

Manufacturing Processes and Defects

Materials and Introduction to Processing

ACMA4000

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[1] Introduction:

Metals are incredibly versatile materials, having a large range of uses throughout the world. With so many metals and uses there comes a multitude of ways to get a desired metal to be in the shape and have the required properties, and since metals are indisputably the most useful materials, it should be common practice for an engineer to be familiar with them and the ways metals are fabricated. This report will detail three metal fabrication techniques, one forming operation, one casting technique and an uncategorised technique, the techniques discussed in this report are as follows:

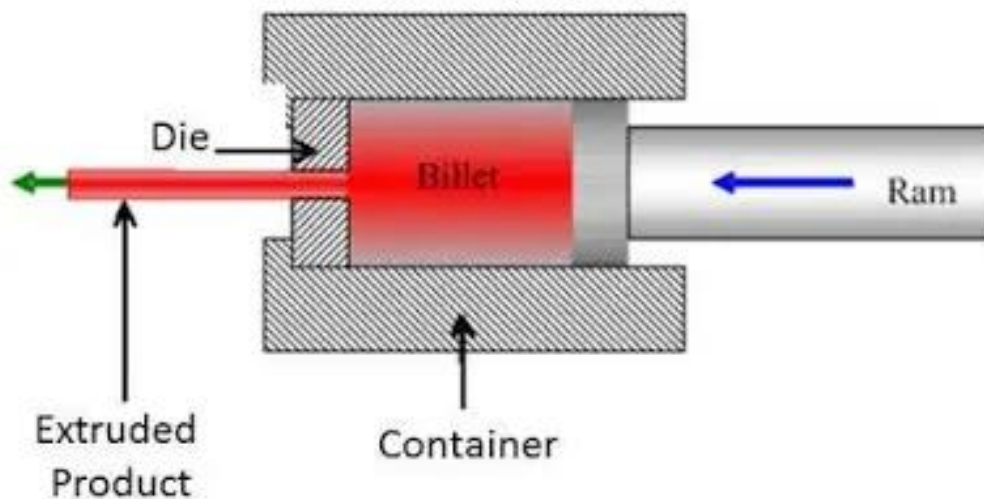
Forming Operation:	Extrusion Forming
Casting Technique:	Die Casting
Miscellaneous:	Welding

Each of the above fabrication processes will have different effects on the metals structure and properties and will be discussed and showcased further into the report.

[2] Extrusion Forming:

[2.1] What is Extrusion Forming:

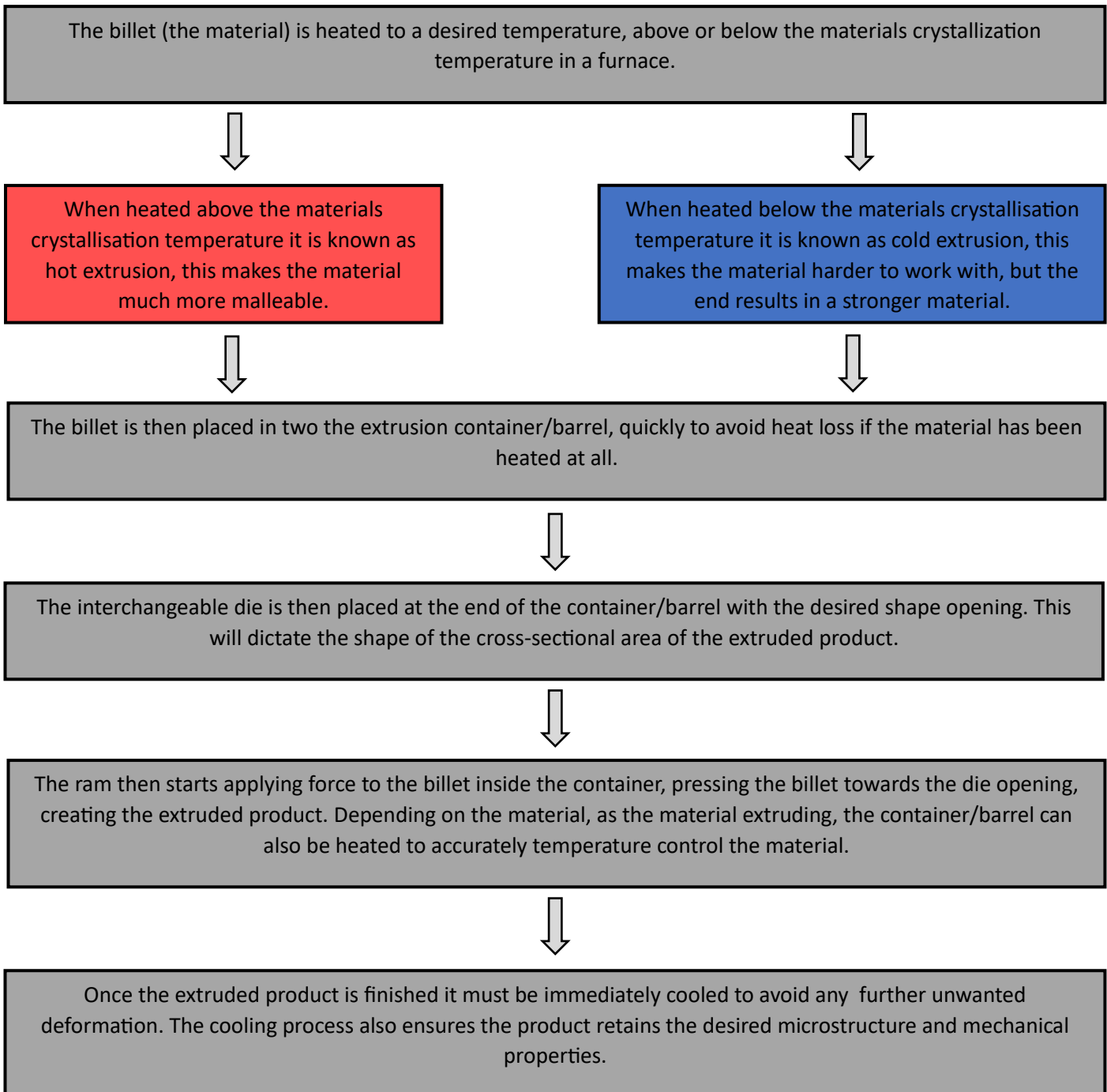
Extrusion is a process where a piece of material is pressed with a large amount of force to change its shape, resulting in deformation of the material with minimal risk of breaking. The following image, *'figure 1'*, is a great example of extrusion to better visualise the process as it is the common method of extrusion.



'Figure 1': simplified diagram of the extrusion process.

When referring to extrusion forming, it will nearly exclusively be about direct extrusion as seen in *'figure 1'*. Other methods may be mentioned if they offer solutions to issues and defects caused by extrusion forming.

[2.2] The Extrusion Process:



[2.3] Applications for Extrusion:

Extrusion is commonly used to produce oblong objects with fixed cross-sectional areas to be used as structural components. Many parts used in the assembly of a vehicle are produced using extrusion such as the parts that make up the doors and various frames. Extrusion is also a simple and fast method to mass produce hollow pipes and aluminium extrusion can be found throughout homes in windows and doors.

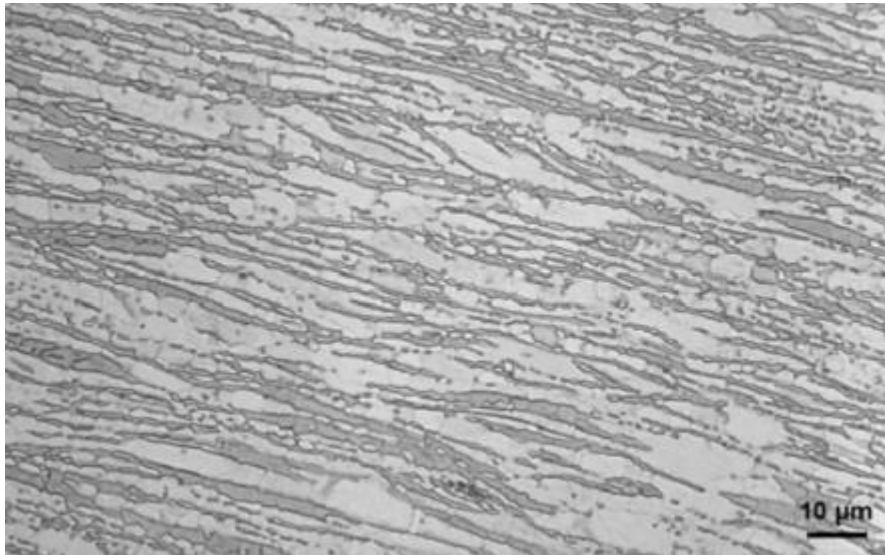
[2.4] Advantages and Disadvantages:

General	
Advantages	Disadvantages
Flexible design for cross-section, High cross sectional area extrusion ratio, Performable with ductile and brittle materials, High potential mechanical properties,	High machinery cost, High required compressive force, Slow process,

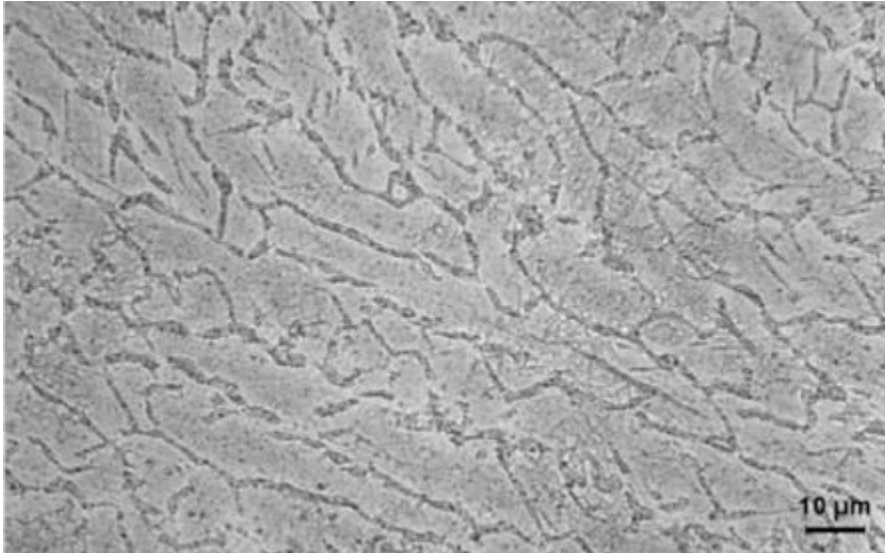
Work Temperature			
Hot Extrusion		Cold Extrusion	
Advantages	Disadvantages	Advantages	Disadvantages
Low force requirement, Easily workable, No stain hardening,	Low surface finish, Damages die, Higher cost, Higher maintenance,	High mechanical properties, High surface finish,	Greater force required, Stain hardening,

[2.5] Microstructure from extrusion:

Extrusion forming typically in metals produces a more compact grain structure with smaller grain sizes compared some other fabrication processes. This produces a material with stronger mechanical properties because smaller, tighter grains increase a materials strength at the cost of ductility.



'Figure 2': Optical image of microstructure of extruded Zinc alloy Zn-0.5%Li-0.1%Ag.

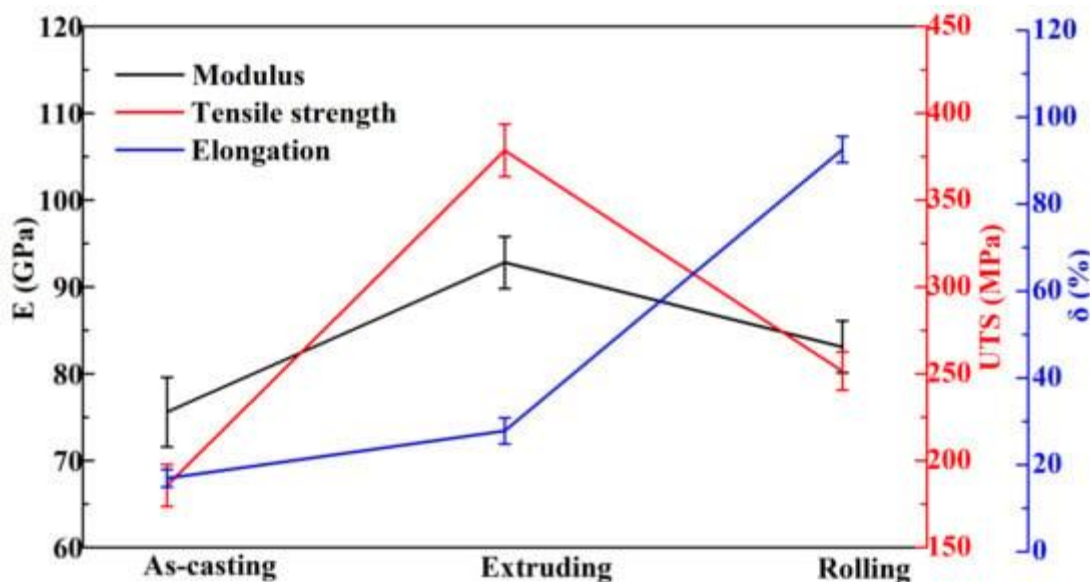


'Figure 3': Optical image of microstructure of cast Zinc alloy Zn-0.5%Li-0.1%Ag.

As seen in 'figure 2' and 'figure 3', extrusion forming produces a much smaller and compact grain structure compared to cast, improving the zinc alloys mechanical properties. Compared to a cast material, extrusion can be used as a good process to make a material more suitable for a higher stress demanding application.

[2.6] Ultimate Tensile Strength:

As mentioned previously, extruded materials typically have more enhanced mechanical properties. As an example of this, 'figure 4' shows a comparison of the ultimate tensile strength of the previously mentioned zinc alloy when cast, when extruded and when rolled. It shows that extrusion provides a major increase to the ultimate tensile strength of material compared to other processes at the loss of potential elongation.



'Figure 4': Mechanical properties of Zinc alloy Zn-0.5%Li-0.1%Ag in different treatment states.

Compared to as-cast, extruding increases the zinc alloys ultimate tensile strength from approximately 187MPa to 375MPa. A huge increase to the materials strength and mechanical properties.

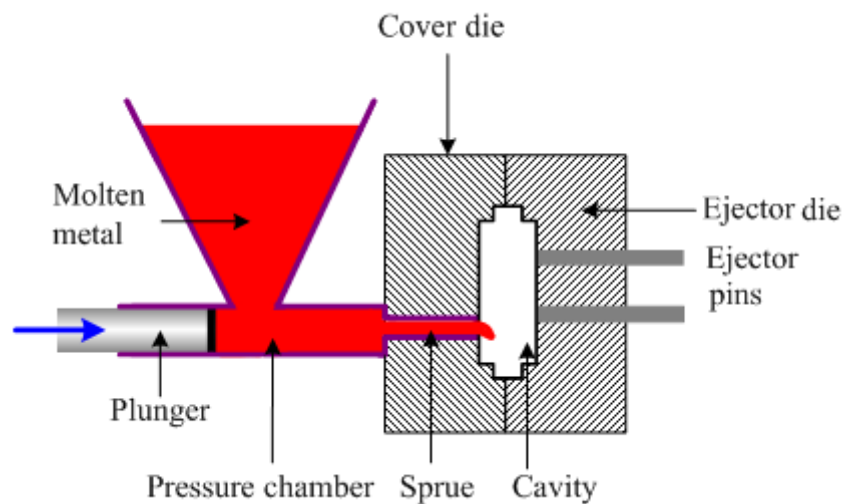
[2.7] Defects and Remedies:

Defects	Remedies
The extruded product can appear burned and discoloured.	Reduce barrel temperature until desired colour is achieved and/or use smaller extrusion container/barrel.
The extruded product can have a bubbly looking rough surface.	Increase die temperature and potentially the container/barrel temperature as well.
Th extruded product can have streaks along its surface from the die.	Incompatible material or increase die temperature.

[3] Die Casting:

[3.1] What is Die Casting:

Die casting is a casting technique that uses exclusively molten metals in a die to form intricate shapes. The molten metal is injected into a die mould cavity with high pressure that can create moulded metal products very quickly. Die casting is often used to create components that have intricate shapes that would be difficult and time consuming to create through other methods. For better visual reference refer to 'figure 5'.



'Figure 5': simplified diagram of the cold chamber die cast process.

When referring to die casting, it will nearly exclusively be about cold chamber die casting as seen in 'figure 5'. Other methods may be mentioned if they offer solutions to issues and defects caused by extrusion forming.

[3.2] Die Casting Process:

The mould is lined with lubricant for temperature control and to allow easier removal of the finished product.
Once complete the die cavity is closed off tightly by the ejector die.



The chosen metal is then heated until it is in a molten state, varies per metal. It is then poured in the pressure chamber.



The plunger then applies force to the molten metal, so it flows into the die. The plunger will continue to apply this force until the moulded metal is fully cooled.



Once fully cooled, using the ejector pins, release the cavity which is only possible if the moulded metal is in a fully solid state from cooling. Once removed from the die, the die is cleaned for scrap metal and the process can be quickly repeated.

[3.3] Applications for Die Casting:

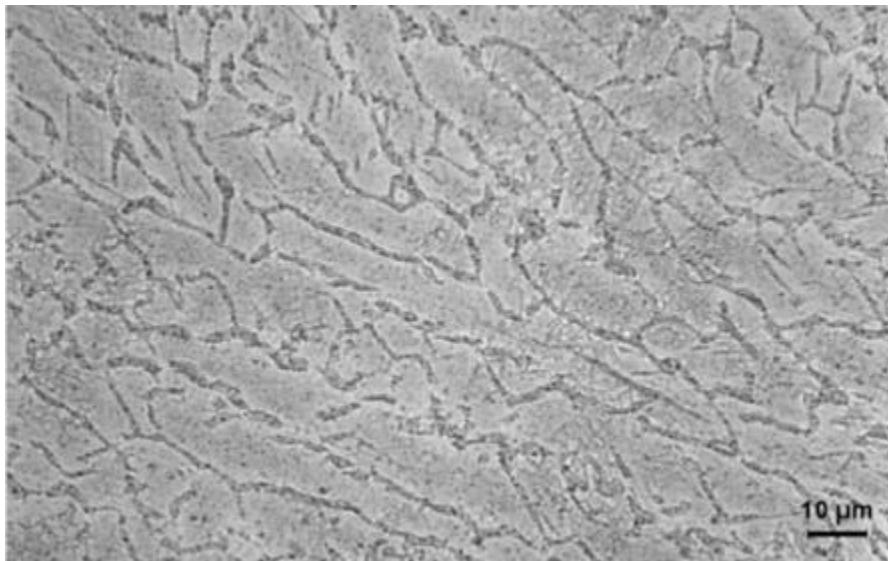
Die casting can be found in so many areas ranging from automotive to structural to complex machinery and electronics. In the automotive industry, die casting is commonly used to create components such as engine blocks, gearbox casings and varying beams. Aluminium is easily most used material for die casting, being used to make the previously mentioned components and range of components in the construction industry to make things such as window frames, roof superstructures, bridges, and skyscrapers.

[3.4] Advantages and Disadvantages:

Advantages	Disadvantages
High productivity with good dimensional accuracy and surface finish	Incompatible with high melting point materials,
Low cost with high volume production,	High cost for each die mould,
Small and intricate shapes can be produced,	Unable to produce large parts,

[3.5] Microstructure from Die Casting:

Die casting on materials tend create spot or island-like formations as their grain structure. The grain structure can also appear to be very inconsistent, often having randomly located large spots and having very tight compact clusters of spots in other areas. From viewing various sources, it appears as though the faster flowing die cast specimens tend to have more chaotic and inconsistent grain structures. So for better mechanical properties it seems best to slower flow rate, not too slow though.

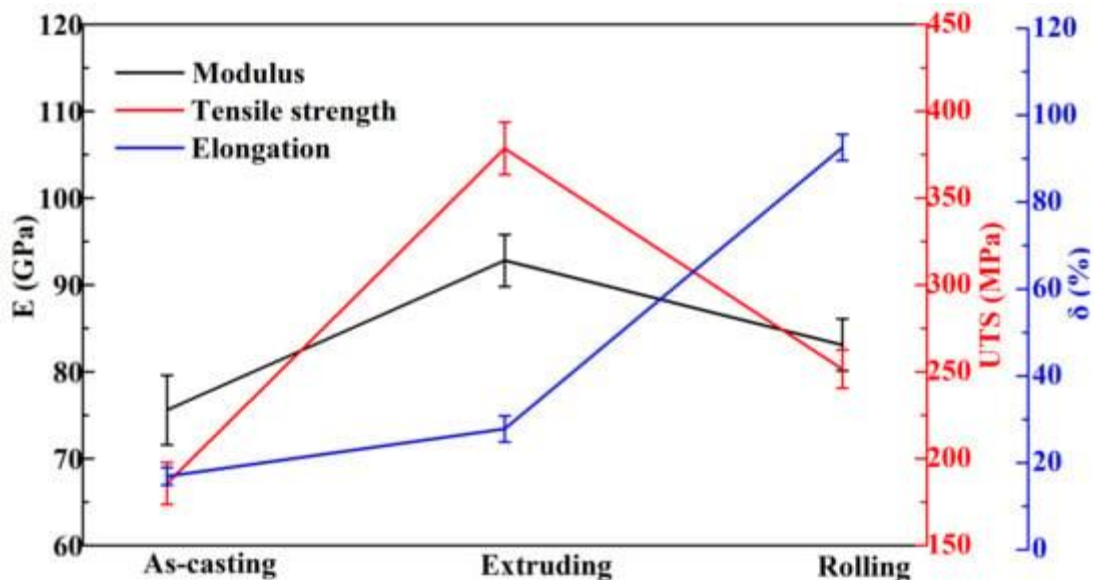


'Figure 3': Optical image of microstructure of cast Zinc alloy Zn-0.5%Li-0.1%Ag

As seen in 'figure 3', cast materials trend to having a more chaotic structure, having unpredictable shapes. 'Figure 3' shows long worm like shapes for many of the grains.

[3.6] Ultimate Tensile Strength:

Die casting does not provide any major enhancements to the mechanical properties of the material. Its ultimate tensile strength will be low when compared to other fabrication methods due to the large grain structure from fully melting the material.



'Figure 4': Mechanical properties of Zinc alloy Zn-0.5%Li-0.1%Ag in different treatment states.

'Figure 4' shows that die casting doesn't excel at anything particular aside from having a slightly smaller ability to strain.

[3.7] Defects and Remedies:

Defects	Remedies
Bubbles forming in the molten metal as its cast.	Lower the mould temperature and/or the material temperature or reduce the injection speed.
Moulded material shrinkage and sometimes causes cavities.	Reduce material pouring temperature, correct the mould wall thickness and/or increase pressure chamber size.
Insufficient pouring, mould not fully casting.	Smelt the material correctly to remove gases and improve the die casts exhaust passages and pouring chamber.

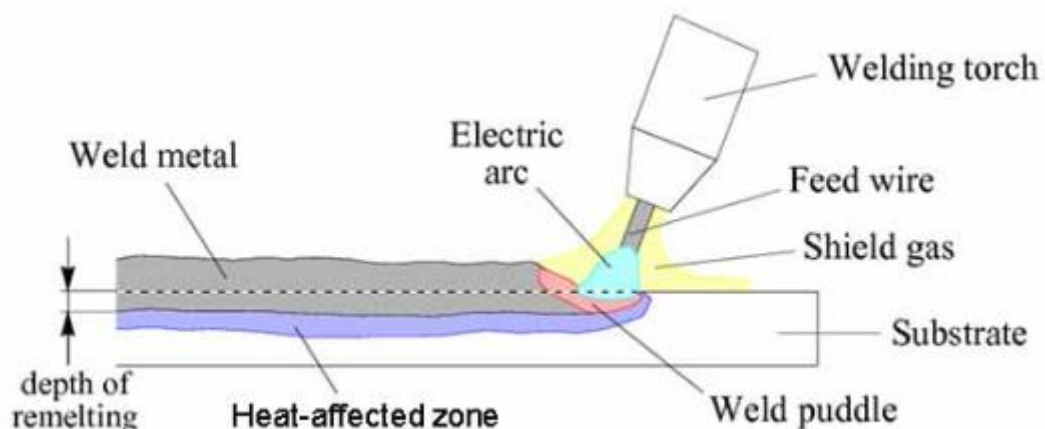
[4] Welding

[4.1] What is Welding:

Welding is the process of joining two metals by heating two metals surfaces to a melting point. This can be achieved many different ways; the following are just some the most common welding types:

MIG	Metal inert gas welding involves using a torch that has a feed wire through it. It is a semi-automatic process where the feed wire requires manual ejection via a trigger. As the wire is injected and contacting the metal, it creates an electric current and creates an electric arc, welding the metal. Also pressing the trigger will release a gas, protecting the weld form outside impurities.
Stick	A filler material stick with an electric current is used to contact the metal producing an arc and creating a weld. A very low-cost process but also messy, requiring further clean up to the weld area.
TIG	Gas tungsten arc welding uses a non-consumable tungsten electrode to contact the metal, creating an arc and a weld. This can be preformed with or without a filler rod.
Flux	Is nearly identical to MIG welding, except its feed wire is has a flux core to it which creates a protective gas shield around the weld when heated.
SAW	Submerged arc welding is where two metals are heated and joined together but the contact points, welding wire and arc submerged under a layer of flux, blocking any emissions.
Gas	Using a torch with a gas flow of oxyacetylene ignites and heats the contact points of the metals, conjoining them.
Thermit	Uses a mixture of aluminium powder and iron oxide, know as thermitite to produce a strong source of heat to melt the metals at the contact points, joining them together.
Forge	The metals are heated to a malleable and hammered into the desired shape. This is one of the oldest techniques and rarely used in the modern era aside from niche circumstances.

Because this section would be incredibly long if it covered all welding types, it will be exclusively covering MIG.



'Figure 6': simplified diagram of the MIG welding process.

[4.2] Welding Process:

Ensure proper safety conditions with fume extractor if possible. Attach a ground clamp to the work area to not electrocute the user and adjust the gas valves to allow for gas flow into the torch gun.



Turn on the welding machine and the wire feed rate and voltage to appropriate values for the particular material and weld.



To begin the weld, it can vary on the user's skill, and what you are welding and the weld shape. As an example, to weld a straight line between two pieces of metal, it would be best to carefully and with constant speed drag the torch gun along the intersection whilst holding the trigger. It is best to be close enough for the arc to form but if it is too close or too slow, the feed wire can become trapped and welded into the surface.

[4.3] Application for Welding:

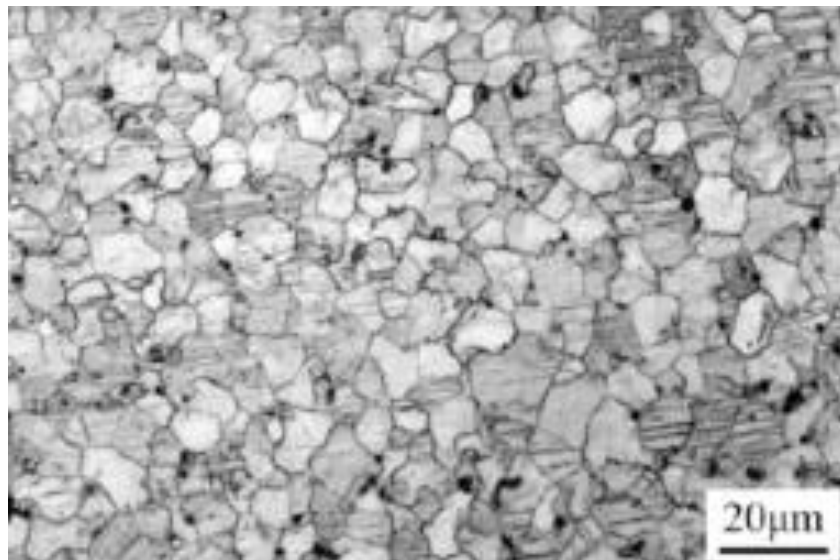
MIG welding is used in many industries for a wide variety of things such as the creation of components, assemblies and structures. It is commonly found used for sheet metal welding, constructing and repairing vehicles, assembling pipelines and welding heavy steel structures like buildings and bridges.

[4.4] Advantages and Disadvantages:

Advantages	Disadvantages
High productivity, rarely needing to stop reload the wire,	Because weld pool, unable for use overhead or vertical welds,
Compared to other welding methods, MIG produces faster and higher quality welds,	Lots of equipment required so not easily transportable,
Can conjoin dissimilar metals together,	
Minor loss of material from weld,	

[4.5] Microstructure from welding:

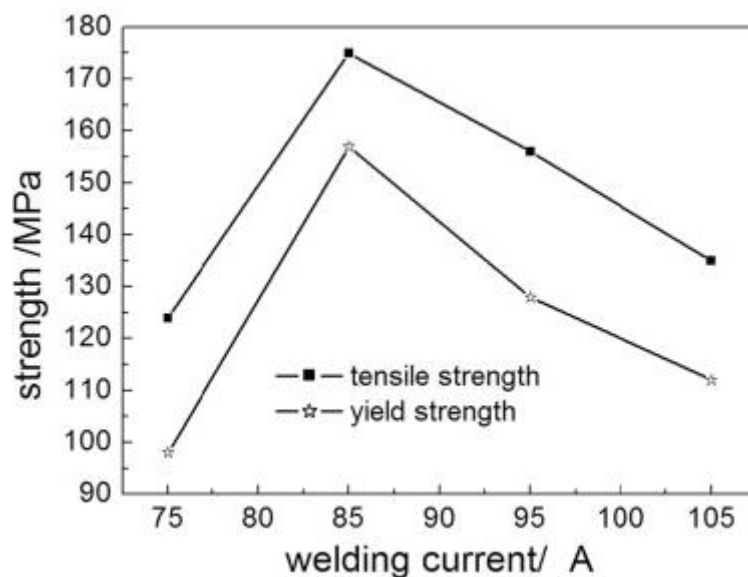
The microstructure of welded materials can vary depending on the technique and current. Typically, the lower the current, the more compact the structure with smaller grains and the higher the current, the larger the grains with a higher chance of defects during the cooling process.



‘Figure 7’: microstructure of Q890D steel welded using welding current: 75A.

[4.6] Ultimate Tensile Strength

As previously mentioned, weld current highly impacts the microstructure and the mechanical properties of the weld. 'Figure 8': shows how much the ultimate tensile strength can vary depending on the current, it appears that the ideal voltage lies around 85 amps. With others fabrication techniques in mind, welding doesn't provide as much strength but nonetheless is still very strong considering it is conjoining two separate pieces of metal together.



'Figure 8': mechanical properties of welded joint of Q890D steel with varying currents.

[4.7] Defects and Remedies:

Defects	Remedies
Welding cracks.	Preheat the material, provide adequate cooling to the weld area, better joint design, weld a larger area and adjust weld speed and current.
Weld contamination.	Properly clean weld area beforehand, adjust arc distance, adjust gas flowrate, and use suitable welding method.
Incomplete weld.	Increase welding current, decrease weld speed, decrease weld pool size and use correct electrode size for the appropriate weld.

[5] Bibliography

Figures:

Figure 1 <https://paulmurphyplastics.com/2019/09/25/extrusion-process-working-types-application-advantages-and-disadvantages/>

Figure 2, 3, 4 <https://www.mdpi.com/2075-4701/12/3/520>

Figure 5 https://www.substech.com/dokuwiki/doku.php?id=die_casting

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