracy and surface finish.

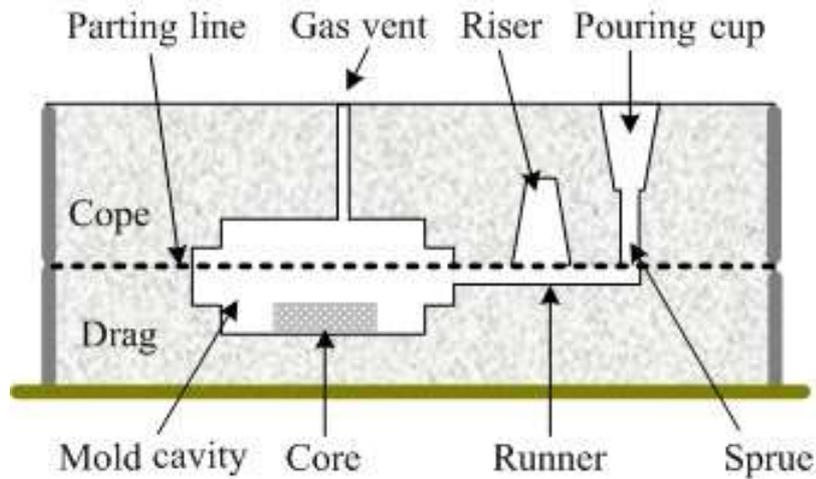


Figure 1: **Schematic set-up of sand molding / casting process**

B. Shell Molding

Shell molding is similar to sand casting. Normally a machined pattern of grey iron or aluminium is used in this process. The pattern is heated to 250°C to 260°C and the sand resin mixture is poured over its surface. The heated pattern melts the resin creating bonds between the sand grains. After a dwell period the pattern and sand inverted and extra sand is cleaned off. The mold cavity is now formed by a hardened shell of sand. The mold is then heated in an oven for further curing. The shell thus formed constitutes one half of the mold. Two such halves are placed over one another to make the complete mold. The sands used in shell molding process are usually finer than the same used in sand casting. This process is ideal for complex shaped medium sized parts. This method can be employed for making an integrate shapes, thin and sharp corners small projection which are not possible in green sand mold. Subsequent machining operations are also reduced due to more dimensional accuracy.

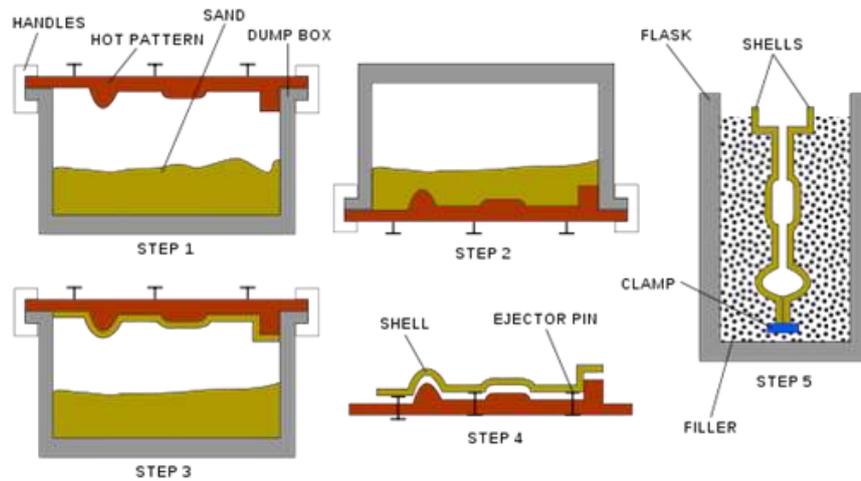


Figure 2: Schematic set-up of shell mold casting process

C. Investment Casting

Investment casting is also referred to as lost-wax casting since the pattern is made of wax. The wax patterns are first dipped into a slurry of refractory material and subsequently, heated so that the wax melts away keeping a refractory mold. The mold is then further cured to achieve proper strength. Very high melting temperature material can be cast in investment casting process because of the refractory mold. The molten metal is poured into the mold and is taken out after solidification by breaking the mold. Very high dimensional accuracy and surface finish can be achieved in investment casting process. However, the tooling cost is usually high and hence, investment casting process is primarily used for large size batch production or for specific requirements of complex shape or casting of very high melting temperature material.

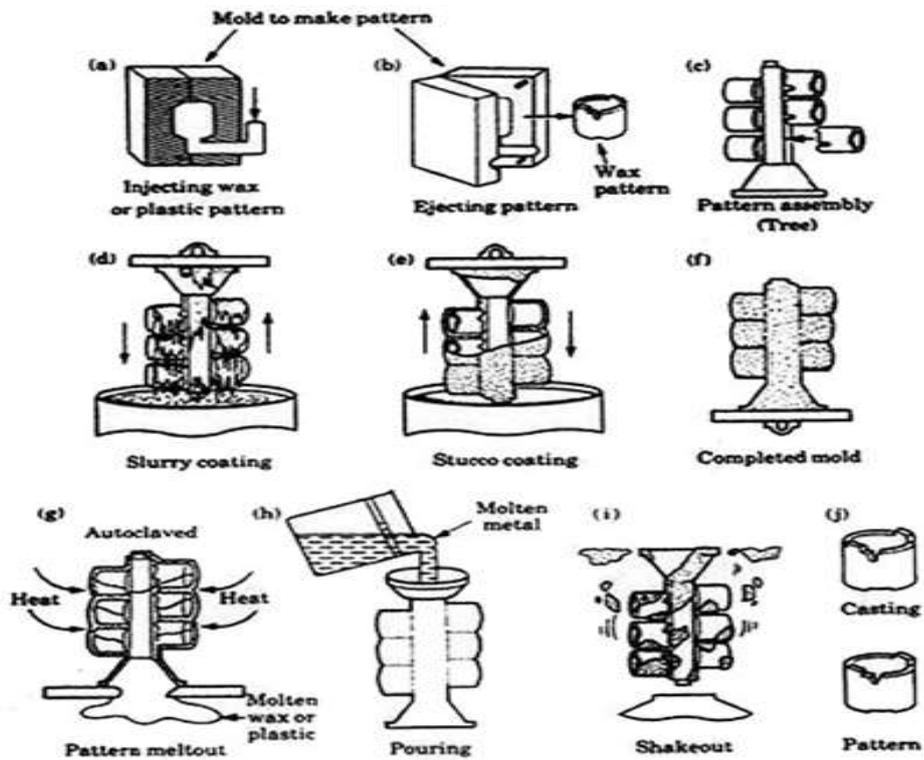


Figure 3: Schematic set-up of and sequences involved in investment casting process

D. Vacuum Casting

In this process, a mixture of fine sand and urethane is molded over metal dies and cured with amino vapour. The molten metal is drawn into the mold cavity through a gating system from the bottom of the mold. The pressure inside the mold is usually one-third of the atmospheric pressure. Because the mold cavity is filled under vacuum, the vacuum casting process is very suitable for thin walled, complex shapes with uniform properties.

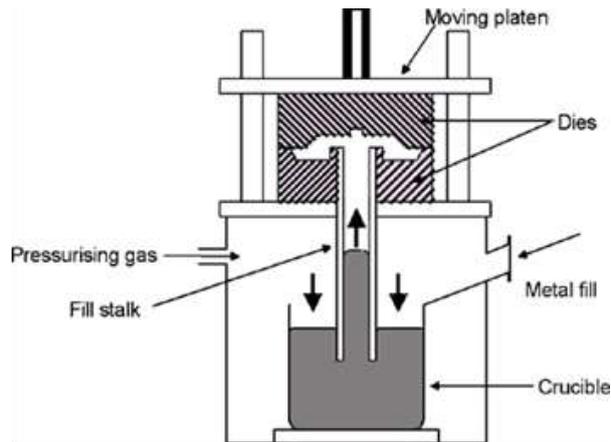


Figure 4: **Schematic set-up of vacuum casting process**

E. Plaster mold casting

Plaster mold casting, also called rubber plaster molding (RPM), is a method of producing aluminum or zinc castings by pouring liquid metal into typical plaster (gypsum) molds. The plaster molds used as negative molds are created from gypsum and water. After mixing and forming the mold shape, the plaster molds are dried and baked in an oven to remove any water remaining in the mold. Often, the molds are made in two halves – i.e. cope and drag molds – and the halves of the plaster molds are clamped together with any required cores positioned appropriately in the mold. Molten metal is subsequently poured into the negative plaster mold and allowed to dry. The final part is taken out after breaking the mold. The final cast may require machining operation depending upon the requisite dimensional accuracy. This process is often used for producing prototypes of final part or component.

F. Ceramic mold casting

The ceramic mold casting is used to produce split molds from a quick-setting ceramic investment. Blended ceramic particles are mixed rapidly with liquid binder to form free flowing slurry that is poured quickly over a pattern. The casting does not require wax patterns and there are no limits to size or alloy. Foundry applications are large and complex impellers, valve bodies, and military hardware. The green strength of ceramic mold casting is high. Ceramic mold casting method uses a ceramic slurry prepared by mixing fine grained

refractory powders of Zircon ($ZrSiO_4$), Alumina (Al_2O_3), Fused Silica (SiO_2) and a liquid chemical binder (Alcohol based Silicon Ester) for making the mold.

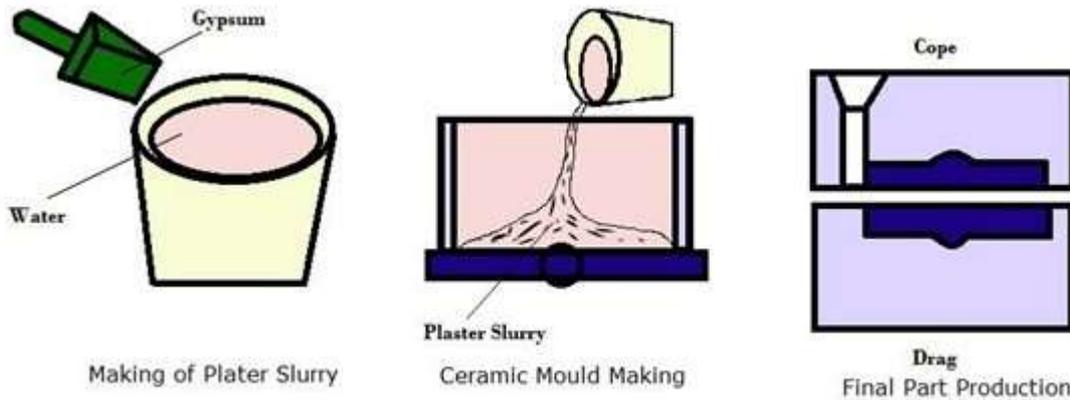


Figure 5: Ceramic mold casting process

Permanent Mold Casting processes

Permanent mold casting processes involve the use of metallic dies that are permanent in nature and can be used repeatedly. The metal molds are also called dies and provide superior surface finish and close tolerance than typical sand molds. The permanent mold casting processes broadly include pressure die casting, squeeze casting, centrifugal casting, and continuous casting.

1. Pressure die casting

The pressure die casting process is the most common for Al, Zn and Mg castings (low melting point). The liquid metal is injected into the mold under high pressure and allowed to solidify at the high pressure. The solidified cast is then taken out of the mold or the die which is ready for the next cast. Pressure die casting is suitable for large batch size production. Two types of pressure die casting are generally common in the industry – (a) high pressure die casting and (b) low pressure die casting. Very high production rates can be achieved in pressure die casting process with close dimensional control of the casting. However, the process is not suitable for casting of high melting temperature materials as the die material has to withstand the melting (or superheated) temperature of the casting. Pressure die castings

also contain porosity due to the entrapped air. Furthermore, the dies in the pressure die casting process are usually very costly.

The schematic below presents the hot-chamber and the cold-chamber die casting processes. In the hot-chamber die casting process, the furnace to melt material is part of the die itself and hence, this process is suitable primarily for low-melting point temperature materials such as aluminum, magnesium etc.

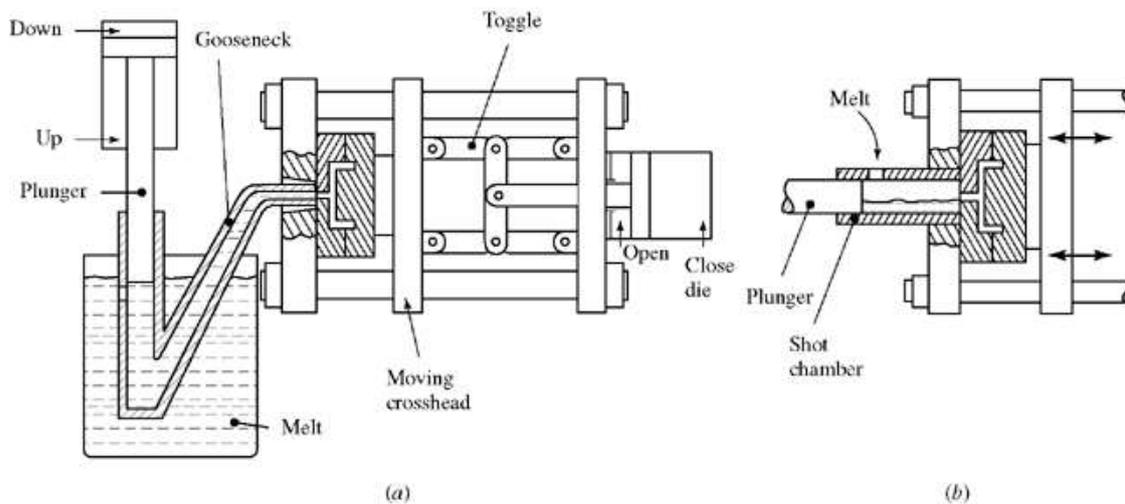


Figure 6: Set-up of (a) hot-chamber and (b) cold-chamber die casting processes

2. Squeeze casting

Molten metal is poured into a metallic mold or die cavity with one-half of the die squeezing the molten metal to fill in the intended cavity under pressure. Fibre-reinforced casting with SiC or Al₂O₃ fibers mixed in metal matrix have been successfully used in squeeze cast and commercially used to produce automobile pistons. However, squeeze casting is limited only to shallow part or part with smaller dimensions.

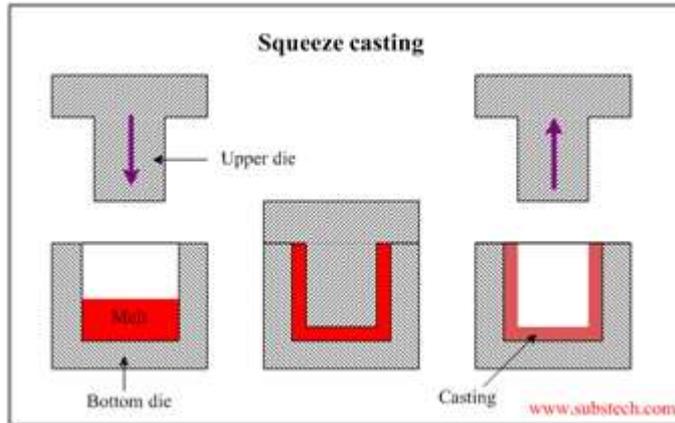


Figure 7: **Schematic set-up of squeeze casting process**

3. Centrifugal casting

In centrifugal casting process, the molten metal is poured at the centre of a rotating mold or dies. Because of the centrifugal force, the lighter impurities are crowded towards the centre of the case. For producing a hollow part, the axis of rotation is placed at the center of the desired casting. The speed of rotation is maintained high so as to produce a centripetal acceleration of the order of 60g to 75g. The centrifuge action segregates the less dense non-metallic inclusions near to the center of rotation that can be removed by machining a thin layer. No cores are therefore required in casting of hollow parts although solid parts can also be cast by this process. The centrifugal casting is very suitable for axisymmetric parts. Very high strength of the casting can be obtained. Since the molten metal is fed by the centrifugal action, the need for complex metal feeding system is eliminated. Both horizontal and vertical centrifugal castings are widely used in the industry.

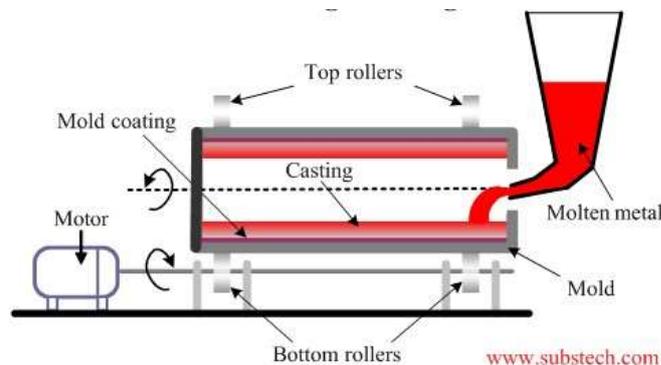


Figure 8: **Schematic set-up of horizontal centrifugal casting process**



Figure 9: **Metallic pipes made using centrifugal casting process**

4. *Continuous casting*

Continuous casting process is widely used in the steel industry. In principle, continuous casting is different from the other casting processes in the fact that there is no enclosed mold cavity. Molten steel coming out from the furnace is accumulated in a ladle. After undergoing requisite ladle treatments, such as alloying and degassing, and arriving at the correct temperature, the ladle is transported to the top of the continuous casting set-up. From the ladle, the hot metal is transferred via a refractory shroud (pipe) to a holding bath called a tundish. The tundish allows a reservoir of metal to feed the casting machine. Metal is then allowed to pass through a open base copper mold. The mold is water-cooled to solidify the hot metal directly in contact with it and removed from the other side of the mold. The continuous casting process is used for casting metal directly into billets or other similar shapes that can be used for rolling. The process involves continuously pouring molten metal into an externally chilled copper mold or die walls and hence, can be easily automated for large size production. Since the molten metal solidifies from the die wall and in a soft state as it comes out of the die wall such that the same can be directly guided into the rolling mill or can be sheared into a selected size of billets.

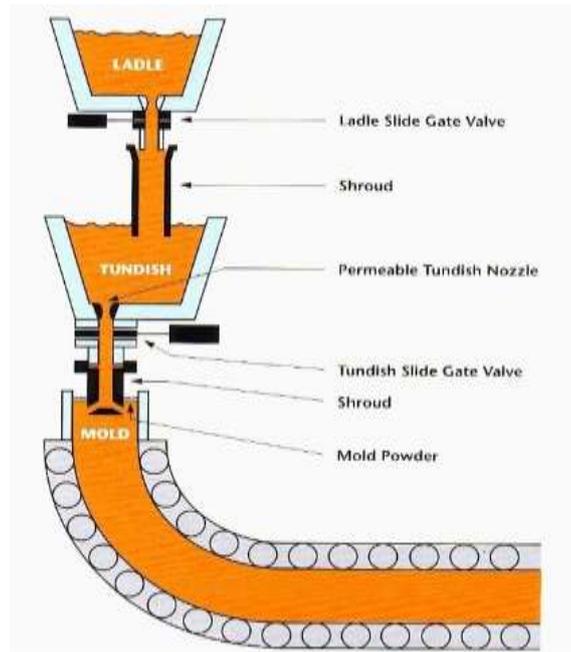


Figure 10: **Schematic set-up of continuous casting processes**

Defects in Casting Processes

The figure below schematically shows various defects that are experienced during casting, in particular, sand casting processes. A brief explanation of some of the significant defects and their possible remedial measures are indicated in the text to follow.

1. Shrinkage

Shrinkage of molten metal as it solidifies is an important issue in casting. It can reduce the 5-10% volume of the cast. Gray cast iron expands upon solidification due to phase changes. Need to design part and mold to take this amount into consideration. The thickness of the boss or pad should be less than the thickness of the section of the boss adjoins and the transition should be gradual. The radius for good shrinkage control should be from one half to one third of the section thickness. Shrinkage defect can be reduced by decreasing the number of walls and increasing the draft angle.

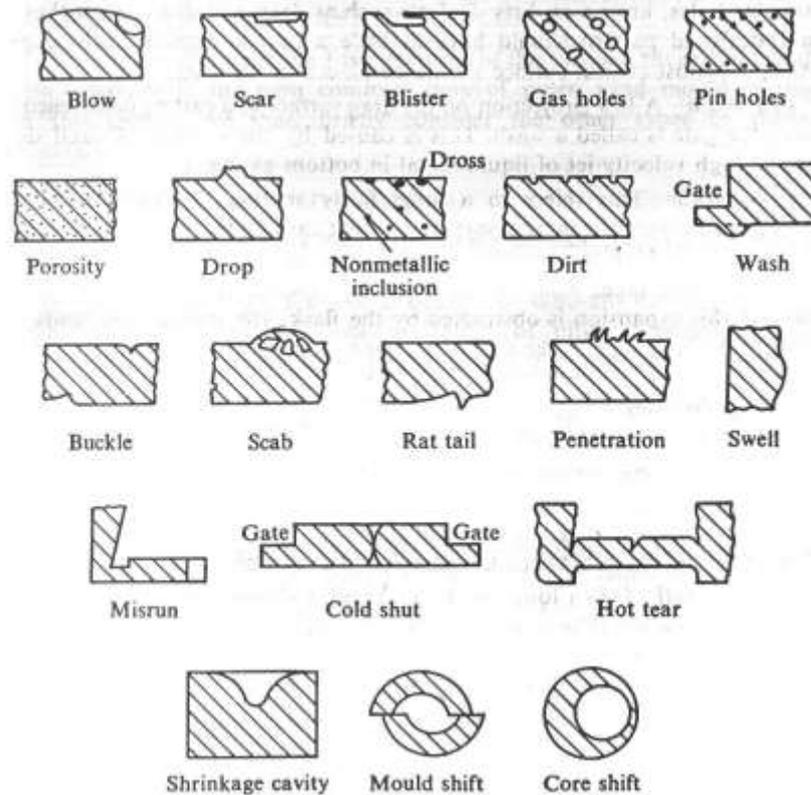


Figure 11: **Schematic pictorial presentation of various casting defects**

2. Porosity

Porosity is a phenomenon that occurs in materials, especially castings, as they change state from liquid to solid during the manufacturing process. Casting porosity has the form of surface and core imperfections which either affects the surface finish or as a leak path for gases and liquids. The poring temperature should be maintained properly to reduce porosity. Adequate fluxing of metal and controlling the amount of gas-producing materials in the molding and core making sand mixes can help in minimizing this defect.

3. Hot tear

Hot tears are internal or external ragged discontinuities or crack on the casting surface, caused by rapid contraction occurring immediately after the metal solidified. They may be

produced when the casting is poorly designed and abrupt sectional changes take place; no proper fillets and corner radii are provided, and chills are inappropriately placed. Hot tear may be caused when the mold and core have poor collapsibility or when the mold is too hard causing the casting to undergo severe strain during cooling. Incorrect pouring temperature and improper placement of gates and risers can also create hot tears. Method to prevent hot tears may entail improving the casting design, achieving directional solidification and even rate of cooling all over, selecting proper mold and poured materials to suit the cast metal, and controlling the mold hardness in relation to other ingredients of sand.

4. Scar

It is usually found on the flat casting surface. It is a shallow blow.

5. Blowhole

Blowholes are smooth round holes that are clearly perceptible on the surface of the casting. To prevent blowholes, moisture content in sand must be well adjusted, sand of proper grain size should be used, ramming should not be too hard and venting should be adequate.

6. Blister

This is a scar covered by the thin layers of the metal.

7. Dross

The lighter impurities appearing on the top of the cast surface is called the dross. It can be taken care of at the pouring stage by using items such as a strainer and a skim bob.

8. Dirt

Sometimes sand particles dropping out of the cope get embedded on the top surface of a casting. When removed, these leave small angular holes is known as dirt.

9. Wash

It is a low projection on the drag surface of a casting commencing near the gate. It is caused by the erosion of sand due to high velocity liquid metal.

10. Buckle

It refers to a long fairly shallow broad depression at the surface of a casting of a high temperature metal. Due to very high temperature of the molten metal, expansion of the thin layered of the sand at the mold face takes place. As this expansion is obstructed by the flux, the mold tends to bulge out forming a V shape.

11. Rat tail

It is a long shallow angular depression found in a thin casting. The cause is similar to buckle.

12. Shift

A shift results in a mismatch of the sections of a casting usually as a parting line. Misalignment is common cause of shift. This defect can be prevented by ensuring proper alignment of the pattern for die parts, molding boxes, and checking of pattern flux locating pins before use.

13. Warped casting

Warping is an undesirable deformation in a casting which occurs during or after solidification. Large and flat sections are particularly prone to wrap edge. Wrap edge may also be due to insufficient gating system that may not allow rapid pouring of metal or due to low green strength of the sand mold or inadequate / inappropriate draft allowance in the pattern / mold cavity.

14. Metal Penetration and Rough Surfaces

This defect appears as an uneven and rough external surface of the casting. It may be caused when the sand has too high permeability, large grain size, and low strength. Soft ramming may also cause metal penetration.

15. Fin

A thin projection of metal, not intended as a part of casting, is called a fin. Fins occur at the parting of the mold or core sections. Molds and cores in correctly assembled will cause the fin. High metal pressures due to too large downsprue, insufficient weighing of the molds or improper clamping of flasks may again produce the fin defect.

16. Cold Shut and Mis-Run

A cold shut is a defect in which a discontinuity is formed due to the imperfect fusion of two streams of metal in the mold cavity. The reasons for cold shut or mis-run may be too thin sections and wall thickness, improper gating system, damaged patterns, slow and intermittent pouring, poor fluidity of metal caused by low pouring temperature, improper alloy composition, etc.

Inspections of Casting

1. Visual Inspection

Visible defects that can be detected provide a means for discovering errors in the pattern equipment or in the molding and casting process. Visual inspection may prove inadequate only in the detection of sub surface or internal defects.

2. Dimensional Inspection

Dimensional inspection is one of the important inspections for casting. When precision casting is required, we make some samples for inspection the tolerance, shape size and also measure the profile of the cast. This dimensional inspection of casting may be conducted by various methods:

- Standard measuring instruments to check the size of the cast.
- Contour gauges for the checking of profile, curves and shapes
- Coordinate measuring and Marking Machine
- Special fixtures X-Ray Radiography

In all the foundries the flaw detection test are performed in the casting where the defects are not visible. This flaw detection test is usually performed for internal defects, surface defects etc. These tests are valuable not only in detecting but even in locating the casting defects present in the interior of the casting. Radiography is one of the important flaw detection test for casting. The radiation used in radiography testing is a higher energy (shorter wavelength) version of the electromagnetic waves that we see as visible light. The radiation can come from an X-ray generator or a radioactive source.

3. Magnetic Particle Inspection

This test is used to reveal the location of cracks that extend to the surface of iron or steel castings, which are magnetic in nature. The casting is first magnetized and then iron particles are sprinkled all over the path of the magnetic field. The particles align themselves in the direction of the lines of force. A discontinuity in the casting causes the lines of the force to bypass the discontinuity and to concentrate around the extremities of the defect.

4. Fluorescent Dye-penetration Test

This method is very simple and applied for all cast metals. It entails applying a thin penetration oil-base dye to the surface of the casting and allowing it to stand for some time so that the oil passes into the cracks by means of capillary action. The oil is then thoroughly wiped and cleaned from the surface. To detect the defects, the casting is painted with a coat of whitewash or powdered with tale and then viewed under ultraviolet light. The oil being fluorescent in nature, can be easily detect under this light, and thus the defects are easily revealed.

5. Ultrasonic Testing

Ultrasonic testing used for detecting internal voids in casting is based on the principle of reflection of high frequency sound waves. If the surface under test contains some defect, the high frequency sound waves when emitted through the section of the casting, will be reflected from the surface of defect and return in a shorter period of time. The advantage this method of testing over other methods is that the defect, even if in the interior, is not only detected and located accurately, but its dimension can also be quickly measured without in any damaging or destroying the casting.

6. Fracture Test

Fracture test is done by examining a fracture surface of the casting. it is possible to observe coarse graphite or chilled portion and also shrinkage cavity, pin hole etc. The apparent soundness of the casting can thus be judged by seeing the fracture.

7. Macro-etching Test (macroscopic examination)

The macroscopic inspection is widely used as a routine control test in steel production because it affords a convenient and effective means of determining internal defects in the metal. Macro- etching may reveal one of the following conditions:

- Crystalline heterogeneity, depending on solidification
- Chemical heterogeneity, depending on the impurities present or localized segregation and
- Mechanical heterogeneity, depending on strain introduced on the metal, if any.

8. Sulphur Print test

Sulphur may exist in iron or steel in one of two forms; either as iron sulphide or manganese sulphide. The distribution of sulphur inclusions can easily be examined by this test.

9. Microscopic Examination

Microscopic examination can enable the study of the microstructure of the metal alloy, elucidating its composition, the type and nature of any treatment given to it, and its mechanical properties. In the case of cast metals, particularly steels, cast iron, malleable iron, and SG iron, microstructure examination is essential for assessing metallurgical structure and composition. Composition analysis can also be done using microscopic inspection. Distribution of phase can be observed by metallographic sample preparation of cast product. Grain size and distribution, grain boundary area can be observed by this procedure. Distribution of non-metallic inclusion can also be found from this process of inspection.

10. Chill Test

Chill test offers a convenient means for an approximate evaluation of the graphitizing tendency of the iron produced and forms an important and quick shop floor test for ascertaining whether this iron will be of the class desired. In chill test, accelerated cooling rate is introduced to induce the formation of a chilled specimen of appropriate dimension. It is then broken by striking with a hammer in such a manner that the fracture is straight and midway of its length. The depth of chill obtained on the test piece is affected by the carbon

and silicon present and it can therefore be related to the carbon equivalent, whose value in turn determines the grade of iron.

Design Recommendations for Casting

1. Compensate the shrinkage of the solidified molten metal by making patterns of slightly oversize.
2. In sand casting, it is more economical and accurate if the parting line is on a flat plane. Contoured parting lines are not economical. Further, some degree of taper, or draft is recommended to provide to the pattern for its easy removal. The recommended draft angles for patterns under various conditions are given elsewhere.
3. In sand casting, it is recommended to attach the riser near to the heavier section. The thinnest sections are farthest from the riser and solidify first and then the solidification proceeds toward the direction of riser i.e. towards the heavier section.
4. Sharp corners in a casting design cause uneven cooling and lead to formation of hot spots in the final cast structure. Moreover sharp corner in a casting structure acts as a stress raiser. Rounding the corner decreases the severity of the hot spot and lessens the stress concentration.
5. Abrupt changes in sections should be avoided. Fillets and tapers are preferable to sharp steps.
6. The interior walls and sections are recommended to be 20% thinner than the outside members to reduce the thermal and residual stresses, and metallurgical changes.
7. When a hole is placed in a highly stressed section, add extra material around the hole as reinforcement.
8. To minimize the residual stresses in the gear, pulley or wheel casting, a balance between the section size of the rim, spokes and hub is maintained.
9. An odd number of curved wheel spokes reduce cast-in-residual stresses.

10. Similar to sand casting, permanent mold castings also require draft for the easy withdrawal of the casting from the mold. The recommended draft angles are given elsewhere.

11. Due to pattern shrinkage, investment shrinkage and metal shrinkage during solidification, there is always a tendency for an investment part to “dish” (develop concave surfaces where flat surfaces are specified). This condition takes place in areas of thick cross section. Dishing is minimized by designing parts with uniformly thin walls.

INTRODUCTION TO WELDING

In the Navy as well as private industry, welding is widely used by metal workers in the fabrication and repair of parts and structures. While there are many methods for joining metals, welding is one of the most convenient and rapid methods available.

The term welding refers to the process of joining metals by heating them to their melting temperature and causing the molten metal to flow together. These range from simple steel brackets to nuclear reactors.

Welding, like any skilled trade, is broad in scope and you cannot become a welder simply by reading a book. You need practice and experience as well as patience; however, much can be gained through study. For instance, by learning the correct method or procedure for accomplishing a job from a book, you may eliminate many mistakes that otherwise would occur through trial and error.

A *weld* is made when separate pieces of material to be joined combine and form one piece when heated to a temperature high enough to cause softening or melting. Filler material is typically added to strengthen the joint.

Welding is a dependable, efficient and economic method for permanently joining similar metals. In other words, you can weld steel to steel or aluminum to aluminum, but you cannot weld steel to aluminum using traditional welding processes.

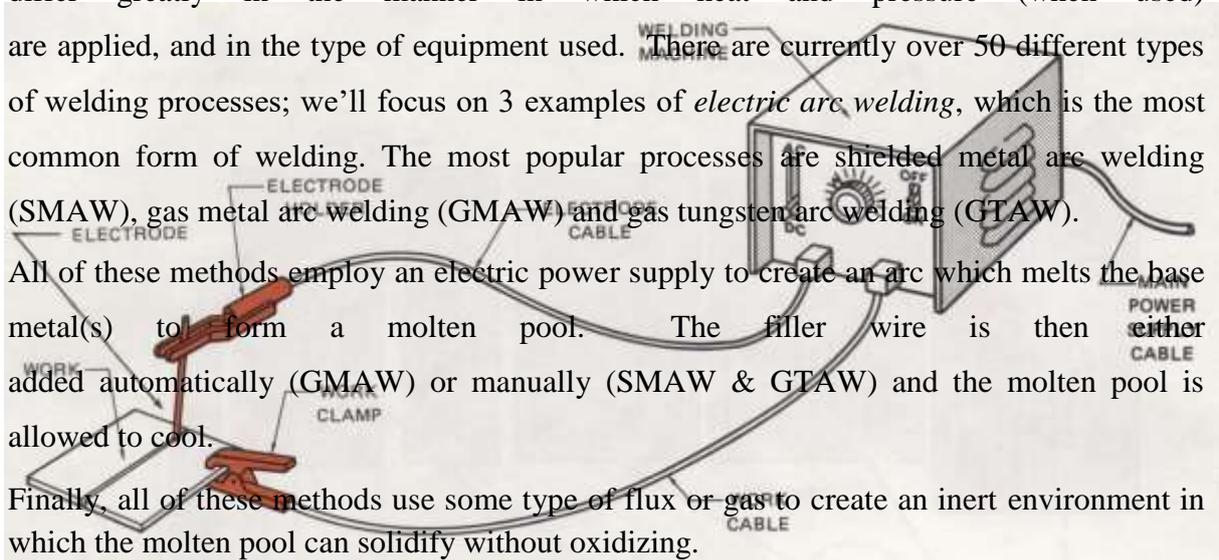
Welding is used extensively in all sectors of manufacturing, from earth moving equipment to the aerospace industry.

Welding Processes

The number of different welding processes has grown in recent years. These processes differ greatly in the manner in which heat and pressure (when used) are applied, and in the type of equipment used. There are currently over 50 different types of welding processes; we'll focus on 3 examples of *electric arc welding*, which is the most common form of welding. The most popular processes are shielded metal arc welding (SMAW), gas metal arc welding (GMAW) and gas tungsten arc welding (GTAW).

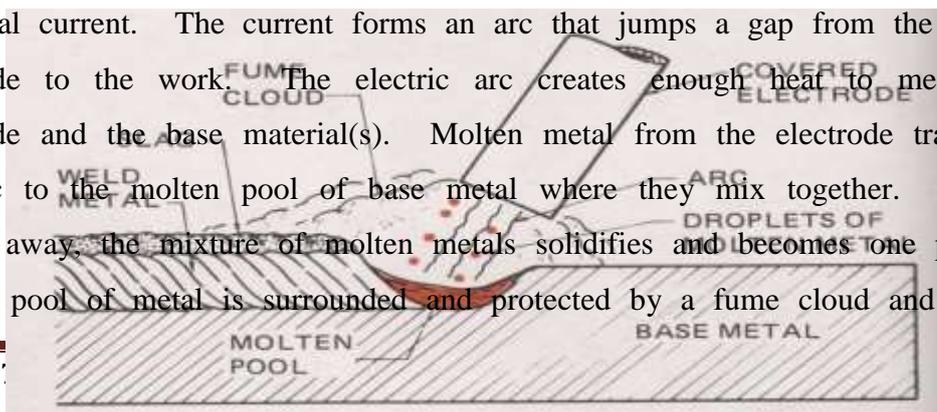
All of these methods employ an electric power supply to create an arc which melts the base metal(s) to form a molten pool. The filler wire is then either added automatically (GMAW) or manually (SMAW & GTAW) and the molten pool is allowed to cool.

Finally, all of these methods use some type of flux or gas to create an inert environment in which the molten pool can solidify without oxidizing.



Shielded Metal Arc Welding (SMAW)

SMAW is a welding process that uses a flux covered metal electrode to carry an electrical current. The current forms an arc that jumps a gap from the end of the electrode to the work. The electric arc creates enough heat to melt both the electrode and the base material(s). Molten metal from the electrode travels across the arc to the molten pool of base metal where they mix together. As the arc moves away, the mixture of molten metals solidifies and becomes one piece. The molten pool of metal is surrounded and protected by a fume cloud and a covering

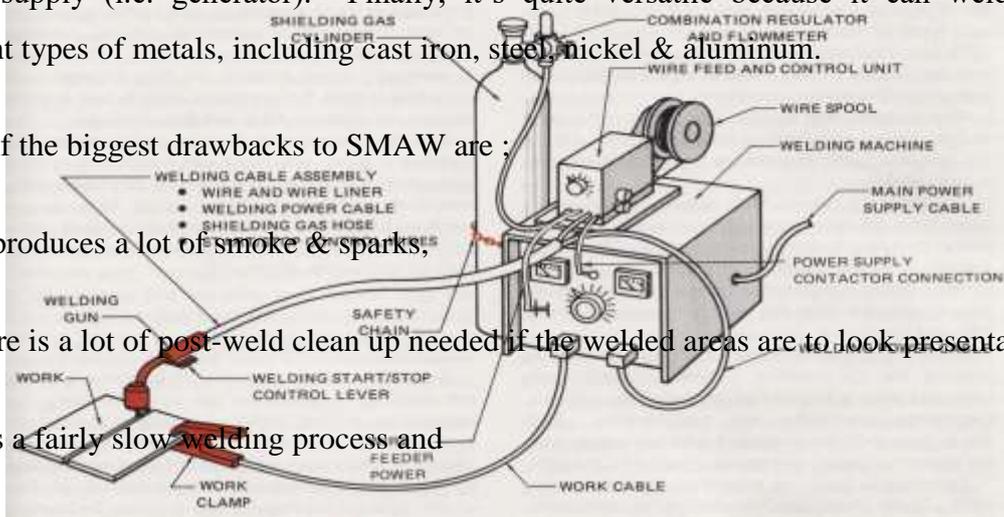


of slag produced as the coating of the electrode burns or vaporizes. Due to the appearance of the electrodes, SMAW is commonly known as 'stick' welding.

SMAW is one of the oldest and most popular methods of joining metal. Moderate quality welds can be made at low speed with good uniformity. SMAW is used primarily because of its low cost, flexibility, portability and versatility. Both the equipment and electrodes are low in cost and very simple. SMAW is very flexible in terms of the material thicknesses that can be welded (materials from 1/16" thick to several inches thick can be welded with the same machine and different settings). It is a very portable process because all that's required is a portable power supply (i.e. generator). Finally, it's quite versatile because it can weld many different types of metals, including cast iron, steel, nickel & aluminum.

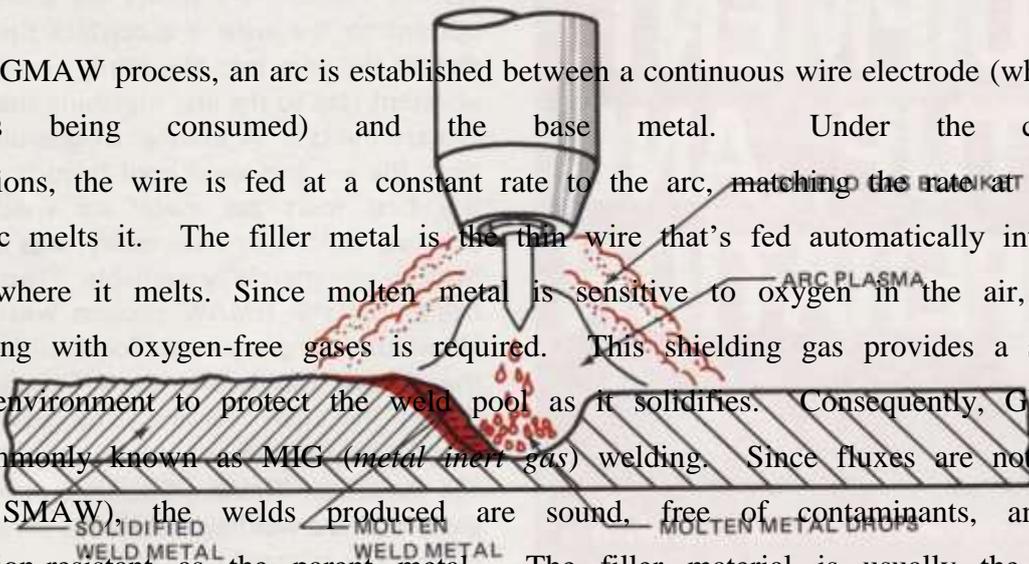
Some of the biggest drawbacks to SMAW are :

- (1) it produces a lot of smoke & sparks,
- (2) there is a lot of post-weld clean up needed if the welded areas are to look presentable,
- (3) it is a fairly slow welding process and
- (4) it requires a lot of operator skill to produce consistent quality welds.

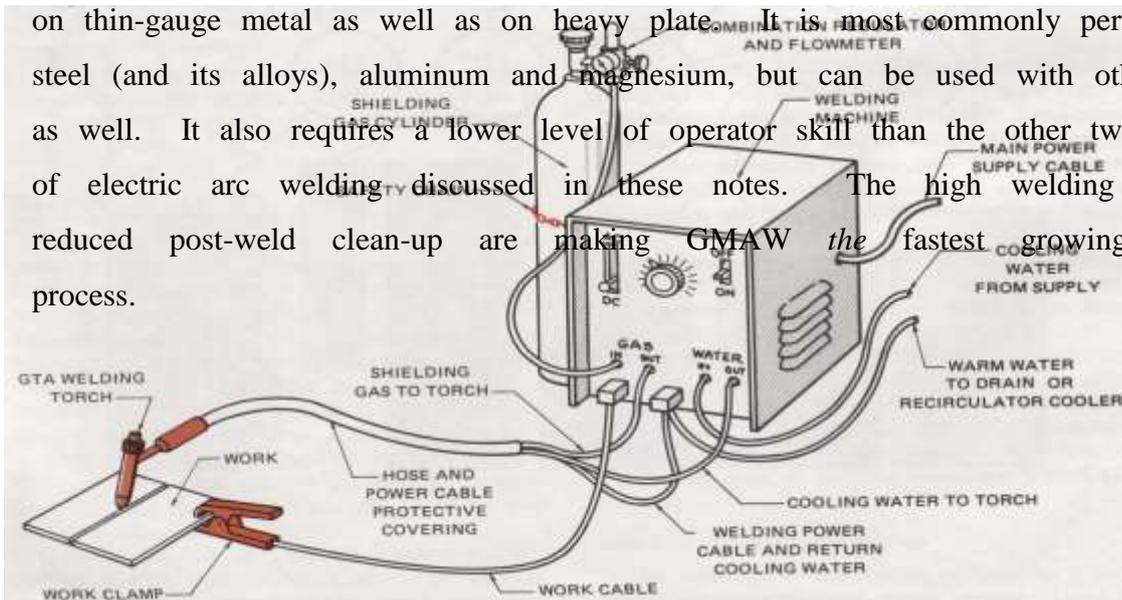


Gas Metal Arc Welding (GMAW)

In the GMAW process, an arc is established between a continuous wire electrode (which is always being consumed) and the base metal. Under the correct conditions, the wire is fed at a constant rate to the arc, matching the rate at which the arc melts it. The filler metal is the thin wire that's fed automatically into the pool where it melts. Since molten metal is sensitive to oxygen in the air, good shielding with oxygen-free gases is required. This shielding gas provides a stable, inert environment to protect the weld pool as it solidifies. Consequently, GMAW is commonly known as MIG (*metal inert gas*) welding. Since fluxes are not used (like SMAW), the welds produced are sound, free of contaminants, and as corrosion-resistant as the parent metal. The filler material is usually the same composition (or alloy) as the base metal.

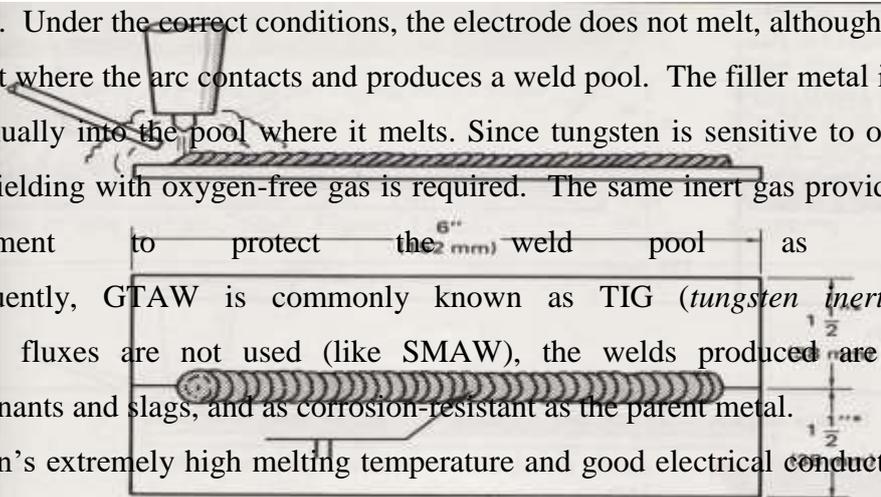


GMAW is extremely fast and economical. This process is easily used for welding on thin-gauge metal as well as on heavy plate. It is most commonly performed on steel (and its alloys), aluminum and magnesium, but can be used with other metals as well. It also requires a lower level of operator skill than the other two methods of electric arc welding discussed in these notes. The high welding rate and reduced post-weld clean-up are making GMAW the fastest growing welding process.



Gas Tungsten Arc Welding (GTAW)

In the GTAW process, an arc is established between a tungsten electrode and the base metal(s). Under the correct conditions, the electrode does not melt, although the work does at the point where the arc contacts and produces a weld pool. The filler metal is thin wire that's fed manually into the pool where it melts. Since tungsten is sensitive to oxygen in the air, good shielding with oxygen-free gas is required. The same inert gas provides a stable, inert environment to protect the weld pool as it solidifies. Consequently, GTAW is commonly known as TIG (*tungsten inert gas*) welding. Because fluxes are not used (like SMAW), the welds produced are sound, free of contaminants and slags, and as corrosion-resistant as the parent metal. Tungsten's extremely high melting temperature and good electrical conductivity make it the best choice for a non-consumable electrode. The arc temperature is typically around 11,000° F. Typical shielding gasses are Ar, He, N, or a mixture of the two. As with GMAW, the filler material usually is the same composition as the base metal.



GTAW is easily performed on a variety of materials, from steel and its alloys to aluminum, magnesium, copper, brass, nickel, titanium, etc. Virtually any metal that is conductive lends itself to being welded using GTAW. Its clean, high-quality welds often require little or no post-weld finishing. This method produces the finest, strongest welds out of all the welding processes.

Selection of the welding process

The selection of the joining process for a particular job depends upon many factors. There is no one specific rule governing the type of welding process to be selected for a certain job. A few of the factors that must be considered when choosing a welding process are:

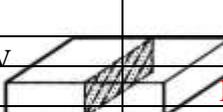
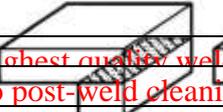
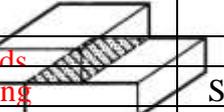
- Availability of equipment
- Repetitiveness of the operation
- Quality requirements (base metal penetration, consistency, etc.)
- Location of work
- Materials to be joined
- Appearance of the finished product
- Size of the parts to be joined
- Time available for work
- Skill experience of workers
- Cost of materials
- Code or specification requirements

General guidelines for selecting one process over another

When selecting one process over the others, it is often useful to examine the principal pros/cons of each type of welding covered in this lecture:

Welding Process	Advantages	Disadvantages
SMAW	Cheap	Major post-weld cleaning
	Portable (no gas required)	Relatively 'dirty' method of welding (sparks/fumes)
	Versatile (can weld various metals & thicknesses)	Requires moderate skill
GMAW	Fastest of all 3 processes	Requires shielding gas
	Versatile (can weld various metals & thicknesses)	Minor post-weld cleaning

STANDARD WELD JOINTS

GTAW			
		<p>Highest quality welds No post-weld cleaning</p>	<p>Requires shielding gas Slowest of all 3 processes</p>
A. BUTT JOINT	B. CORNER JOINT	C. LAP JOINT	Requires high degree of operator skill

Versatile (can weld various metals & thicknesses)

Examples of Welds

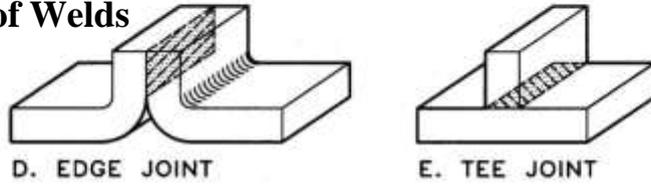


Photo 1. Stick Welding Mild Steel Square Tubing

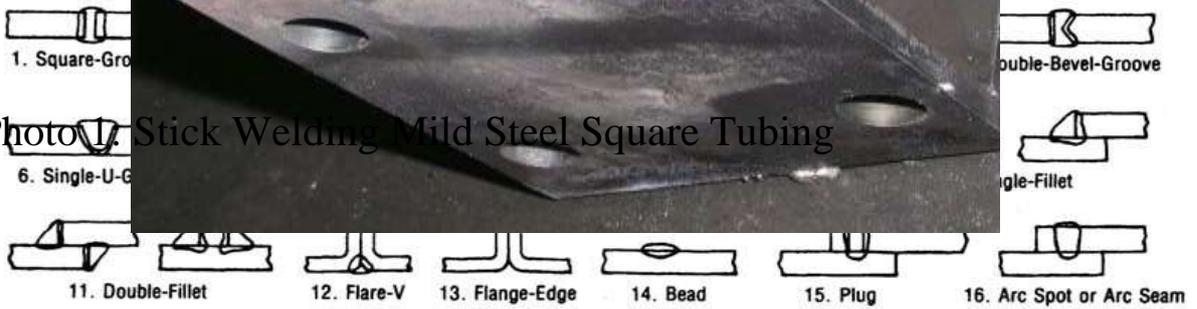




Photo 2: Fillet MIG Weld

Photo 3: U Groove MIG Weld

