Unit 2 Learning Aim A

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Unit 2

Introduction

This report will be detailing the delivery of engineering processes, health and safety legislations and the impact of human factors on the engineering process, using a case study in the context based on a provided engineering product – an **air compressed bracket**.

The production of the air compressed bracket first starts off with the **preparation process** - this ensures that the bracket is manufactured correctly physically, economically, and environmentally. In this context, the preparation process begins with viewing information from the **orthographic drawings**. Essential information included in the orthographic drawings of the bracket include its **dimensions**; the **material used** (cast iron), the **quantity (**500 – a large batch relative to the size of the company), the **finish** (painted black), as well as the **tolerance**(±0.5mm). This information will allow us to effectively manufacture the product to the highest standards and would make the correct judgements when it comes to selecting manufacturing processes.

It is extremely important that this engineered product is manufactured to a high standard, as it is used to store compressed gas containers, which could provide the risk of exploding and causing substantial damage if the air compressed bracket fails. This can be avoided by comparing the standards of the bracket to the **BS 8888 specification**, such as ensuring the bracket is able to fit **standardised gas cylinder sizes** and offers **mechanisms** such as a **quick-release** for use in areas where such a mechanism would be important, such as in the context of the air compressed bracket, where it will be fixed onto the body of ambulances and support pressurised vessels – therefore it's necessary to consider the materials and manufacturing processes used to prevent the product failing and causing damage.

Human Factors Affecting the Performance of Engineering Processes

While it is important to ensure that this engineered product is made within the correct specifications. It's also important to consider the **human factors** that can have a large impact on the general engineering process, as it influences employee work outcomes such as the **productivity**, **quality**, **safety** and **reliability**, and would affect how successful the business and product is. Examples of human factors that need to be considered include:

The Professionalism of the Individual(s)

An important human factor in maintaining the productivity and quality is being able to rely on workers to get their work done. Situations such as the lack of attendance of workers puts **pressure** on co-workers in the sense that they would have to carry out more tasks to reach a certain goal or deadline, which eventually could lead to **fatigue**, **stress** and a **loss in quality**, eventually leading to a loss in work output. A professional individual would be **trusted** to adhere to codes of conduct and legislations set in place, increasing the safety of the workplace. Lastly, they would be able to effectively learn from their **mistakes** and use their **past experiences** to create a working environment that is **safe**, **productive** and **cost-effective**.

The Ethics and Behaviours of the Individual(s)

On the one hand where the skills and professionalism are important, an individual's inputs into the engineering process is necessary. It is still important to consider what *type* of person the person is – i.e. their characteristics, behaviours and ethics. This is because an individual who is not honest, motivated and someone who does not have a good attitude will **negatively** impact the team and will put their productivity, quality and safety in jeopardy. For example, an individual may not report damage done to a machine, due to their lack of responsibility and honesty, and can cause serious harm to others when the machine is used again and fails.

A way that good characteristics, behaviours and ethics can be encouraged is through management, inclusivity and communication. It is important that teams can trust each other and can communicate openly as this can reduce the chances of setbacks, increase productivity and work output as potential problems that could occur are expressed and dealt with. Additionally, good ethics and behaviours can be more encouraged using systems, such as organizational code of ethics, ethics training and offering protective mechanisms (ethical counsellors, ombudsmen or ethical officers). This sets a strong model of how an employee should act - and as a result will decrease ethical ambiguities.

The Limitations of the Individual(s)

In the workplace there are both physical and mental limitations associated with any task an employee does. When planning a manufacturing process, it's important to consider limitations such as: stress; time pressure; fatigue; capability; motivation; knowledge and experience and finally the person's health. These limitations need to be considered as stress forming from time pressure, fatigue and a lack of motivation, knowledge or experience creates a sense of psychological strain or anxiety that can negatively impact the employee's ability to carry out their duties safely, productively and to the highest standard.

Health and Safety Legislations and Requirements Related to the Production of the Bracket

All legislations and Regulations listed relevant to health and safety is gathered from legislation.gov.uk

Before determining the manufacturing process, it is important to consider the UK's legal framework in health and safety to ensure the manufacturing process is safe and to consider how this will impact the success of the manufacturing process. Listed below is a selection of important regulations and legislations commonly encountered in an engineering environment, and that are very likely to be in effect in the context of the manufacture of the air compressed bracket.

Health and Safety at Work Act 1974

The Health and Safety at Work Act (HSWA / HSW Act) is a legislation that covers job-related health and safety in the workplace. It provides responsibilities to employers and employees to ensure that the health and safety of people in the workplace is not jeopardized.

General Duties of Employers and Employees

The responsibilities of employers include the provision and maintenance of plant and systems used so that they are safe and do not risk the health of those in the surrounding area, and lastly to ensure information, instruction, training and supervision is used accordingly.

The responsibilities of every employee while at work includes the responsibility of the employee to take reasonable care for the health and safety of themselves and other people who may be affected by their duties, and lastly to co-operate with their employer in a way that enables them to carry out their duties.

How this will Affect the Manufacture of the Air Compressed Bracket

The Health and Safety at Work Act will ensure that all workers are well trained, informed and instructed as well as all machinery being maintained to a high standard. As discussed earlier in the human factors section, the limitations caused by a lack of knowledge, capabilities or experience can cause more stress and a decrease in productivity as it puts strain on workers trying to complete their work, and this legislation will prevent this, reducing the impact of negative human factors and improve work output as machinery is well maintained and it’s unlikely delays or problems will arise.

Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) 2013

This regulation specifies that all accidents and incidents, no matter how minor, in the workplace should be recorded in a type of accident book to compile into a report for analysis by a Health and Safety Executive (HSE). This will allow the HSE to compile statistics on the types of accidents and incidents occurring and can enforce new safety procedures to mitigate them or prompt an investigation if the company has failed to introduce these additional control measures. It is very important to consider this as it can benefit the workplace in the sense of making it safer.

When RIDDOR comes into Effect

Some examples of accidents or incidents that cause RIDDOR to come into effect include:

- Death
- Fracture of bones or amputation
- Loss of any sense (eyesight, hearing, etc)
- Any type of burn
- Loss of consciousness from head injuries or collisions

How this will Affect the Manufacture of the Air Compressed Bracket

While RIDDOR obviously increases the safety of workers in the workplace, it also helps the company vision where accidents are more likely to occur and to accurately enforce new measures to prevent them from happening. RIDDOR will encourage the use of engineering processes that are safer, simpler and easier to use – also decreasing the impact of a worker’s lack of experience or knowledge around a specific process, like the HSWA.

Personal Protective Equipment (PPE) at Work Regulations 1992

As the name suggests, this involves the use of PPE in the work environment. PPE is regarded as protective clothing, helmets, goggles or other equipment designed to protect the wearer’s body from injury or infection and should also protect the user from hazards which are physical, electrical, and chemical or that involves heat. Examples of PPE are shown below:

Safety Helmet protects the user in head collisions

Safety Goggles protects the user’s eyes

Ear Defenders protects the user in high-volume environments

High Visibility Vest makes the user visible in low light environments

Steel Toe Capped Boots protects the user’s feet and ankles

This regulation requires the employer to provide suitable PPE for their employees based on the hazards they need to handle within the workplace. Employers cannot charge employees for their PPE and any training associated with the effective use of PPE. While the employer has these responsibilities, it is up to the employee to maintain and use the PPE when needed, otherwise they will be considered the responsible person when an injury occurs.

Control of Substances Hazardous to Health Regulations (COSHH) 2002

This regulation involves the requirement for hazardous substances to be stored, used and disposed of safely in a way that prevents harm to employees and to avoid environmental contamination. The employer has to provide control measures for the storage of such substances, provide training to employees, who in this regulation, have to follow procedures, wear PPE provided and report any concerns with the storage of substances, for their safe use and also outline any contingency plans in the event of hazardous incidents.

This regulation is very important as not following these regulations can have a detrimental impact, not just on a workplace, but the surrounding area. For example, 15 tons of fireworks, barrels of kerosene and acid, and thousands of tons of ammonium nitrate were improperly handled in Beirut's Port and in 2020, caused a large explosion due to the combustible chemical compound ammonium nitrate detonating, killing at least 78 people.

Manual Handling Operations Regulations 1992

As the name implies, this regulation involves the employer being able to recognise and protect employees from injuries and risks associated with heavy lifting. **Heavy Lifting** is classified as "*any transporting or supporting of a load by hand or bodily force*". This regulation is important as there are large risks of permanent injuries that the employee could experience such as:

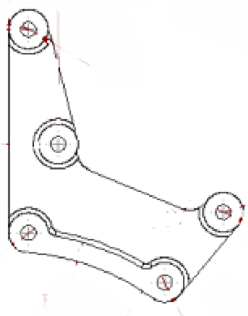
- Back and neck injuries
- Joint Injuries
- Hernias
- Stress Fractures
- Strains and sprains
- Occupational Overuse Syndrome (OOS)

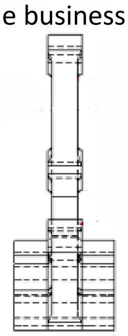
These sorts of injuries can be generally avoided by the employer providing lifting equipment such as chain hoists. However, if lifting equipment can't be used then the employers are required to provide manual handling training to employees so that they are able to lift objects safely using the correct techniques. The employee has the responsibility of following workplace rules and not attempting to lift or move objects that are considered a hazardous weight and that when this does occur, they use the guidance provided from training.

The Engineering Process of the Manufacture of the Bracket

Now that the preparation process: identifying critical information and analysing the human factors and the health and safety regulations that need to be considered, has been completed. We are now able to begin on the manufacturing process.

As stated before, the engineering drawings specify a quantity of 500, cast iron brackets need to be manufactured for use in emergency vehicles. The engineering processes selected consider the costs, the speed and quality of the product, allowing for a product that is not likely to fail, and is sustainable and economical to ensure the business succeeds.





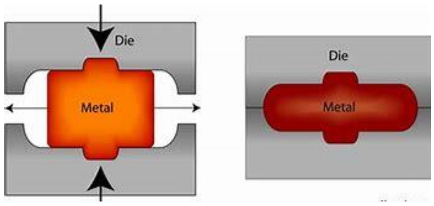
Impression Die Forging

Before the piece is drilled or reamed, the bracket needs to be forged to create the complex shape of what it is. Impression Die Forging is a potentially suitable manufacturing process as shown below.

How does Impression Die Forging Work?

Before the impression die forging process can be made, a worker would first be required to create a die set for the bracket. This would involve using a material that has a significantly higher melting point compared to the iron material being used. An example of such material is tungsten, which has a melting point of around 3500°C and is a relatively cheaper material used in the production of die sets. The worker would then have to use a CNC Milling Machine to ensure the die set is made within the closest possible tolerance. The worker would have to first create a CAD and CAM file for the milling machine, which would involve them using the CAD model of the bracket and then selecting an inverted profile to make the die set. These files would then be sent to the milling machine where it would be precisely cut, then the process of impression die forging can begin:

1. An employee would have to heat the cast iron stock in a furnace so that it is just below its melting point of 1500°C.
2. Once the stock is malleable, the worker would then use large tongs to grab the molten stock and place it into the die set.
3. Once the stock has been secured, very powerful hydraulic presses would be used to press the molten metal between the two dies to create the precise shape, the two dies would then be bolted together and the metal will be allowed to cool.
4. The stock bracket is then removed from the die set and machined to create its other features



While there are many types of forging methods, Impression Die Forging has many **benefits** compared to other forging methods. For example, impression die forging is a very accurate process as impression die forging is a type of closed die forging method whereby there's a restriction in metal flow between the two die contours, meaning complex shapes that need very close tolerances can be formed. Additionally, it is affordable compared to other types of forging methods when it comes to large batch production. Therefore, production and operation costs are much lower. Lastly, due to the fact that impression die forging only deforms and stretches the internal structure, resulting part resists fatigue and impact because the bonds within the structure aren't weakened, forming a higher strength-to-weight ratio (where this would be necessary if placed close to high-pressure vessels) with resulting parts possibly being up to 20% stronger in all ways compared to other forging methods.

While Impression Die Forging offers many ideal benefits, impression die forging still possesses some **limitations**. For example, impression die forging is an extremely unsafe process due to a high-heat environment and workers being surrounded by powerful machinery, meaning a lot of measures would need to be put in place to create a relatively safe working environment. Additionally, it requires a lot of preparation processes before it could be done, as explained earlier in this document. All these factors would increase production and operation costs, which could prevent this process from being cost-effective and potentially cause the business to lose income.

Health and Safety Factors that need to be considered in Impression Die Forging

During Impression Die Forging there are multiple hazards to consider such as: the operator being burnt; encountering the hydraulic press; molten metal being ejected from the dies due to dies that are too thin or the material still being cool; etc. In this process, regulations such as the *Personal Protective Equipment (PPE) at Work Regulations 1992* and *Health and Safety at Work Act 1974* will need to come in full effect. This would involve the employer providing the operator with heat-resistant safety goggles and gloves, fire proximity suits and safety shoes with heat-resistant soles. Additionally, the employer would need to ensure that the machinery is properly functioning, is well maintained and introduce safety control measures to ensure the risk of injuries are limited.

Examples of safety control measures include:

- Introducing exclusion zones close to the hydraulic presses
- Use temperature sensors to ensure the material is at a high enough temperature to be secured in the dies
- Ensure all operators are be fully trained and qualified to come within distance of this process

Control measures such as those above can be put into place that will help improve the health and safety factors and reduce the impacts of human factors on this manufacturing process.

How Human Factors Can Influence the success of this process

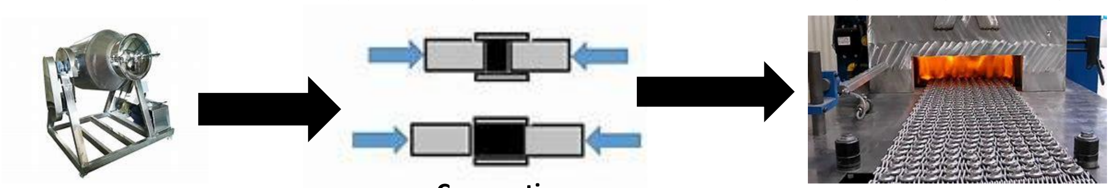
Due to this process being semi-automated, potential human factors can have a large impact on the success of this manufacturing process. For example, a skilled worker would need to be able to create a CAD and CAM file to produce a mold that is accurate and within tolerance, human factors such as the technician's knowledge and experience would need to be very specialised with the Impression Die Forging process to ensure that it is done sustainably and cost-effectively. Additionally, since workers would be working in a high-heat environment, human limitations such as heat stress would have an extremely high chance of creating a negative impact, meaning more workers are required to create a on-off shift to reduce the risk of heat stress in workers.

Iron Powder Metallurgy

How does Iron Powder Metallurgy Work?

Before the powder metallurgy process can begin, the powder must first be produced. In the case of iron powders, the most common processes used are either the sponge iron process or a water atomisation process. The sponge iron process is a chemical process where finely divided iron ore is chemically reduced by removing the iron oxide surface, creating a spongy mass of solid iron, which is then crushed into finer fragments to create a powder. Meanwhile, water atomisation is a process that collides water at pressures between 50-150 MPa with molten iron to produce a fine iron powder. Water atomisation is more commonly used because of how it can produce very fine powders compared to the sponge iron process.

Once a powder has been produced, the iron powder metallurgy process can be started. There are three main stages when it comes to Iron Powder Metallurgy which are mixing, compacting and sintering. At the beginning, an iron powder is heated to just below their melting point and the powder is mixed so that the powder becomes one molten mass, it is then fed into a die where it takes it shape and is then compacted even further to create the most precise end result. After this, it is then compacted, which is a process where the iron particles within the product are applied pressure, forcing them into a solid configuration (particles being close together), and increasing its strength and density. Lastly, the iron bracket would then be sintered, which is a form of heat treatment that further fuses particles together to create a product with a high strength-to-weight ratio.



Mixing **Compacting** **Sintering**

Iron Powder Metallurgy offers multiple **benefits** that could make it an ideal manufacturing process to use on the bracket. For example, the process produces a very good surface finish and a very accurate result, eliminating the need for additional processes to create a smooth texture in certain areas. Additionally, iron is the least costly powder metal material that can be used and is a more automated process compared to Impression Die Forging, meaning human factors would have less of an impact on the process and the operation and production costs will be relatively lower.

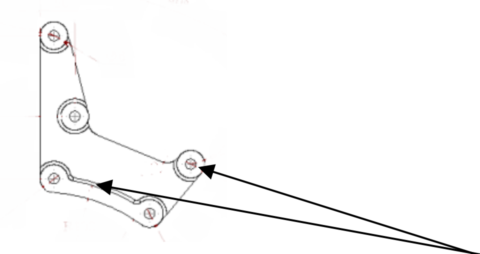
While Iron Powder Metallurgy offers multiple benefits, there are some **limitations** to consider. For example, even though iron is relatively the most cost-effective powder used, the price of metal powders is much higher compared to the cost of raw materials that would be used in impression die forging. Additionally, the parts formed by the powder metallurgy process generally have a lower ductility and strength compared to forging because of the difficulty in creating a density product.

Health and Safety concerning Iron Powder Metallurgy

Similar to impression die forging, as workers would be subjected to a high-heat environment, thermal resistant PPE, such as flame-retardant suits, would need to be used under *the PPE at Work Regulations 1992*. Additionally, the employer would be obligated to introduce control measures that limits how long a worker is subjected to a high-heat environment under the *Health and Safety at Work Act 1974*. An example of a control measure is introducing a shift schedule where workers rotate over the day, to allow for time for workers to cool. This would be an important control measure as it would decrease the risk of heat stress.

Human Factors concerning Iron Powder Metallurgy

Although this a very automated process compared to impression die forging, there are still some human factors that could influence how successful this manufacturing process is. For instance, since workers experience a high-heat environment, heat stress is something that is likely to occur. This would cause workers to have an inability to concentrate and possible muscle cramps, leading to the manufacturing process becoming dangerous to those nearby as it would stop workers from being able to work in a way that's safe.



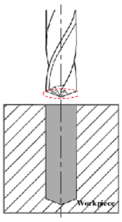
Pillar Drilling and Threading

Once the bracket has been forged, the M6 threaded holes would need to be drilled. This process would be relatively simple to carry out, as a general pillar drill would be used.

How does Drilling Work?

Before the bracket can be drilled, it is important to properly prepare the bracket so that the drilled holes are precisely where they are supposed to be. The worker would have to carefully secure the bracket into a machine vice to prevent the piece from moving when it is centre punched. Centre punching involves using a punch and hammer to create a dent in the surface of the bracket so that when the piece is drilled, the drill bit wouldn't "slip" on the material's surface and make an inaccurate cut.

Once the bracket has been prepared, the user can now consider the actual drilling process. Pillar drilling works by using a drill bit to cut a circular hole by "excavating" the material it punctures using hydraulics supported by the input of a mechanical force provided by the technician.



Since iron is a relatively dense material, a lot of heat could be produced if the drilling process is done incorrectly. Initially, the technician would first have to slowly drill a pilot hole using a smaller drill bit such as a 2mm, and gradually work up in size. Alternatively, since an M6 hole needs to be drilled (equivalent to a 5mm drill bit) the technician could use lubricant and slowly drill the piece to minimise any overheating that could potentially damage the pillar drill, drill bit or bracket. The technician would need to ensure the correct drill feed and speed is used to decrease any unnecessary heat production whilst being time-effective, in the case of iron, a low cutting feed and fast RPM should be used. To also help with the reduction of heat production, it would be important to use a drill bit made of High-Speed Steel (HSS) as it offers general properties that are ideal for this drilling process such as its high heat and wear resistance which would limit how many drill bits would need to be replaced and reduce operation costs.

Before the holes can be threaded, the holes need to be deburred to remove any waste material that could've remained after drilling so that is doesn't interfere with the threading. Once this has been done, a simple threading tool can be used to create the threads. This would involve holding a threading tool perpendicular to the surface of the hole and rotating clockwise continuously and occasionally turning anti-clockwise for half a turn to ensure the threads are smoothly cut.

Health and Safety Factors that would need to be Considered During Pillar Drilling

Compared to Impression Die Forging, drilling the piece with a pillar drill is very safe. The operator would only need to acknowledge the basic control measures and some general training from the employer to ensure they can follow general procedures like wearing the correct PPE, such as goggles. However, if the technician were working with lubricant then regulations under the *Control of Substances Hazardous to Health 2002* would be in effect. It would be necessary to ensure that there is a designated storage area for lubricants that are able to contain any spills, the employer would also need to provide additional PPE such as coveralls, work clothing and vinyl/ nitrile protective gloves to protect the technician's skin from contamination.

How Human Factors Can Influence the success of this process

While this is a very simple process, since pillar drilling depends on manual labour, human factors can have a potential impact on the success of the manufacture of the bracket. For example, a technician would need to have the knowledge and experience to correctly set up the pillar drill and prepare the bracket for drilling. Additionally, human factors such as fatigue and human error can have a big impact on the quality and accuracy on the product, which is vital in this context as it could cause the product to fail to meet the BS 8888 specifications and make the product unsuccessful.

CNC Drilling

Like the name suggests, this is a manufacturing process that is very similar to Pillar Drilling, with the only essential difference being that this process doesn't require a human to prepare the bracket, physically drill the piece or thread the holes, but is rather done by the machine by supplying it with electrical energy.

How does CNC Drilling work?

CNC Drilling works very similarly to pillar drilling but is completely automated and controlled by programming. Before the bracket could be drilled, a technician would have to input a G-code programme, which is a relatively simple programming language, with a letter being followed with a set of numbers which have multiple functions such as changing the geometry of the tooling. G-code is an extremely accurate programming language, meaning the bracket could be made to very close tolerances which is an intention in the manufacture of the bracket. Once the G-code has been submitted, the bracket would be automatically placed in the correct configuration. A door would be closed, the workpiece would be secured with a pneumatic clamp, and the program would be turned on, with powerful motors turning the drill bit, leading to a drilled bracket. In the CNC Drilling machine, multiple drilling tools can be stored in the tool post, meaning with the use of G-code, the machine could automatically change to a threading tool after drilling the holes, eliminating the need for it to be done by a technician.

CNC Drilling offers many **benefits** compared to a manual form of drilling. For instance, once the G-code has been inputted into the machine, it can be recalled using systems such as barcode scanners so that the G-code for the drilling and threading of the bracket can be used for large batches. This means that each drilling and threading process is done consistently and accurately, assuming the technician programmed the code correctly. Additionally, most CNC drilling machines are equipped with automatic lubrication which is released dependant on how much resistance the drill bit encounters when drilling, leading to a reduction in heat production and essentially creating smooth cuts as no material is melted or deformed. Compared to Pillar Drilling, CNC Drilling saves a lot of production time, with most machines being able to travel speeds of up to 50m per minute, leading to a fast process that does not limit the quality of the products. Lastly, a CNC Drilling machine can be combined with a CNC milling machine, which will be discussed, and would reduce the number of processes required to manufacture the bracket.

However, CNC Drilling machines do have a few **limitations**. For example, the set-up costs are very high with most industrial drilling machines being priced over £10,000, as well as maintenance costs being very high in terms of replacing the lubricant and drill bits if necessary, meaning the investment that is put into the CNC Drilling machine must be worthwhile. Additionally, while G-code is simple to learn and input, it is very complex to create a program that is accurate and to the correct specifications, therefore **human factors** such as experience and knowledge may still have an impact on the quality of outcome.

Health and Safety that would need to be considered during CNC drilling

Since the technician would not be necessarily operating the machine and the piece being secured behind a shatter-resistant screen, very few health and safety legislations would be put into place. Although the *Health and Safety at Work Act 1974,* would be in place as the employer is obligated to maintain and provide provision on the systems used so that no failures that could be dangerous could occur.

How Human Factors could Influence the Success of this Process

This process is heavily automated, meaning human factors wouldn't have much of an impact on the success of this process. However, this process requires a skilled technician heavily experienced in G-Code to ensure that the bracket is made to the correct tolerances, which could make this a challenging process.

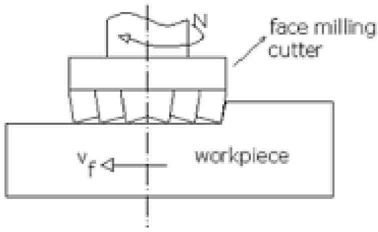
<u>CNC Milling</u>

The last process in the manufacture of the air compressor bracket is milling, which is used to create a flat, smooth and square finish so that it would sit flat against a wall.

How Does Milling Work?

Milling is very similar to drilling; in that it removes material off the product. In this case, the milling process removes material by performing many separate and small cuts using a rotating milling bit that rotates at a very high speed. A manual milling machine is operated similar to a lathe in that there are generally wheels that control the position of the miller cutter in the X, Y and Z axis. The technician would need to use depth stops in order to achieve the correct measurements and tolerances – however as mentioned in the CNC drilling section, milling and drilling can be combined into one machine, reducing the need for additional machines that are costly. Additionally, a CNC milling machine would be more suitable for volumes of production such as with the bracket and since consistency and accuracy is essential.

A way in which a CNC milling machine may differ from a CNC drilling machine is that instead of using G-code to program all of the movements of the drill bit, a CNC milling machine would use a CAD drawing and base its cuts on that file. This would require the technician to use CAD software such as SolidWorks to create a 3D model of the bracket which can then be converted into a CAM file that the milling machine would be able to read and create a series of instructions for the miller cutter. A glass frame would then be closed and the bracket would be secured once the program has been turned on the milling machine will carry out the set of instructions it determined from the CAM file, milling the bracket to create a smooth surface.



There are multiple **benefits** concerning CNC Milling. For example, CNC Milling is an extremely accurate process because of the use of CAD and CAM files, the process can be repeated consistently, leading to an increase production speed and efficiency, saving costs in these areas. The use of this computer-numerical control system offers multiple types of financial and production advantages as well relative to other manufacturing methods. For instance, since the CNC Milling machine is very automated an only requires a technician to turn on the programme in terms of operation, it allows technicians to operate in other manufacturing methods while the bracket is being machined, additionally, CNC Milling allows for rapid prototyping, which would allow designers and engineers to make corrections to the bracket so that it would fit in the correct tolerances.

However, there are some **limitations** of a CNC Milling machine that need to be considered – the biggest limitation being that workers who programme the machine and operate it must be highly trained, with the addition that designing and programming is a time-consuming process which could make it not cost-effective for smaller batches

Health and Safety Factors that need to be considered during milling

Similar to CNC Drilling, the number of health and safety measures that would need to be introduced is limited due to the process being very automated. However, there are still some safety measures that need to be considered. For example, the milling machine uses lubrication to control the heat produced while cutting, meaning *Control of Substances Hazardous to Health 2002*

How Human Factors can influence the success of this process

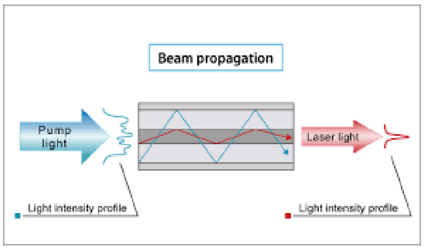
Although this process is mainly automated, it depends on the operator’s code to function properly, which is why the operator needs to be skilled in programming and be aware of any mistakes/ bugs that could be present in the programme that could affect the end results.

Fiber Laser Cutting

While laser cutters are generally used to cut sheet metals. They can be used for surface finishing by evaporating away the surface.

How does FIber Laser Cutting work?

A laser cutter uses a similar preparation process to the CNC Milling machine in that it requires a technician to create a CAD and CAM file that would be used by the laser cutter to monitor how much energy should be supplied to the laser cutter which would determine how much material would be evaporated from the surface. Commonly CO2 lasers are used for laser cutting for thin sheet metal materials, however, since this manufacturing method would be used to level and finish sections of the bracket, a fiber laser would be more suitable. A fiber laser works by using specially designed glass fibers that amplify light beams. These high-energy light beams then transfer energy to the surface of the cast iron, causing an energy build-up in the thermal energy stores of the cast iron structure, causing the structure to weaken and evaporate, leaving a smooth finish.



A FIber Laser Cutting machine offers multiple **benefits** that could make it a suitable manufacturing method for the bracket. For example, a fibre laser cutting machine has a very small focal diameter, meaning tolerances from 0.003mm to 0.006mm can be achieved. Additionally, relative to a CNC Milling machine, energy costs are drastically lower, with typical fiber lasers being able to operate at 25-100W similar to CO2 lasers, but can produce strong and stable beams that are up to 100 times more intense. Lastly, fiber lasers are generally maintenance-free and have a long service life of up to 25,000 laser hours, meaning that while set-up costs may be high, they're able to generate a positive net income for large batches such as with the bracket.

However, a fiber laser cutting machine does feature some **limitations**. In the context of the bracket, the thickness and density of the material means that a higher power consumption would need to be used as well as a more specialised fiber laser, leading to higher energy and set-up costs. Although the fiber laser has a very small focal length that would allow it to cut to extremely small tolerances, it would be a very time-consuming process to ensure that the process is done correctly and that there is no distortion or warping because of the heat produced.

Health and Safety Factors that need to be Considered during Fiber Laser Cutting

As mentioned, this process involves a laser cutter evaporating the surface of cast iron, this evaporation process could cause the iron to react with oxygen, producing iron oxide which is extremely dangerous for a worker's health. To mitigate this, a high level of ventilation would be required around the machine to decrease exposure.

How Human Factors could Influence the Success of this Process

Although this a heavily automated process, human factors are still present in the preparation process for this manufacturing method. For example, a technician must be specially trained to ensure that the fibre laser is properly calibrated to ensure that the laser cut is perpendicular to the surface, otherwise it could create tapered cuts on the edges of the finished areas, which could cause it to be weaker when in use.

Evaluation of Suitable Manufacturing Methods

Impression Die Forging / Iron Powder Metallurgy

After consideration, I believe that Iron Powder Metallurgy would be a more ideal manufacturing method compared to Impression Die Forging for a number of reasons. For example, it is significantly cheaper and sustainable because of its very low wastage and the fact that a drastically lower temperature would need to be used, making a more efficient process with lower energy usage. Additionally, this process is much less time consuming compared to Impression Die Forging – this is because a mold can consist of multiple inverted profiles of the bracket, meaning up to 10 brackets can be formed at the same time, further saving costs, increasing sustainability and production efficiency. Lastly, in terms of health and safety, while workers would still be subjected to a high-heat environment, it would be much safer compared to Impression Die Forging which contains workers having to work at temperatures 900°C higher than power metallurgy, leading to a reduction in the risk of heat stress.

Pillar Drilling / CNC Drilling

While Pillar Drilling does offer some great benefits that could potentially make it ideal for the manufacture of the bracket. I believe that CNC Drilling would be a much better suited manufacturing option for the bracket. The bracket needs to be made to the highest standards possible to ensure it doesn't fail in the potentially extreme environments it could be placed in. The highest standards possible can only be achieved with the least amount of human errors being present, which is why CNC drilling is a much better suited option – a CNC Drilling machine uses stepper and servo motors that are able to achieve high precision drilling processes, and if done correctly could lead to no single defects within the bracket. A CNC Drilling machine also has a much higher production efficiency compared to Pillar Drilling because of its repeatability and consistency, this provides economical benefits to the company as a higher number of units being produced within a shorter time frame drops unit costs, attracting more customers and increasing profits.

CNC Milling / Fiber Laser Cutting

There's no doubt CNC Milling would be the most ideal manufacturing method compared to Fiber Laser Cutting. This is because a CNC Milling machine has a much higher production efficiency compared to a fiber laser cutting machine, a laser cutter would take a large amount of time and energy to evaporate a single area, while a CNC milling machine would be able to do this within a couple seconds. Additionally, CNC Milling has a much safer preparation process compared to fiber laser cutting which uses a high-energy light beam that could seriously damage workers and equipment if not set up correctly, while a CNC milling machine only requires a technician to securely lock the drill bits in place.