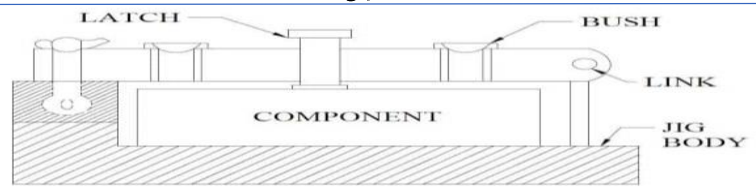
Jig definition and its existing solutions

Function of a jig: A jig is a type of fixture that holds onto a given object and assists in aligning drilling or cutting tools via the use of markings or holes that align perfectly with where the object is intended to be cut or machined, with said holes, the cutting tools can slide in with perfect alignment each time.

Leaf jig (existing solution): A leaf jig has hinge attached to it allowing the work piece to be easily loaded and unloaded. Inside the jig, a spring pushes the work piece to the edge, its then clamped shut, and the hinge is then finally closed with the drill bushes being on it the surface of the piece its moving. This type of jig is used when a piece with a single faced to be drilled on and a quick drilling process are needed due to the easier loading process



Box jig (existing solutions): Box jigs enclose the entirety of the work piece except from the inserting side, within the jig, a series of pins and clamped are used to hold and align the piece. From there drill bushes can be placed around the box jig to align the bench drill. The is a good solution when drilling on multiple angled and side is needed since holes can be placed anywhere around the jig to drill the work piece.

Health and safety

Manufacturing: The powdered material should be sealed to prevent it from being airborne and workers should wear respiratory masks when working around the powder. An LEV machine should be setup to prevent airborne particles when the powder is being collected at the end of the process. The machine's guard should also never be opened until all argon gases within the chamber have been extracted.

Product: Product safety consists of the following points: edges should be rounded to prevent accidental cuts by the user. The design should include clamping tools to prevent having to use external tools for clamping which could result in accidents. Location of any tools on the jig should be easy to reach so that the user does not have to put their hand in a weird position to reach them.

User: Wearing safety goggles to protect from flying debris while drilling and also wearing protective gloves and boots if the jig was heavy in order to protect the user if it were to fall on their hands or legs.

Potential manufacturing processes

Sand casting:

Sand casting is using a sand-made mold that has binders mixed into it, after which, gates are setup to allow for material to flow into the mold. From there molten metal is poured into the mold and is waited on until it solidifies. Finally, the sand mold is broken, and the final product is extracted.

Reasons to use for jig production:

- Cheap, around $500 to $7500
- Little to no waste (sustainability)
- Can work with many types of materials

Potential drawbacks:

- Bad surface finish; due to sand mold's texture
- Bad tolerances at around ±0.55mm to ±1.03mm
- Parts are weaker due to porosity
- Bad lead time
- Parts need to be assembled separately

SLM printing:

SLM is a metal AM process. A digital 3D model is installed into the printer, powdered material is then laid onto a base plate called the bed using a roller. A laser is directed at the powder making the shape of the product. The process is repeated until every layer needed is made. Excess powder is removed, and the product is extracted.

Reasons to use for jig production:

- Great accuracy at around ±0.1mm
- Great design freedom
- Product is assembled during printing
- Very short lead time
- Parts are stronger; very little porosity
- Very little waste

Potential drawbacks:

- Bad surface finish
- Materials need to be powdered first
- High capital cost at around $100k

CNC milling:

CNC mills work by installing a CAD file into the machine with a set of instructions that tell it how to operate. From there, a block of material is placed within the machine, which is then shaved and cut down to the required dimensions and shape, with the block of material being stationary and cutting tool moving around the material.

Reasons to use for jig production:

- Very short production time
- Amazing tolerance of ± 0.04mm
- Can achieve great surface finishes
- Works with a wide range of materials

Potential drawbacks:

- Requires a lot of training to use
- High capital cost ($60k) and tooling
- Limited geometric freedom
- Products require separate assembly
- Lots of waste is produced

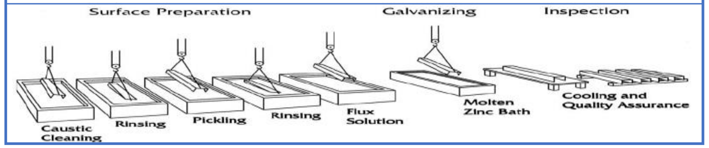
Process of choice: SLM was chosen as it would provide necessary design freedom, something unavailable to CNC machining and sand casting, it would be able to print all the jigs required at once, making it a fast process, and it produces very little waste, all aspects that are needed and are not available for either CNC machining and sand casting. The bad surface finish could be a problem but a good one is not necessary.

Finishing techniques

Machining (For sand casting): *Because of the high tolerances in sand casting, the final product would be machined so that any inaccuracies are adjusted before the final product is given to the consumer.*

Normalizing (For SLM and CNC milling): *In SLM and CNC milling, the material undergoes a lot of thermal stress, causing residual stress on the product, making it weaker. To counteract this, normalizing is done, the metal is heated to a given temperature point, held at that temperature, and then is allowed to cool naturally at either room temperature or outside. This alleviates said residual stresses and toughens up the metal.*

Galvanizing (All processes): *This involves repeatedly dipping and rinsing the material from molten zinc, a rust resistant material, therefore making the material rust-resistant, something that is needed for all the mentioned processes as they all use mild steel, a material with a lot of iron, and therefore can easily rust.*



Sustainability

Raw material: *The original material used is mild steel, its composition consists of 0.05% to 0.25% carbon, 0.7% manganese, around 97& to 98% of iron, with the rest being minor elements and impurities that make up a small percentage such as phosphorous, silicon, sulphur, and some others. The method used to extract materials is generally through surface mining to acquire their ores that are then melted to extract the raw material. The main supply of iron on earth will run out approximately by 2070, with carbon and the other materials being extremely abundant and would not run out any time soon. Although iron supply is concerning, for the purposes of creating jigs now, the abundance of raw materials should not be a point of concern and can be considered as sustainable.*

Design: *Three areas contribute to the design's sustainability, the first being using thicker and more durable locators, locators are the pins used to restrict the work piece from moving and aligns it with the holes, any forces acting on the work piece are also acted on them, meaning they need to be strong, which can be done by making them thicker. The design of the drill holes needs to be concave to align the drill easily, this should be done using a fillet instead of a chamfer, as fillets are able to reduce stress concentration better than chamfers. Finally, the design should have as little as possible components as less components means less chance for any of them to break.*

Waste/recyclability: *Mild steel – just like most other metals – is 100% recyclable. Its main component – iron – is a recyclable material and so are all the other materials that it constitutes of, which benefits its sustainability. As such, any wasted material during the manufacturing process could be easily reused by melting down the recycled, purifying from any contaminants such as rust, and then is shaped it once again for further use.*

Material properties and requirements

Material requirements

- *Should not deform under heat → More accurate; since drilling holes could expand due to hate, therefore increasing tolerances (mid-priority)*
- *Should resist wear and tear → Better product longevity (high priority)*
- *Cheap → Jigs are an essential part to accurate manufacturing; however, they still need to be cheap to make. (mid-priority)*
- *Lightweight → to make handling of the tool easier which would prevent fatigue (low priority)*
- *Prevents vibration travel → Less chance for movement when drilling, meaning higher accuracy (high priority)*

Material properties

- *High melting point → This means that it has a low coefficient of thermal expansion, hence it won't deform from heat generated by the machine.*
- *Density → Being dense means that the material would be heavy; as mass of an object increases, frequency of vibrations decreases. This is against the need for being lightweight, but being lightweight is less important than preventing vibrations.*
- *High shear, tensile, and compressive strengths → To be able to prevent stress and strain in all of those three aspects means the material will be strong and resistant to wear and tear*

Material of choice: *The material of choice is High Carbon Steel (HCS) to replace what is being used, mild steel. HCS is very similar to mild steel as it costs only slightly more at around $0.55, has the same coefficient of thermal expansion of $11*10^{-6}$mm/K, and has around the same density at 7860kg/m^3, all of which meet the required properties. However, HCS is much stronger at 685MPa of maximum tensile strength while mild steel is at 400MPa. Overall, HCS has the same advantages as mild steel but is also stronger.*

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