CHAPTER 1
INTRODUCTION

Manufacturing is the production of merchandise for use or sale using labor and machines, tools, chemical and biological processing, or formulation. The term may refer to a range of human activity, from handicraft to high tech, but is most commonly applied to industrial production, in which raw materials are transformed into finished goods on a large scale.

When developing a prototype it's useful to consider the different tools available and the various processes used for producing different parts within a novel design. Prototype production for plastic parts typically falls into one of three buckets: 3D printed parts (otherwise known as "additive" manufacturing), CNC machined parts (otherwise known as "subtractive" manufacturing) and injection molded parts (typically only used for pre-production prototypes).

1.1. ADDITIVE MANUFACTURING

Additive Manufacturing is actually a synonym for 3D printing and/or any process by which 3D objects are constructed by successively depositing material in layers such that it becomes a predesigned shape. Modern 3D printing has always been very useful for rapid prototype development but it is starting to make its impact on the manufacturing world as well.

1.2. SUBTRACTIVE MANUFACTURING

Subtractive manufacturing is a process by which 3D objects are constructed by successively cutting material away from a solid block of material. Subtractive manufacturing can be done by manually cutting the material but is most typically done with a CNC Machine. Advanced CNC machines utilize multiple tools and cut around at least three (x, y, and z) axes such that they minimize the requirement for designers to flip the block. One of the principal advantages to subtractive manufacturing is the ability to machine an extremely thin piece of plastic into a living hinge.

The emergence of on-demand manufacturing is leading more and more manufacturers to give some serious thought to additive manufacturing. However, when it comes to mass production, subtractive manufacturing is always preferred. 3D printing is always recommended for prototyping in plastic but not for metals. Most metal parts are voluminous and therefore take more time to print through 3D printing rather than subtractive manufacturing. Moreover, subtractive manufacturing is cheaper than additive manufacturing in 90 per cent of the cases.

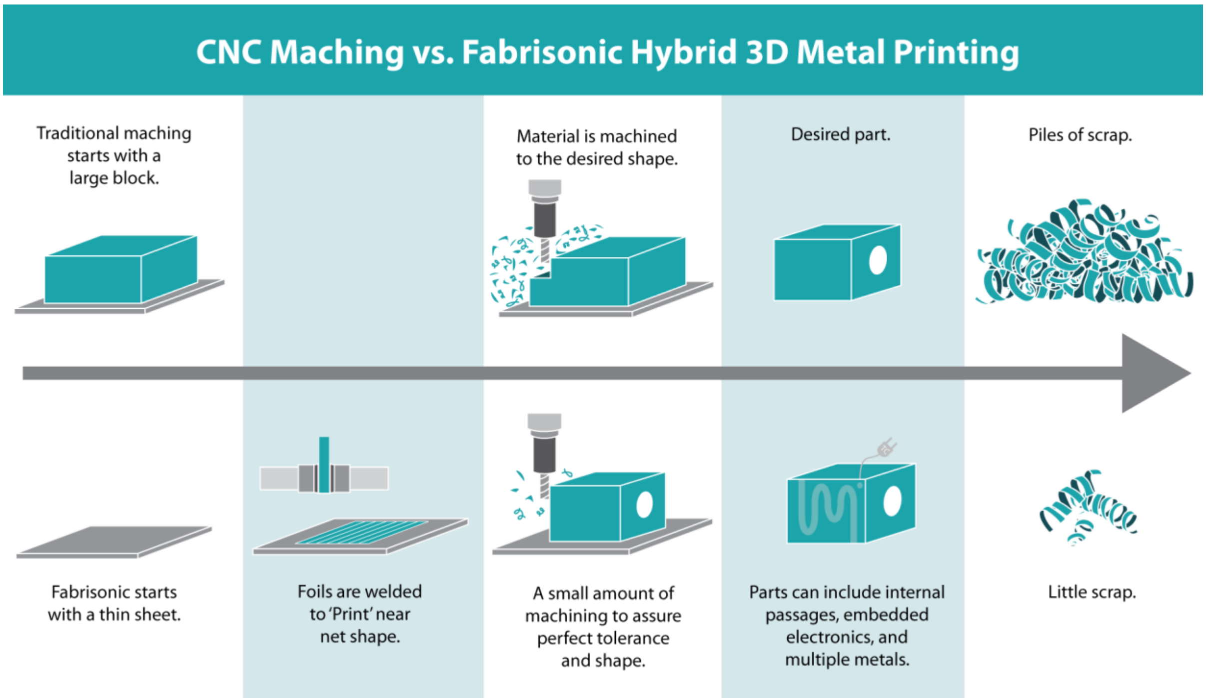

Fig. 1.1: CNC Machining vs. Fabrisonic Hybrid 3D Metal Printing

Fig 1.1 shows the basic differences between CNC Machining (Subtractive Manufacturing) and Fabrisonic Hybrid 3D Metal Printing (Additive Manufacturing). To add to the complexities in the additive manufacturing process, it is constrained by the range of materials available for metal 3D printing. The size of the components also acts as a constraint for 3D printing. Subtractive manufacturing on the other hand is seen as creating a lot of waste in every process. But what sets subtractive manufacturing apart is that most processes are comparatively faster and cheaper for the same level of precision through subtractive manufacturing thus creating a competitive edge. Additive manufacturing, however, is creative and innovative removing barriers to innovative design, improving precision, reducing wastage and creating parts layer by layer. Both additive and subtractive manufacturing have their pros and cons. While subtractive manufacturing has a cost and time advantage and is suitable for mass manufacture, additive manufacturing enables innovative design and is preferred by design engineers who have a more creative outlook towards manufacturing irrespective of cost.

CHAPTER 2
APPLICATIONS OF 3D PRINTING

3D printing is an additive manufacturing process that creates a physical object from a digital design. There are different 3D printing technologies and materials you can print with, but all are based on the same principle: a digital model is turned into a solid three-dimensional physical object by adding material layer by layer.

Every 3D print starts as a digital 3D design file – like a blueprint – for a physical object. Trying to print without a design file is like trying to print a document on a sheet of paper without a text file. This design file is sliced into thin layers which is then sent to the 3D printer.

From here on the printing process varies by technology, starting from desktop printers that melt a plastic material and lay it down onto a print platform to large industrial machines that use a laser to selectively melt metal powder at high temperatures. The printing can take hours to complete depending on the size, and the printed objects are often post-processed to reach the desired finish. Available materials also vary by printer type, ranging from plastics to rubber, sandstone, metals and alloys - with more and more materials appearing on the market every year.

Although 3D printing is commonly thought of as a new 'futuristic' concept, it has actually been around for more than 30 years. Chuck Hull invented the first 3D printing process called 'stereolithography' in 1983. In a patent, he defined stereolithography as 'a method and apparatus for making solid objects by successively "printing" thin layers of the ultraviolet curable material one on top of the other'. This patent only focuses on 'printing' with a light curable liquid, but after Hull founded the company '3D Systems', he soon realized his technique was not limited to only liquids, expanding the definition to 'any material capable of solidification or capable of altering its physical state'. With this, he built the foundation of what we now know today as additive manufacturing (AM) – or 3D printing.

2.1. INDUSTRIAL APPLICATIONS OF 3D PRINTING

i. ***Car Manufacturers***: 3D printing is no stranger to the automotive industry when it comes to both prototypes as well as finished parts. Among others, many Formula 1 racing teams have been using 3D printing for prototyping, testing and ultimately, creating custom car parts that are used in competitive races.

ii. ***Doctors***: The medical and prosthetics field has largely benefited from the adoption of 3D printing. Custom shapes such as hearing aids no longer require manual labor, with 3D printing the can be made with the click of a button. This means substantially lower costs and lower production times.

iii. ***Dentists***: Today, a dental surgeon or orthodontist can now 3D scan a client's jaw and teeth and digitally construct and manufacture custom braces unique to the end user. The dental industry as a whole has fully embraced 3D printing and there are even dedicated 3D printer models designed specifically for manufacturing dental aids and molds.

iv. ***Aircraft Manufacturers***: GE Aviation and Safran have developed a method to 3D print fuel nozzles for jet engines. The technology allows engineers to replace complex assemblies with a single part that is lighter than previous designs, saves weight and boosts a jet engine's fuel efficiency by up to 15%.

CHAPTER 3
FUSED DEPOSITION MODELING

There are several different methods of 3D printing, but the most widely used is a process known as Fused Deposition Modeling (FDM). FDM printers use a thermoplastic filament, which is heated to its melting point and then extruded, layer by layer, to create a three dimensional object.

The technology behind FDM was invented in the 1980s by Scott Crump, co-founder and chairman of Stratasys Ltd., a leading manufacturer of 3D printers. Other 3D printing organizations have since adopted similar technologies under different names. The Brooklyn-based company MakerBot (now owned by Stratasys), was founded on a nearly identical technology known as Fused Filament Fabrication (FFF).

3.1. 3D PRINTING PROCESSES

3D printers that run on FDM Technology build parts layer-by-layer from the bottom up by heating and extruding thermoplastic filament. The process is simple:

i. *Pre-processing*: Build-preparation software slices and positions a 3D CAD file and calculates a path to extrude thermoplastic and any necessary support material.

ii. *Production*: The 3D printer heats the thermoplastic to a semi-liquid state and deposits it in ultra-fine beads along the extrusion path. Where support or buffering is needed, the 3D printer deposits a removable material that acts as scaffolding.

iii. *Post-processing*: The user breaks away support material or dissolves it in detergent and water, and the part is ready to use.

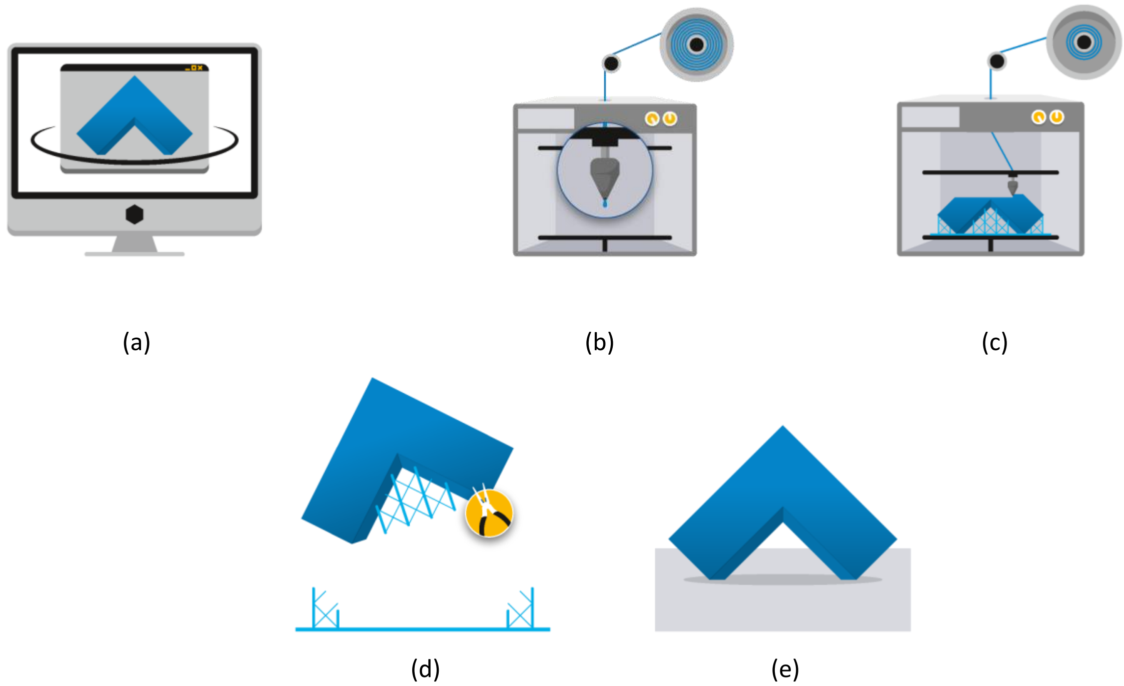

Fig. 3.1: Five Steps in FDM (a) Designing (b) Manual Setting (c) Printing (d) Removal of Support Material (e) Final Product

3.2. ANATOMY OF A 3D PRINTER

The 3D printers that work on FDM technology consist of the printer platform, a nozzle (also called as printer head) and the raw material in the form of a filament.

i. The Printer Platform

The printer platform or the bed is typically made of some metal, ceramic or hard plastic, and each successive layer is deposited on this platform.

ii. Nozzle/Printer Head

The nozzle of FDM printers is attached to a mechanical chassis which uses belt and / or lead screw systems to move it. The entire extrusion assembly is allowed to move in X, Y and Z dimensions by a motorized system. A fourth motor called as the stepper motor is used to advance the thermoplastic material into the nozzle. All the movements of the head and the raw material are controlled by a computer.

iii. The Raw Material

The raw material is typically production grade thermoplastics, though sometimes metal is used as well. The thermoplastic material is capable of being repeatedly melted when exposed to heat and re-solidified when the heat is withdrawn. The thermoplastic filament or metal wire is wound as a coil on a mounted spool. It is then fed through the printer nozzle. The better class of 3D FDM printers allows the temperature of the nozzle to be maintained just close to the glass transition temperature of the material being extruded. This allows the material to be extruded in a semi-liquid state, but return to solid state immediately. This results in a better dimensional accuracy.

iv. Filament

This is the plastic that's consumed by the printer. It comes on a spool. Printers use two different sizes of filament, 1.75 mm and 3 mm. There are a variety of different materials.

v. Extruders

The extruder is the core of the printer. It is where the plastic gets drawn in, melted, and pushed out. It is essentially a fancy hot glue gun. It is small, but it is where most of the printer's technology is located. The extruder consists of two parts: the hot end and the cold end. The cold end has a motor that draws the filament in and pushes it through. The hot end is where the filament gets melted and squirted out.

vi. Power Supply

This takes the 120V AC electricity from the wall and converts it to low voltage DC power for your printer to use.

ATX Power Supplies- These are the same power supplies used in desktop computers. They have been repurposed for use in many printers. They are very beefy and efficient, and have separate lines that provide power at a variety of voltage (12V, 5V, 3.3V).

Voltage - some machines run 12 volt systems, while others run 24 volt systems. This becomes critical if you are going to replace components - especially your heater cartridge or hot end.

vii. Motherboard

The motherboard is the brain of the printer. It takes the commands given to it by your computer (in the form of G-Code) and orchestrates their execution. The motherboard contains a microcontroller (essentially a tiny, self-contained computer) and all the circuitry needed for running the motors, reading the sensors, and talking to your computer. Here is a comparison of the different motherboards we carry.

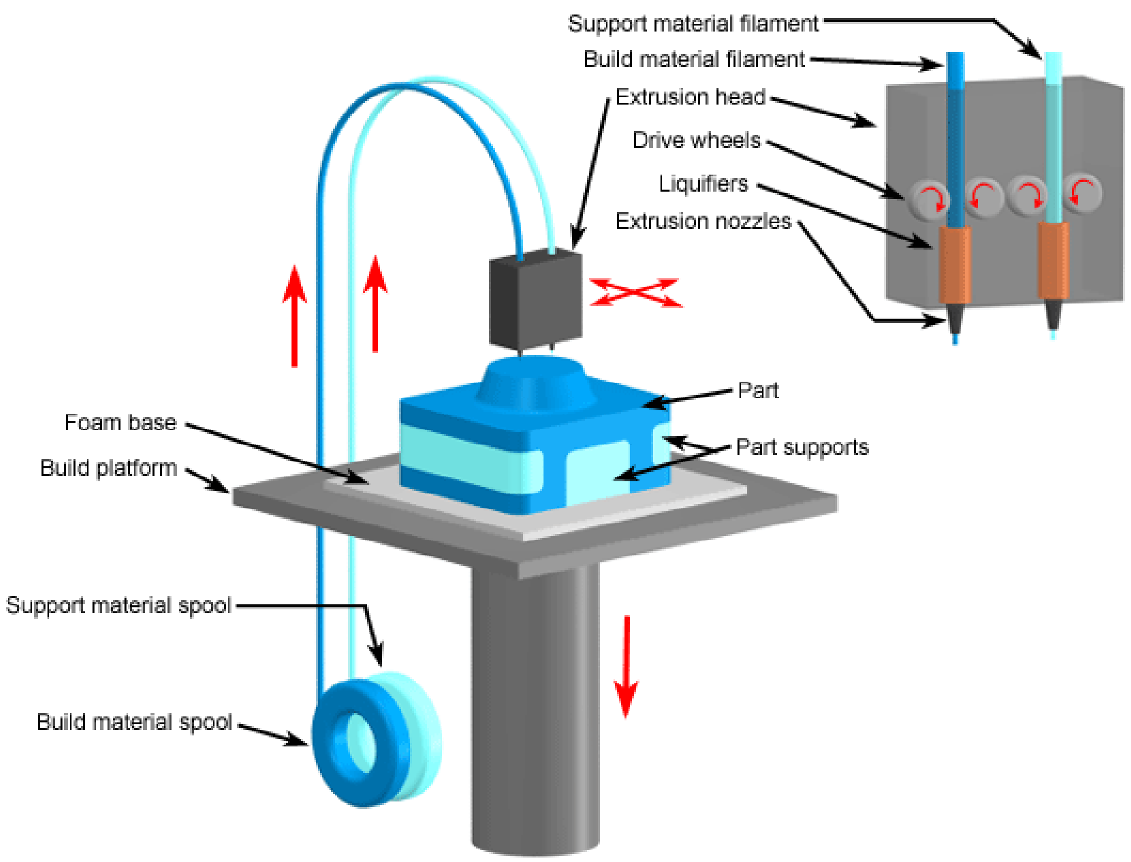

Fig. 3.2: Components of a 3D Printer using FDM

viii. Stepper Drivers

These chips are responsible for running the stepper motors. They fire the coils of the motor in sequence, causing it to move in increments. Many motherboards have the stepper drivers built in, but some also have them in modules that can be unplugged. By balancing the power fed to each coil, the driver is also able to divide steps up into further increments. This is called micro stepping, and allows more precise control over the motor than is normally possible. The stepper driver also controls how much electrical current is fed to the motor.

More power makes the motor stronger, but also makes it run hotter. See this article for more information on adjusting your motor current.

ix. User interface

Some printers have an LCD screen so they can be controlled directly without hooking them up to a computer. These can be basic black and white displays like the VIKI 2 or advanced Wi-Fi enabled touchscreens like the MatterControl Touch.

x. SD Card Slot

Some printers also have an SD card slot from which they can load G-Code files. This allows them to run independently without a computer.

3.3. MATERIAL

FDM printers use two kinds of materials, a modeling material, which constitutes the finished object, and a support material, which acts as a scaffolding to support the object as it's being printed.

The most common printing material for FDM is acrylonitrile butadiene styrene (ABS), a common thermoplastic that's used to make many consumer products, from LEGO bricks to whitewater canoes. Along with ABS, some FDM machines also print in other thermoplastics, like polycarbonate (PC) or polyetherimide (PEI). Support materials are usually water-soluble wax or brittle thermoplastics, like polyphenylsulfone (PPSF)[1].

Thermoplastics can endure heat, chemicals and mechanical stress, which makes them an ideal material for printing prototypes that must withstand testing. And because FDM can print highly detailed objects, it's also commonly used by engineers that need to test parts for fit and form.

CHAPTER 4
FDM - WORKING

4.1. 3D MODELING SOFTWARE

3D modeling software come in many forms. There's industrial grade software that costs thousands a year per license, but also free open source software, like Blender, for instance

3D modeling software are often made to suit the functions of the user's industry. This has resulted in the rise of software suited to specific niches. As a result, there are software applications on the market that cater to aerospace or transportation, furniture design or fabrics and fashion among many others. When you have a 3D model, the next step is to prepare it in order to make it 3D printable.

4.1.1. Slicing

We will have to prepare a 3D model before it is ready to be 3D printed. This is called slicing. Slicing is dividing a 3D model into hundreds or thousands of horizontal layers and needs to be done with slicing software.

Slicing software is a necessary element of 3D printing, because 3D printers cannot translate a CAD drawing by themselves. 3D printers need the specifications of the object you design to be translated into a language which they can interpret.

Basic slicing software – in fact all slicing software – will create paths for a 3D printer to follow when printing. These paths are instructions for geometry, and they tell a 3D printer what speed to print at for various points and what layer thicknesses to adopt – if applicable (sometimes it is best to do this manually). More advanced slicing programs also take into account GD&T (Geometric Dimensioning and Tolerancing)[2]. With this, it is possible to not only create slicer information about the geometry of a part, but to create information about that part's design intent so that the finished part is suitable for longer-term end-use.

Sometimes a 3D model can be sliced from within a 3D modeling software application. It is also possible that you are forced to use a certain slicing tool for a certain 3D printer.

Once a 3D model is designed or simply downloaded off of a repository like Thingiverse, the file (these usually have extensions such as 3MF, STL, OBJ, PLY, etc.) must be converted into something called G-code. G-code is a numerical control computer language used mainly for computer aided manufacturing (both subtractive and additive manufacturing).

It is a language which tells a machine how to move. Without G-code there would be no way for the computer to communicate where to deposit, cure or sinter a material during the fabrication process. Programs such as Slic3r are required in order to convert 3D model files into G-code. Once the G-code is created it can be sent to the 3D printer, providing a blueprint as to what its next several thousand moves will consist of. These steps all add up to the complete fabrication of a physical object. There are other computer languages out there and perhaps many will eventually gain popularity, but for now G-code is by far the most important.

When a 3D model is sliced, we are ready to feed it to the 3D printer. This can be done via USB, SD or Wi-Fi. It really depends on what brand and type 3D Printer we have. When a file is uploaded in a 3D printer, the object is ready to be 3D printed layer by layer.

Fig. 4.1: Slicing

4.1.2. G-Code

G-code (also RS-274), which has many variants, is the common name for the most widely used numerical control (NC) programming language. It is used mainly in computer-aided manufacturing to control automated machine tools. G-code is sometimes called G programming language, not to be confused with LabVIEW's G programming language.

There are a few different ways to prepare GCode for a printer. One method would be to use a slicing program such as Slic3r, Skeinforge or Cura. These programs import a CAD model, slice it into layers, and output the GCode required to print each layer. Slicers are the easiest way to go from a 3D model to a printed part, however the user sacrifices some flexibility when using them. Another option for GCode generation is to use a lower level library like mecode. Libraries like mecode give you precise control over the tool path, and thus are useful if you have a complex print that is not suitable for naive slicing. The final option is to just write the GCode yourself. This may be the best choice if you just need to run a few test lines while calibrating your printer.

G-code is a language in which people tell computerized machine tools how to make something. The "how" is defined by g-code instructions provided to a machine controller (industrial computer) that tells the motors where to move, how fast to move, and what path to follow. The most common situation is that, within a machine tool, a cutting tool is moved according to these instructions through a toolpath and cuts away material to leave only the finished workpiece. The same concept also extends to noncutting tools such as forming or burnishing tools, photo plotting, additive methods such as 3D printing, and measuring instruments.

4.2. SUPPORT MATERIAL

The FDM/FFF processes require support structures for any applications with overhanging geometries. For FDM, this entails a second, water-soluble material, which allows support structures to be relatively easily washed away, once the print is complete. Alternatively, breakaway support materials are also possible, which can be removed by manually snapping them off the part. Support structures, or lack thereof, have generally been a limitation of the entry level FFF 3D printers. However, as the systems have evolved and improved to incorporate dual extrusion heads, it has become less of an issue.

4.3. WORKING

During printing, these materials take the form of plastic threads, or filaments, which are unwound from a coil and fed through an extrusion nozzle. The nozzle melts the filaments and extrudes them onto a base, sometimes called a build platform or table. Both the nozzle and the base are controlled by a computer that translates the dimensions of an object into X, Y and Z coordinates for the nozzle and base to follow during printing.

In a typical FDM system, the extrusion nozzle moves over the build platform horizontally and vertically, "drawing" a cross section of an object onto the platform. This thin layer of plastic cools and hardens, immediately binding to the layer beneath it. Once a layer is completed, the base is lowered — usually by about one-sixteenth of an inch — to make room for the next layer of plastic.

Printing time depends on the size of the object being manufactured. Small objects — just a few cubic inches — and tall, thin objects print quickly, while larger, more geometrically complex objects take longer to print. Compared to other 3D printing methods, such as stereolithography (SLA) or selective laser sintering (SLS), FDM is a fairly slow process.

Once an object comes off the FDM printer, its support materials are removed either by soaking the object in a water and detergent solution or, in the case of thermoplastic supports, snapping the support material off by hand. Objects may also be sanded, milled, painted or plated to improve their function and appearance.

4.4. ADVANTAGES AND DISADVANTAGES

Some of the advantages of 3D Printing using FDM are as follows:

i. Create Complex Designs: 3D printing lets designers create complex shapes and parts – many of which cannot be produced by conventional manufacturing methods. By the natural laws of physics, manufacturing through additive methods means that complexity doesn't have a price; elaborate product designs with complicated design features now cost just as much to produce as simple product designs that follow all the traditional rules of conventional manufacturing.

ii. Customize each and every item: Have you ever wondered why we purchase our clothing in standardized sizes? With traditional production methods, it's simply cheaper to make and sell products at an affordable price to the consumer. Alternatively, 3D printing allows for easy customization; one only needs to change the design digitally to make changes with no additional tooling or other expensive manufacturing process required to produce the final product. The result? Each and every item can be customized to meet a user's specific needs without additional manufacturing costs.

iii. No need for tools and molds, lower fixed costs: When metal casting or injection molding, each part of each product requires a new mold – a factor that can balloon manufacturing costs very quickly. To recoup these upfront manufacturing costs, most companies rely on thousands of the same item being sold. Alternatively, since 3D printing is a “single tool” process there is no need to change any aspect of the process and no additional costs or lead times are required between making an object complex or simple. Ultimately, this leads to substantially lower fixed costs.

iv. Speed and ease of prototyping, faster and less risky route to market: Since there is no expensive tooling required to create objects through 3D printing, it is particularly a cost effective method for designers or entrepreneurs who are looking to do market testing or small production runs – or even launch their products through crowdfunding sites like Kickstarter. At this stage, it is also easy for design changes to be made without compromising more formal – and expensive – manufacturing orders. Thus, 3D printing offers a much less risky route to market for those who are looking into manufacturing a product idea.

v. Less waste: Many conventional manufacturing processes are subtractive: you start with a block of material, cut it, machine it, and mill it until it has been processed as your intended design. For many products – such as a bracket for an airplane – it’s normal to lose 90% of the raw material during this process.

Alternatively, 3D printing is an additive process; you create an object from the raw material layer by layer. Naturally, when an object is manufactured this way, it only uses as much material that is needed to create that particular object. Additionally, most of these materials can be recycled and repurposed into more 3D printed objects.

Even then there are some disadvantages of 3D Printing using FDM

i. Higher cost for large production runs: Despite all of the benefits of manufacturing through additive methods, 3D printing is not yet competitive with conventional manufacturing processes when it comes to large production runs. In most cases, this turning point is between 1,000 to 10,000 units, depending on the material and the design. As the price of printers and raw materials continue to decrease, however, the range of efficient production is expected to increase further.

ii. Less material choices, colors, finishes: Despite there being more than six-hundred 3D printing materials available today – most of which are plastics and metals – the choices are still limited compared to conventional product materials, colors and finishes. However, this field is rapidly catching up, the number of new materials added to the 3D printing palette is growing rapidly every year including wood, metals, composites, ceramics, and even chocolate.

iii. Limited strength and endurance: In some 3D printing technologies the part strength is not uniform due to the layer-by-layer fabrication process. As such, parts that have been 3D printed are often weaker than their traditionally manufactured counterparts. Repeatability is also in need of improvement as well; parts made on different machines might have slightly varying properties. However, as technical improvements continue to be made on new continuous 3D printing processes like Carbon3D, these limits will likely to vanish in the near future.

iv. Lower precision: Although we may not be able to 3D print objects that have cutting edge tolerances like an iPhone, 3D printing is still a very capable method of creating objects at a precision of around 20-100 microns – or about the height of a single sheet of paper. For users who are creating objects with few tolerances and design details, 3D printing offers a great way for making products real. For objects requiring more working parts and finer details – such as the silent switch on the iPhone – it’s difficult to compete with the high precision capabilities of certain manufacturing processes.

CHAPTER 5
PRODUCTS

i. Arc Bicycle

People in the Netherlands will soon be able to cycle over the world's first 3D-printed steel bridge on the world's first 3D-printed steel bicycle.

The Arc Bicycle was designed by a student team at TU Delft and 3D-printed from steel by MX3D – the research studio that plans to use the same technique to create a bridge over a canal in Amsterdam.

Created as part of the six-month Advanced Prototyping course at the university, the bicycle's frame is made from a metal lattice welded in layers by robots.

Fig. 5.1: Arc Bicycle

MX3D's six-axis robotic arms allow metals and resins to be printed mid-air in any direction, without the need for support structures. "3D printing has exploded in popularity in the last decade, but for those wanting to print medium- to large-scale objects there are still significant limitations in the technology," said Harry Anderson from the 3D Building FieldLab team at TU Delft, also known as the Delft University of Technology.

"This method of 3D printing makes it possible to produce medium- to large-scale metal objects with almost total form freedom," he added.

The team, led by project coordinator Jouke Verlinden, claims that its bicycle is the first to be fabricated using this process. The vehicle weighs around the same as a standard steel bike, and its frame can withstand rides over cobbled streets.

"It was important for us to design a functional object that people use every day. Being students in the Netherlands, a bicycle naturally came to mind," said team member Stef de Groot. "A bicycle frame is a good test for the technology because of the complex forces involved."

Laarman told Dezeen that their printing technique could be used to produce "endless" different structures in an exclusive movie. 3D-printing has previously been used to create a lightweight titanium alloy frame for a bicycle, and aluminium parts for a wooden bike.

ii. 3D Printed UAV

Aurora Flight Sciences, a Virginia-based manufacturer specializing in advanced unmanned aerial vehicle (UAV) systems, is pushing the envelope of UAV design by teaming up with Stratasys to create the world’s first jet-powered, 3D printed aircraft.

Aurora’s UAV demonstrates Stratasys' FDM-based 3D printing solutions ability to build a completely enclosed, hollow structure which, unlike other manufacturing methods, allows large – yet less dense – objects to be produced

Using 80% 3D printed parts, the UAV is composed of Stratasys’ ULTEM™ 9085 lightweight material to achieve flight speeds of over 150 mph. The high-speed system boasts an impressive 9-foot wingspan and weighs in at only 33 lbs. Dan Campbell, Aerospace Research Engineer at Aurora Flight Sciences, explains how the UAV project met a number of goals using Stratasys 3D printing solutions.

“A primary goal for us was to show the aerospace industry just how quickly you can go from designing and building to flying a 3D printed jet-powered aircraft. To the best of our knowledge, this is the largest, fastest, and most complex 3D printed UAV ever produced.”

Fig. 5.2: Aurora's UAV demonstrates Stratasys' FDM-based 3D printing solutions ability to build a completely enclosed, hollow structure which, unlike other manufacturing methods, allows large – yet less dense – objects to be produced

Stratasys 3D printing solutions provided Aurora with unlimited design freedom and the capability to improve upon the design without the constraints of traditional manufacturing [3]. Aurora was able to reduce time-to-market by cutting design and build time by 50% using Stratasys' Fused Deposition Modeling (FDM) 3D printing technology.

Another advantage of employing Stratasys 3D printing was the ability to produce the structural components using high-performance ULTEM thermoplastic. ULTEM has become a popular choice for a variety of aerospace applications. Meeting FAA's flame, smoke and toxicity (FST) requirements, it offers the greatest durability and highest heat and chemical resistance of any FDM thermoplastic. Additionally, ULTEM's lightweight mechanical properties provide ideal conditions for aerospace operations.

iii. Cortex Cast

3D-printed casts for fractured bones could replace the usual bulky, itchy and smelly plaster or fibreglass ones in this conceptual project by Victoria University of Wellington graduate Jake Evill. The prototype Cortex cast is lightweight, ventilated, washable and thin enough to fit under a shirt sleeve.

A patient would have the bones x-rayed and the outside of the limb 3D-scanned. Computer software would then determine the optimum bespoke shape, with denser support focused around the fracture itself.

The polyamide pieces would be printed on-site and clip into place with fastenings that can't be undone until the healing process is complete, when they would be taken off with tools at the hospital as normal. Unlike current casts, the materials could then be recycled.

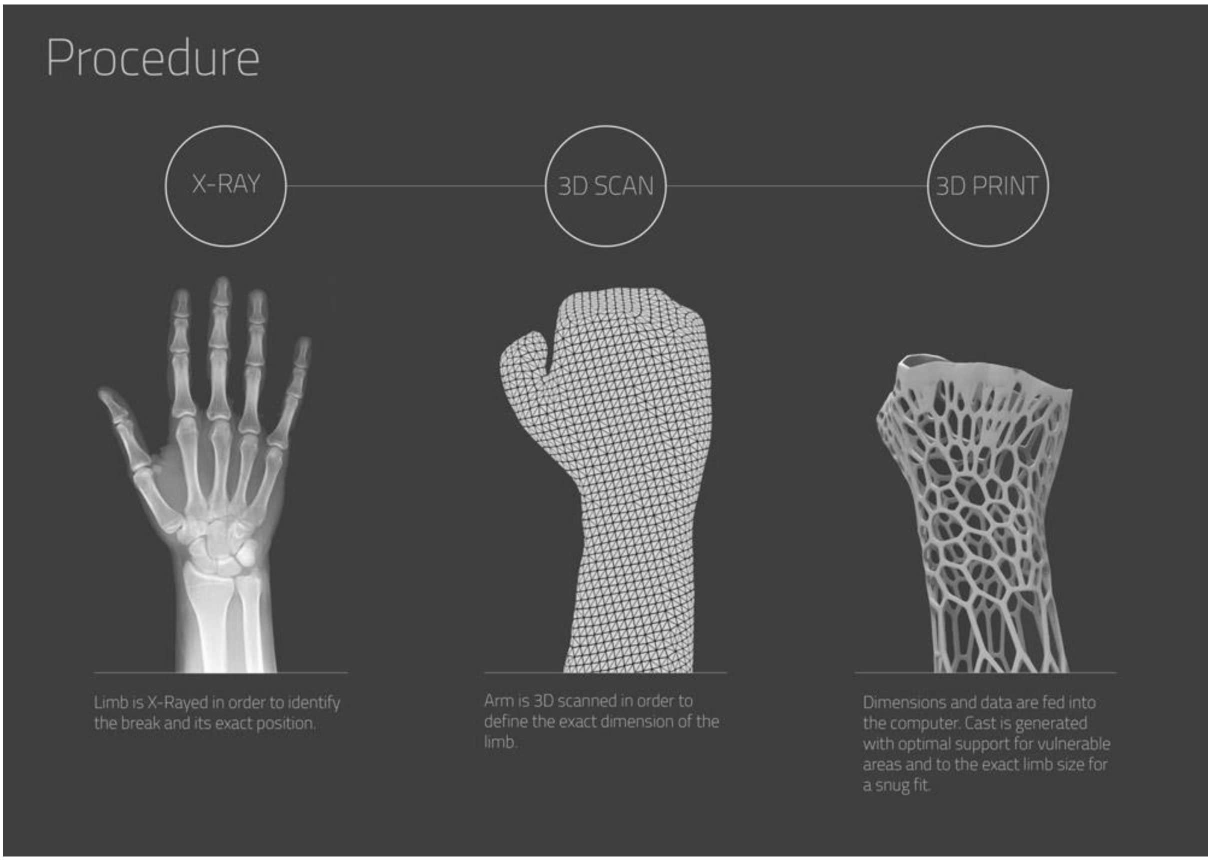

Fig. 5.3: Procedure - Manufacturing of Cortex exoskeleton

"At the moment, 3D printing of the cast takes around three hours whereas a plaster cast is three to nine minutes, but requires 24-72 hours to be fully set," says the designer. "With the improvement of 3D printing, we could see a big reduction in the time it takes to print in the future."

He worked with the orthopaedic department of his university on the project and is now looking for backing to develop the idea further.

The Cortex exoskeletal cast provides a highly technical and trauma-zone-localised support system that is fully ventilated, super light, shower friendly, hygienic, recyclable and stylish. The Cortex cast utilizes the x-ray and 3D scan of a patient with a fracture and generates a 3D model in relation to the point of fracture.

CHAPTER 6
CONCLUSION

The worldwide 3D printing industry is expected to grow $12.8Billion by 2018, and exceed $21Billion by 2020 in revenue. Given the huge bank of opportunities in this sector and the rapid development of this technology, we can say with a sense of certitude that 3D printing will soon take over many more industries in the near future. Considering the prediction, startups and entrepreneurs in India are seeing immense potential in 3D printing technologies.

Imagine printing a new valve for a broken water faucet or a new plate when your five-year-old drops the good dishes. Imagine not being limited by commercial pipe sizes or designs requiring individual pieces that can be fit together by current commercial equipment. Imagine custom creating every gift given to each friend or family member to incorporate favorite song lyrics, literary quotations, inside jokes, or photographs. This world isn’t yet a reality, but it’s getting closer every day thanks to advancements in the field of rapid prototyping and 3-dimensional printing.

Several projects and companies are making efforts to develop affordable 3D printers for home desktop use. Much of this work has been driven by and targeted at DIY/enthusiast/early adopter communities, with additional ties to the academic and hacker communities.

The cost of 3D printers has decreased dramatically since about 2010, with machines that used to cost $20,000 now costing less than $1,000. For instance, as of 2017, several companies and individuals are selling parts to build various RepRap designs, with prices starting at about GB£99 / US$100. The bestselling desktop FDM printer, Prusa i3 MK2, costs US$900 assembled or US$600 for self-assembly kit.

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