

Prototyping Booklet

The Knowledge Series

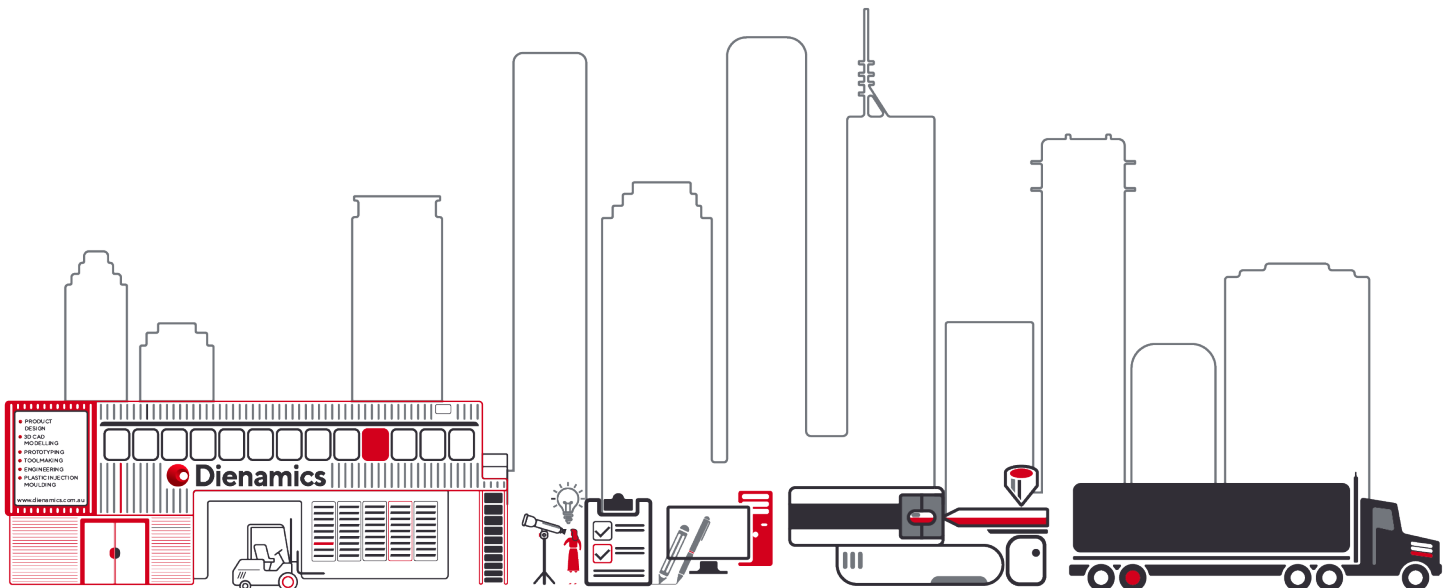


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01 Introduction to Prototyping

Prototyping Knowledge Series Blog

February 3, 2020



Product Prototyping, your R&D guide to design success.

At Dienamics, we know that the key to a project's success is to ensure our customers are informed and kept in the loop. We want you to understand the work that goes into developing a design idea and to appreciate the importance of each step in the design development process.

The following blog series will **explain the world of product prototyping**. We'll look at the different types of prototypes and the misconceptions and expectations surrounding them (e.g. experimental prototype vs. appearance prototype) as well as the options you have when it comes to prototype manufacturing processes and the advantages and disadvantages of each (e.g. CNC machining vs. 3D printing).

Above all, the message you should take away from this article series is that prototyping is a necessary & vital aspect of the design research and development process. You prototype to find errors in your design before you go and spend money building tooling & beginning manufacturing.

A prototype allows you to tangibly feel and test a 3D CAD design. **Physical interaction is the best way to find design errors and inspire modifications.** Even if a product looks right on a computer, it doesn't guarantee it will be what you are after in the real world. This is why we always suggest to all of our clients that they get prototypes made.

With that said, even if you make a prototype it doesn't 100% guarantee the success of the design or the final manufactured product; you may need to make multiple prototypes as well as further changes to the final manufacturing tooling or process after that again. For example, let's say you have an idea for a plastic product:

- After the CAD drawing is done you make an initial prototype, you find some errors in the design (this is a good thing)
- Changes are made to the CAD drawing and you then make a second prototype that works out great, you decide to move on to building an injection moulding tool
- After the injection moulding tool is built, you order an initial moulding run
- It is rare that the first moulding run produces perfect products because it is a different manufacturing process to that of a prototype and as such is going to produce a part that is not identical to a prototype – it'll be close, but never 100% the same
- It is likely that further modifications will need to be made to the tool before you have shipments of final ready-to-sell products arriving at your door

So if you have to make changes to tooling and manufacturing even after making one or multiple prototypes, why would you even bother with making prototypes to begin with? The answer is simple – it is because tooling is expensive and takes a lot of time to make. **In the long run it is going to be more cost effective and more time efficient for you to use prototypes to work out the majority of kinks beforehand.**

If a product could be taken from a 3D CAD drawing straight to a final manufactured, ready-to-sell, product the R&D (Research and Development) industry would not exist. To put it all into perspective, between July and September 2019 Apple Inc. spent \$4.2billion on product R&D alone. Another example would be James Dyson, who made 5,217 prototypes when he was developing the bag-free, cyclonic action vacuum.

The next issue in this series will look at what you need to do, know and think about before prototyping.

Prototyping capabilities advance as technology develops and changes. Leave it to Dienamics to keep you up to date. Watch this space!

02 Before You Prototype

Prototyping Knowledge Series Blog

February 12, 2020

Things You Need to Understand Before You Prototype:

1. You need to budget for it, you need to make sure you've got sufficient funds and enough time set aside so that you don't rush any prototyping or testing
2. You also need to develop a clear understanding of why you are prototyping and what you want to get out of that prototype
3. And you need to understand that prototypes are to check, prove and find faults

1/ Understand the Budget – depending on what you are looking for in the outcomes of the prototype will depend on your budget. Your first prototype is maybe just to check the concept design so you can feel confident in moving ahead with more involved designs. Or it may be to test the design and check the CAD work before making multiple prototypes for field testing. So, you may start off with a 3D printed or SLS prototype but for your final you may do Vac cast or CNC prototypes.

2/ What do you want the prototype for? Is it non-functioning for display or sales? Is it to test a design and check the CAD work? If you're wanting to test the mechanical properties of the design, you would have to prototype using the same material, or as close to it as possible. Be clear of what you are after, all designers will prototype to test the CAD work and the functionality of the design; this will be our first priority. Sales and marketing are something that we won't be concerned about unless the customer specifically requests this in the prototype. Even if they do, the first rounds of prototypes will more than likely still focus on the design and function of the prototype; designers are always trained to prove the design before sales or marketing is addressed.

3/ People often rush the prototyping stage because once they have the CAD designs done or what they think is completed, they become eager to get to tooling and begin producing products for consumers. Customers can sometimes get upset or frustrated if the prototypes has highlighted issues. Understand that if the prototype picks up mistakes, design issues or other failures, this does not mean that the prototype was a failure. In fact, it is the complete opposite, the prototype has been a success as it has done its job and found issues before costly tooling is built. Most customers need to prototype several times to prove a design & you need to understand this before you begin the process. If designs and CAD data could be guaranteed to be correct before prototyping, we wouldn't need prototyping or an R&D (Research and Development) industry.

In the next installment of this series we'll take a look at the various types of prototypes there are, how they are used in different stages of the design process and what types we use at Dienamics to help you reach your goal of developing your product idea.

03 Types of Prototypes

Prototyping Knowledge Series Blog

February 19, 2020

In Part 2. 'Before You Prototype,' we looked at the importance of developing a clear understanding of why you are prototyping and what you're wanting to achieve from it. In this issue, we'll list some of the different types of prototypes and their purpose; we'll go into depth on each one in later issues.

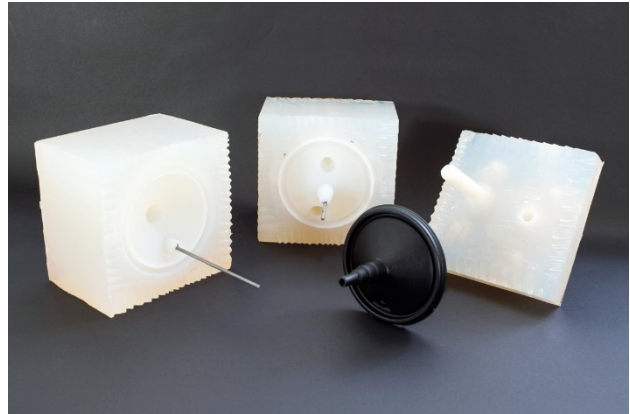
SLS 3D Printing



Selective Laser Sintering or SLS is a 3D printing technique that works to build a 3D object by sintering fine layers of material powder together.

- Unlike traditional 3D printing methods, support structure does not need to be removed post-print
- Rapid process
- Offers a low-medium finish quality
- Used for small, unique and complex design
- Few days to make

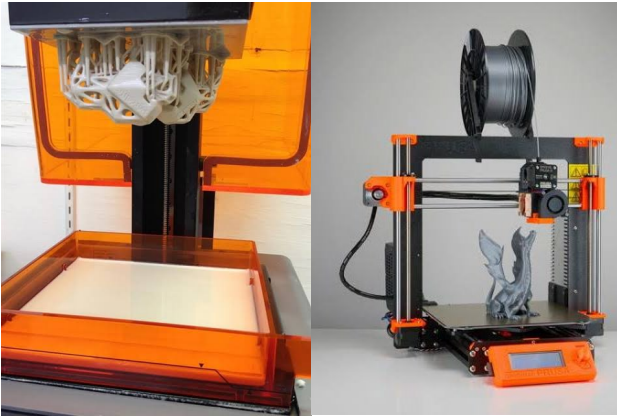
Vacuum Casting



A master model is made to create a mould. Plastic resin is drawn by vacuum into the mould to make a copy.

- Up to 25 copies can be made from the single mould (depending on the moulds complexity and material used)
- Price of mould spreads thinner the more copies you manufacture
- Surface quality comparable to injection moulding
- Few weeks to make and produce copies

SLA & FDM 3D Printing



Stereolithography (SLA) & Fused Deposition Modelling (FDM) are the two most common 3D printing technologies. FDM works by heating and extruding plastic filament. SLA works by selectively hardening plastic in a resin basin with ultraviolet light.

- For prototyping small components
- Poor mechanical properties
- Comparatively cheap processes
- Few days to make

Part 4. of this Prototyping Series will look deeper into the importance of conducting user research and testing with your prototypes.

We've got over 30 consecutive years' experience in the design and manufacturing industry at Dienamics, so please feel free to [call or email](#) if you have any queries or questions about a product idea you're keen to get off the ground!

CNC Machining



Prototype is formed by cutting away from a block of material using a computer controlled spindle with cutting tool attachments.

- High dimensional accuracy
- High surface finish
- Choice of materials (plastics, metal wood, etc. all suitable)
- Week to two weeks to make

04 User Testing and Research

Prototyping Knowledge Series Blog

February 26, 2020

In Part 3, Types of Prototypes, we looked at some of the different types of prototypes and their purpose. In this issue, we'll talk about the importance of the user testing and research phase of making your prototype.

The 'build it and they will come' fallacy is a common oversight in product design. There are countless examples of failed products that could've been successful if only prototypes had have been correctly employed to find errors. This issue isn't limited to small companies or individuals either. For example, let's look at the Sunbeam Marc Newson Kettle. This is a kettle design that was the winner of the 2016 Good Design Australia Awards, yet if you google reviews for it online, you'd struggle to find anything rating it above 2/5 stars. Whilst being quite stunning to look at and being something you'd admire in any home or interior decorating magazine, when it comes to making a cup of tea or coffee you wouldn't exactly call it ideal.



For starters, the handle is parallel to the bench making it good for lifting the kettle straight up and down but when you go to pour it, your arm is forced into a rather awkward position. Then, when you look at the lid, there is no button but rather an in-laid knob with which you have to grasp two fingers around and pull upwards. This would be well enough if not for the handle positioning which only allows you to pull the lid upwards slightly so that you must then slide the lid out sideways. In

addition, thin stainless steel is used to make the kettle bowl and without the weight of the water in it, this light/thin material makes the kettle feel cheap and fragile. These are all issues that if the design had have been prototyped well could have been picked up early on in the design process. Prototyping is a trial and error process and as such a successful prototype is one that allows you to find errors.

Prototyping gives you clarity. You aren't going to know how people will react to a design until you make it three dimensional – think, at any product expo or display do you pay more attention to the poster or pamphlet or more to the physical product they have on display. Henry Ford had a great quote, *"If I had asked people what they wanted, they would have said faster horses."* Essentially, you don't know what users or consumers want until they see and hold your product in their hands for the first time. Prototyping is the best way to initially achieve this – you can't do user testing with a CAD drawing.

Succinctly, get a prototype made, and get it in the hands of your end customer. In the next issue, we'll give you the advantages and disadvantages of prototyping using SLS 3D printing.

05 SLS 3D Printing

Prototyping Knowledge Series Blog

March 3, 2020

In Part 4, 'User Testing and Research,' we talked about the importance of the user testing and research phase of making your prototype. In this edition, SLS 3D Printing, we'll look at the considerations for the process, step by step.



Originally developed back in the 1980's, Selective Laser Sintering or SLS is a 3D printing technique that works to build a 3D object by selectively sintering layers of material granules (powder) together with the sintered layers beneath.

Unlike Fused Deposition 3D Printing (FDM) – which is the technology most home 3D printers' use – SLS printing does not require support structure because as the object is formed it is fully supported by non-sintered material powder.

Use

SLS printing is perfect for small batch prototyping – anything from a single prototype, up to batches of 5 or even 10. If you're looking at producing prototype batches of 10+ or up to 25 components, vac-casting may be a better option.

Outside of rapid prototyping, SLS printing has two other uses – limited run manufacturing and complex/impossible geometry printing:

- Limited Run Manufacturing
 - Industries that require specialised, low volume parts (such as aircraft manufactures) will sometimes use SLS printing to create products for everyday use. They do this because if only a couple specialised parts are required quickly, it is likely that it isn't viable to produce tooling or do injection moulding runs.
- Complex/Impossible Geometry
 - SLS printing (& most other additive manufacturing/prototyping processes) afford designs to be successfully prototyped even if they aren't actually suitable for final manufacturing process. Complex geometries such as undercuts & nesting can be SLS printed yet can't be injection moulded. You need to be cautious and ensure that the designer working on your product has expertise in manufacturing – there is no point designing and prototyping a product for it only to be redesigned when you go to tooling & manufacturing.

Quality

Layer thicknesses range between 0.06 and 0.15mm. Being made from material granules, the surface finish of SLS parts is porous. To get a completely smooth part, post-print filling, sanding and painting is required.

In comparison to other 3D printing techniques, the surface finish and mechanical properties of SLS are superior. Because support material is not used, the surface finish of SLS printed objects isn't damaged by its removal, as it is with FDM 3D Printing.



FDM 3D Print



SLS 3D Print

Time

SLS printers work at approx. 50mm/hr. Conversely, FDM 3D printing can be faster at 50 to 150mm/hr. Whilst FDM can be slightly quicker, SLS prints still have a short lead time of between 1 to 4 days.

Materials & Cost

Because support structure is not required, material is not wasted – saving money. The materials used in SLS have to be powder-able polymers. Coincidentally, these materials, such as nylon, tend to exhibit

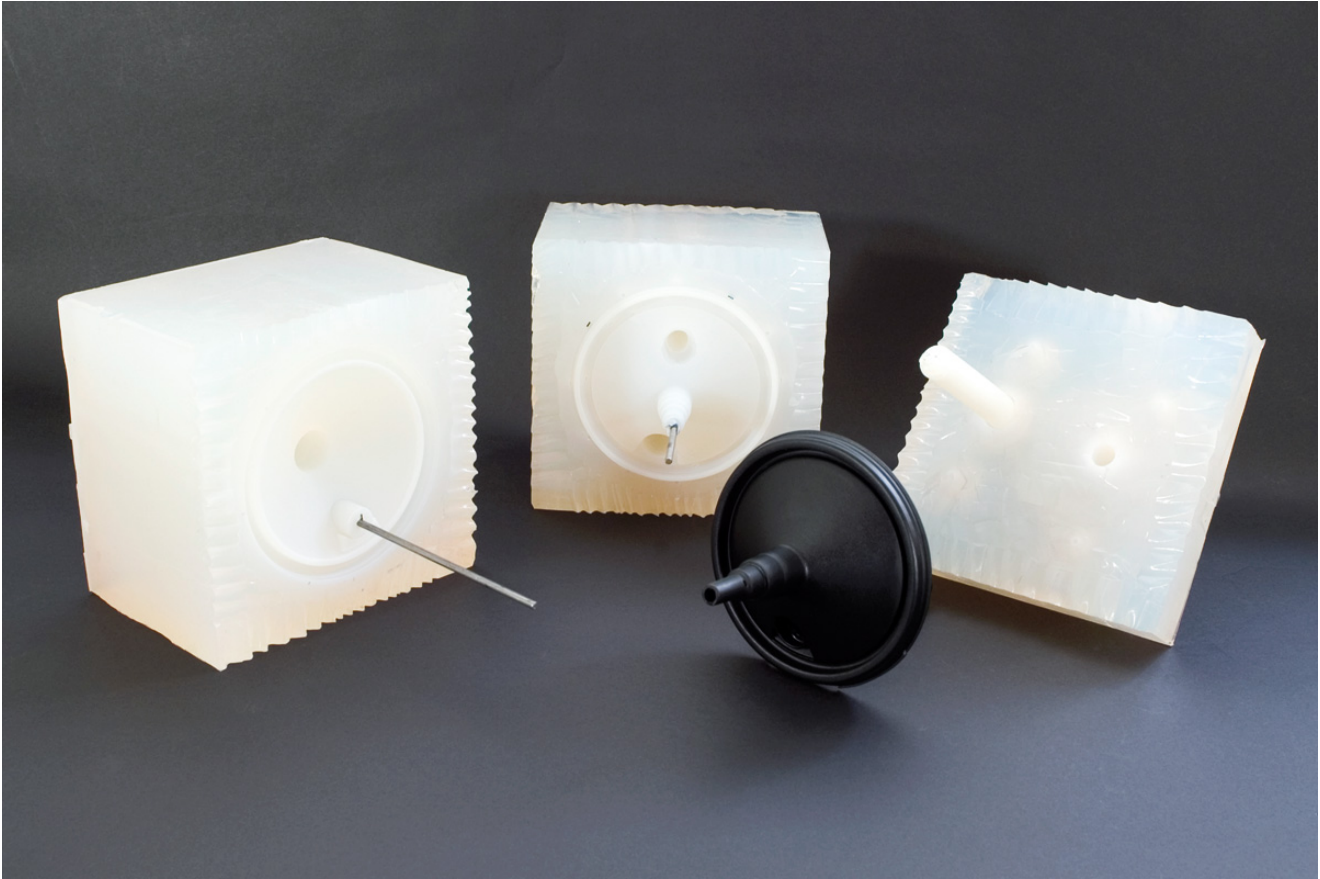
good mechanical properties and chemical resistance. SLS prints can be coloured by painting or alternatively by dyeing the plastic and then bathing the product in a glue to seal the colour in.

The next issue of this Prototyping Knowledge Series will take a deeper look into Vac-Casting and will allow you to easily compare and judge it against the information provided above about SLS printing.

06 Vacuum Casting

Prototyping Knowledge Series Blog

March 11, 2020



In Part 5, 'SLS 3D Printing,' we looked at each consideration for the process, step by step. In this edition of our knowledge series, we'll be discussing the considerations needed for vacuum casting.

Vacuum casting (vac-casting), is a plastic moulding process used to manufacture high quality product prototypes. Vac-casting works by creating a silicone rubber mould using a product master pattern. After the silicone mould is cured in high temperatures, it is cut into sections using a zig-zag cutting technique; the cut is zig-zagged to ensure that when you put the sections together, the mould cavity aligns correctly, Plastic resin is poured in the silicone mould, after which the entire mould is put into a vacuum chamber to ensure that there are no trapped air bubbles.



Use

If you're looking to prototype a complex design, a product that uses soft plastic, or you want to make multiple prototypes, vac-casting is your best bet. Compared to any 3D printing process, vac-cast prototypes have a higher quality and compared to CNC'd prototypes, vac-cast prototypes are less restricted as to what shapes can be made. Furthermore, the moulds can usually be reused up to 5 or 10 times and sometimes even up to 25 or even 50 times.

Quality

Vacuum cast prototypes exhibit physical qualities that are comparable to that of injection moulded products; they aren't as good, but they're closer to than CNC'd or 3D printed ones. This makes them great for functional user or basic mechanical testing and even for marketing or display purposes.

Because the moulds are reusable you're able to repeat fine details such as patterns, dimensions & even textures. You will however notice that the quality does slightly decrease from the first pattern made to the last, until it decreases so much that a new silicone mould is required.

Time

Preparing vac-casting moulds can be a manually intensive and time consuming process depending on the complexity of the product and its' size. Further, the size of the product directly affects the required curing time for which the pattern must sit in the mould. As a result, vac-cast prototypes have a longer lead time – generally looking at around 2 to 3 weeks to produce.

Materials & Cost

Depending on the resin used, or if you use metallic powder or pigment additives, different aesthetic or functional properties can be achieved, including:

- Heat resistance (from 100C up to 140C)
- UV resistance (only if the prototype is coated with a UV resistant paint after it is moulded)
- Flexibility / rigidity
- Softness / hardness
- Clear (can use transparent plastic resin)
- Colours (can tint/colour the resin before it is moulded – or the prototype can be painted once the resin is cured)
- Matte, satin, or gloss surface finish

Sometimes the material you would injection mould your final product from isn't able to be used in the vac-casting process. If this is the case, the closest 'like' material is instead used; this happens with polypropylene products.

Due to the set-up costs, to make one single prototype, vac-casting will be more expensive than 3D printing or CNC'ing. This is because it requires you to make a prototype pattern that is sacrificed to make the mould itself which consequently means that the whole process takes more time and labour. However, because the moulds can be reused to make multiple patterns, your per prototype cost will reduce the more patterns you make; if you're making multiple pattern copies your per prototype cost would be less than if you were using CNC'ing or 3D printing.

By this stage in the knowledge series, you're beginning to understand the world of product prototyping. Stay tuned for the next issue where we'll take a look at SLA & FDM 3D printing!

07 SLA & FDM 3D Printing

Prototyping Knowledge Series Blog

If you've ever looked at buying a desktop 3D printer, chances are it was either a FDM (Fused Deposition Modelling) or a SLA (Stereolithography) one. FDM printers work by extruding molten plastic through a heated nozzle layer by layer to build a 3D object – the 3D printers ALDI sometimes sell, use this technology (See. Image 1 Left). SLA printers instead use a UV laser to cure photopolymer resins into a harden plastic. As each layer is hardened it is lifted out of the resin pool, and then the next layer is cured (See. Image 1).



Image 1: FDM (Left) & SLA (Right) 3D Printers

Use

As product designers, we prototype to prove the mechanics & functionality of the design. Because of the way FDM printer's layer strands of filament, it isn't capable of producing overly accurate or detailed components. This is why designers generally won't use FDM printing to make prototypes. It is however useful for making non-functional models. It is used for this purpose because it is an easy way of testing a conceptual designs form and usability before committing to a design or to more involved prototyping.

Stereolithography printing applications are similar to that of FDM with the addition that SLA allows you to make transparent components (e.g. magnifying glasses). SLA printing is often used for display models or appearance models that require a high quality surface finish but are not required to be functional. Because off the high surface finish, SLA is great for modelling components that have embossed/debossed logos or text.

Quality

Contrary to popular belief, both SLA and FDM 3D prints require support structure. Whilst SLA exhibits better surface quality (See. Image 2), In addition, the bonding forces between layers is much weaker with FDM prints, to a point that layers of the component itself may detach when removing support structure.

- FDM layer thickness ranges between 0.10mm to 0.33mm whilst SLA ranges between 0.05mm to 0.15mm.
- Whilst post processing such as sand blasting, filling, sanding or painting may be required for both types to achieve a better appearance quality,
- FDM requires more processing than SLA.



Image 2: FDM (Left) vs. SLA Surface Quality (Right)

Time

Lead times for 3D printing are quicker than that of CNC'ing or vac-casting. It is achievable to manufacture a product model in as little as 3-5 working days. This will vary depending on the design size and complexity. Lead times will be extended if post-processing is required.

Materials & Cost

FDM is the generally the cheapest 3D printing technology for both the machine and the plastic filament. ABS is the most commonly used plastic, though other filaments are available such as nylon and polycarbonate. Filament prices vary from about \$20 to \$70 per kg.

Just because it is a cheaper technology doesn't necessarily mean that it will be the cheapest model-making or prototyping process for your product design – this is depend on the size, weight and complexity of the design itself.

With SLA, you can get transparent, flexible, or solid prints. Often ABS resin is used for solid components. Transparent resins have to be coated with a UV resistant clear/shiny varnish post-printing to prevent discolouration. Resin cost varies depending on the necessary qualities, it can be as little as \$50 per liter or as much as \$500 per liter.

Having now looked at 3D printing and vac-casting process, our next installment will look and compare them to using CNC machining to manufacture prototypes.

08 CNC Machining

Prototyping Knowledge Series Blog

April 6, 2020



In Issue 5, we looked at SLS 3D Printing, and in Issue 7, we covered both SLA and FDM 3D printing. All of these 3D printing, prototyping, or model-making processes are classified as ‘additive manufacturing.’ In this issue, we’ll look at the opposite, ‘subtractive manufacturing’ process of CNC machining.

Using 3D CAD data, a CNC machine forms a product by using a number of different sized and shaped spindle cutting tools to ‘subtract’ material away from a material block (See. Image 3).

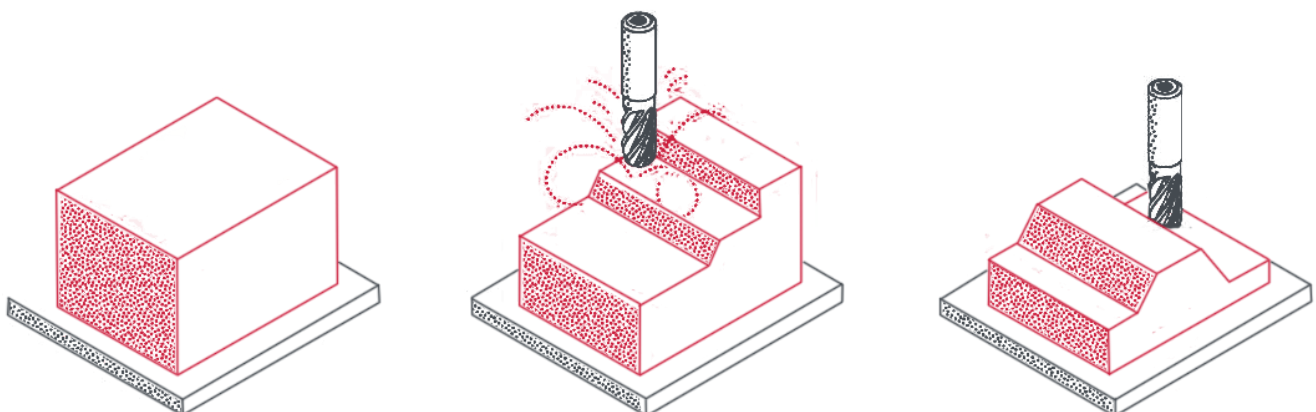


Image 3: CNC Machining Subtractive Manufacturing Process

Pro’s

If you’re looking to create a functional prototype, CNC’ing is a great option. CNC’ing outperforms the accuracy of any 3D printing process:

- It is a lot more accurate;
- CNC'd parts have a much better finish and if they're made from harder plastics, they can also be polished to a high gloss;
- Most CNC plastics can be painted, in some cases producing a finish that is better than an injection moulded part;
- Because the design can be CNC'd in the plastic it will be injection moulded from, CNC'd prototypes are great for physical testing and getting a true feel for what the final product will be like; and
- In some cases it can be as cheap as, or cheaper than 3D printed parts.

Con's

- CNC machines use cutters, alike drill bits, which are round – this means that internal corners will be radiused/rounded; and
- It can be issue if the design has fine details at the bottom of deep pockets – this is because small cutters (1 or 2mm) are required to achieve fine detail. If the detail is at the bottom of a 50mm deep pocket, it couldn't be done as you can't get cutters that small in that length. There is relationship between the diameter and length of cutters that are available.
- A lot of the time this isn't an issue as segments of a design can be CNC'd separately and glued together after;
- It is only an issue if the material slab available isn't long/wide enough or it isn't thick enough – which is rare; and
- Sometimes prototypes will have segments CNC'd separately and glued if the part is too hard to machine, and it makes more sense 'split and glue' it.

To summarise, we highly recommend prototyping using CNC machining. This is because it is accurate, offers many materials to choose from, is cost efficient, and produces prototypes that look like final injection moulded parts. We would do more of these prototypes than any other

Time

CNC'd prototypes have an approximate lead time of 2 weeks. Generally, CNC'ing is quicker than Vac-Casting, but not as quick as some types of 3D printing.