Pearson BTEC Level _ Higher Nationals in Engineering (RQF)

Unit 50: Advanced Manufacturing Technology

Unit Workbook 1

in a series of 2 for this unit

Learning Outcome 1 & 2

Advanced Manufacturing Processes & Technologies

Contents

INTRODUCTION

Recognise a range of advanced manufacturing processes to cite examples of where they are most effective.

- *Manufacturing Processes:*
  - Pressing and forming, casting and moulding, joining and soldering, mixing, final assembly, packaging, material handling, quality control/inspection.
- *Advanced Manufacturing Processes:*
  - Additive manufacturing technology (e.g. replacing forming, moulding, pressing), 3D printing, impact on rapid prototyping, availability of spares/obsolete parts, medical components available and customised.
  - Mass customisation through 3D printing, opening up a self-serve market.
  - Robotics/human interface and automation, high-precision technology and productivity e.g. aerospace, automotive, electronics assembly.
- *Types of Application or Industry:*
  - Industry examples: aerospace, automotive, healthcare, electronics, food and beverage, chemical and pharmaceutical, minerals, oil and gas, retail, fashion.
  - Application examples: assembly, joining, moulding, soldering.

Analyse advanced manufacturing technologies to determine their appropriateness for an application or process.

- *Manufacturing Technologies:*
  - High precision robotics and automation: healthcare (components and processes), aerospace, automotive, process control and visualisation through automation technology.
  - Improvement in productivity through greater automation.
  - Quality of manufacturing processes improved through integration of robotics.
  - Examples of using 3D printing and other forms of additive manufacturing to produce medical equipment, spare parts for items that may have become obsolete, mass customisation; what the customer wants, when they want it.

GUIDANCE

This document is prepared to break the unit material down into bite size chunks. You will see the learning outcomes above treated in their own sections. Therein you will encounter the following structures;

Purpose

Explains *why* you need to study the current section of material. Quite often learners are put off by material which does not initially seem to be relevant to a topic or profession. Once you understand the importance of new learning or theory you will embrace the concepts more readily.

Theory

Conveys new material to you in a straightforward fashion. To support the treatments in this section you are strongly advised to follow the given hyperlinks, which may be useful documents or applications on the web.

Example

The examples/worked examples are presented in a knowledge-building order. Make sure you follow them all through. If you are feeling confident then you might like to treat an example as a question, in which case cover it up and have a go yourself. Many of the examples given resemble assignment questions which will come your way, so follow them through diligently.

Question

Questions should not be avoided if you are determined to learn. Please do take the time to tackle each of the given questions, in the order in which they are presented. The order is important, as further knowledge and confidence is built upon previous knowledge and confidence. As an Online Learner it is important that the answers to questions are immediately available to you. Contact your Unit Tutor if you need help.

Challenge

You can really cement your new knowledge by undertaking the challenges. A challenge could be to download software and perform an exercise. An alternative challenge might involve a practical activity or other form of research.

Video

Videos on the web can be very useful supplements to your distance learning efforts. Wherever an online video(s) will help you then it will be hyperlinked at the appropriate point.

1.1 Manufacturing Processes

In order to consider advanced manufacturing, one must consider manufacturing that is not considered as advanced, that is to say, the common, traditional methods of manufacturing which are still being utilised today. It is necessary to do this so that one can distinguish the differences between traditional and advanced manufacturing, as well as to recognise the development of manufacturing throughout time and how advanced technologies are impacting and building upon on these traditional processes.

1.1.1 Pressing and Forming

Pressing and forming are a group of processes which are commonly used to create parts from sheet or bulk metal or plastic, through means of mechanical deformation.

In the case of bulk material, there are several common forming processes, each resulting in severe deformation, there are extremely high forces involved in each and this bulk forming is usually undertaken under hot working conditions, this is usually always the case with plastics.

Where sheet material is concerned, there is a set of several different processes which can be deployed, depending on the desired final form and shape of the product.

Some of the basic bulk and sheet forming processes are depicted below:

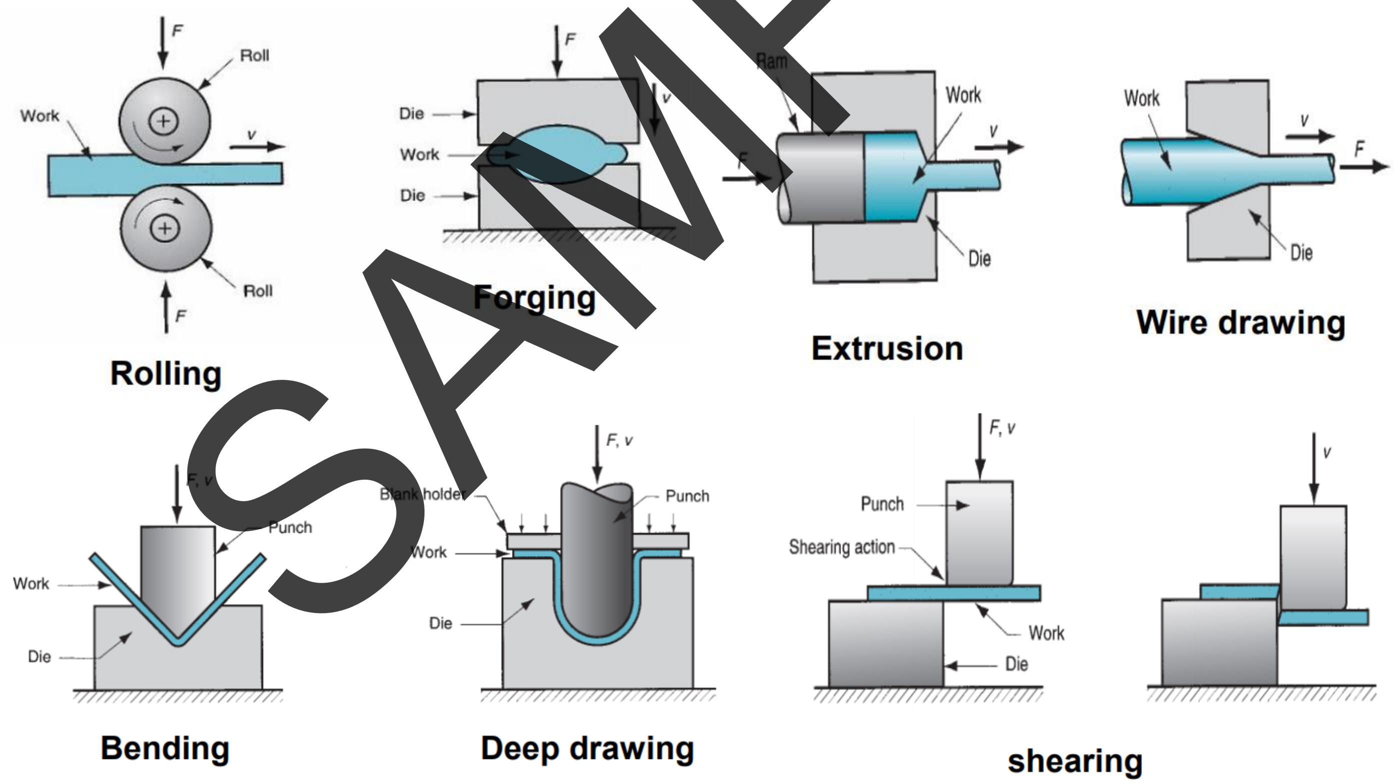

Figure 1.1: *Bulk & Sheet Forming Processes*

There are also numerous types of metal casting commonly in use, as detailed below:

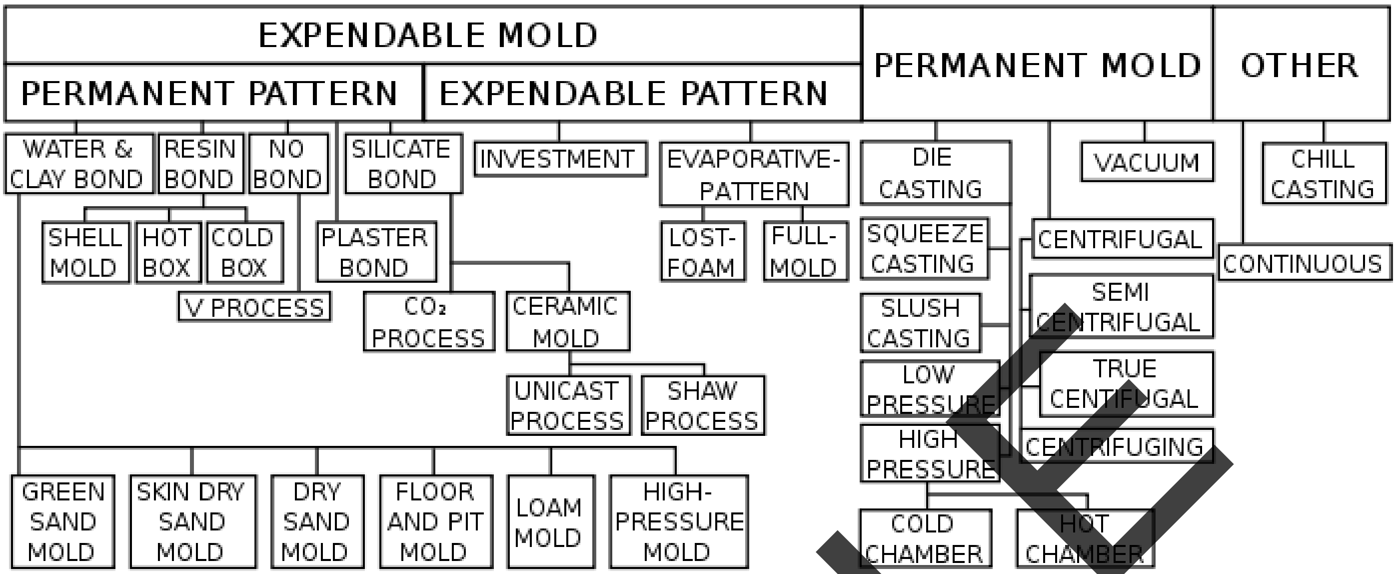

Figure 1.3: *Metal Casting Processes*

1.1.3 Joining and Soldering

In manufacturing, the joining of materials is an integral part of the process overall: parts and components are produced which require joining together and, depending on the situation and application, different joining methods may be used.

Broadly speaking, there are three categories of joining, they are: mechanical joining, welding and adhesive. There are several advantages and disadvantages to each method and often, they are actually combined to bring together the best assets of each method.

The mechanical joining process includes fastening and/or clamping via nuts, bolts, screws, interlocks and rivets. It can be used across all material groups, between similar or dissimilar materials and produces good versatility, usability and dismantlability, which is particularly useful where periodic maintenance is required. However, mechanical processes do have disadvantages because, by their nature, they have to create holes in order to join.

Soldering is a term applied to a process of joining two, usually metal, components together via the use of a filler material and it is very commonly used in the electronics industry. It is similar to the process of welding, however, differs in one major way: in welding, the two workpieces to be joined are heated and the edges are actually melted, whereas in soldering, the workpieces are not heated.

There are many different types of welding, commonly in use today, see the welding processes chart below:

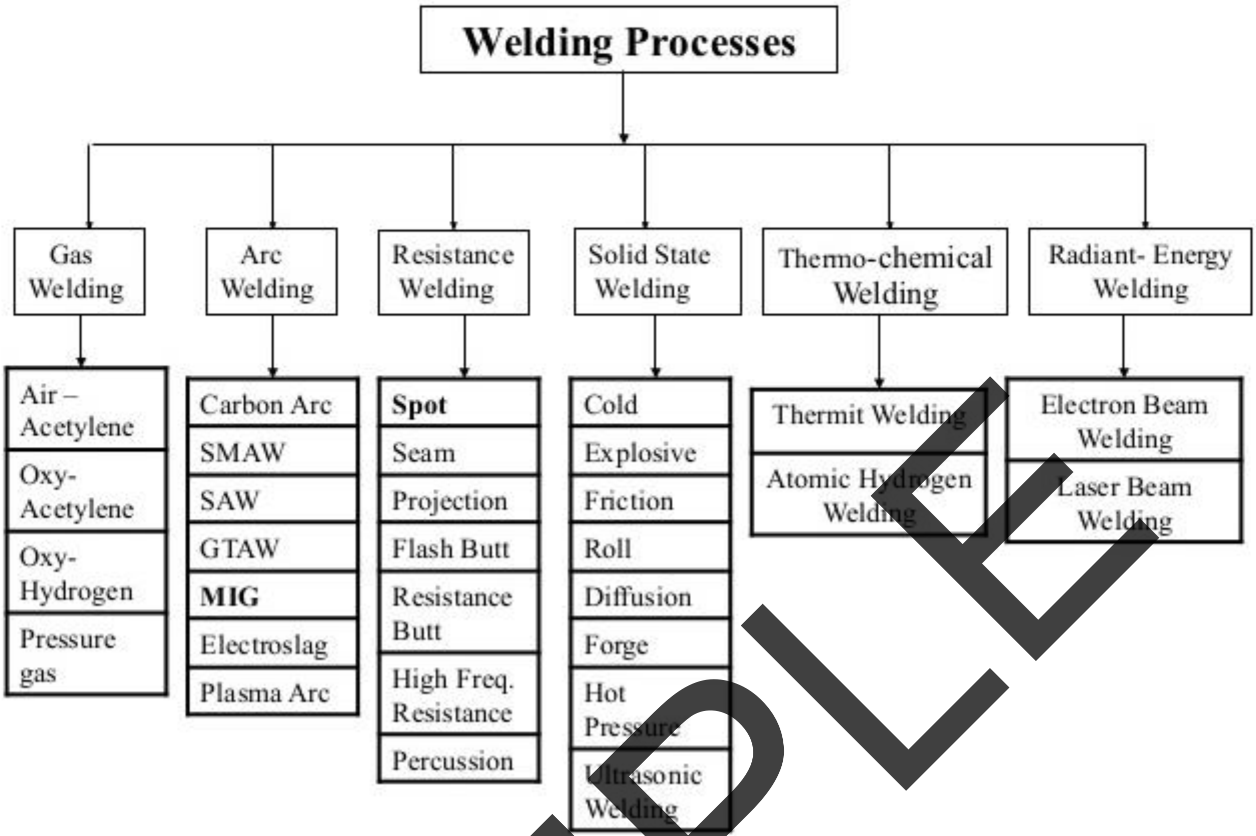

Figure 1.3: *Welding Processes*

Adhesives may also be used to bond materials together; this method of joining can be used to bond dissimilar metals together however it does have a weakness in regard to the joints peeling apart.

1.1.4 Mixing

The process of mixing in engineering refers to action of creating a uniform substance, usually in terms of its composition. A common example can be seen in a swimming pool, whereby the pumps serve the purpose of mixing the water to maintain a consistent temperature across its entire volume. In industry, mixing is frequently utilised in order to mix two liquids, two solids, a liquid and a solid, a liquid and a gas or a solid and a gas.

Figure 1.4: *Industrial Mixing Representation*

1.2 Advanced Manufacturing Processes

1.2.1 Additive Manufacturing

Traditional manufacturing processes tend to rely on forming through mechanical deformation and removal of material, whereas additive manufacturing processes takes a strikingly different approach. It offers several advantages, improved performance, complex geometry and simple fabrication and, contrary to some opinions, has actually been in use for many years.

The main idea of additive manufacturing is that it 'grows' 3D objects layer by layer, with each of these layers being bonded to the previous, with both being partially melted. There are several categories of additive manufacturing, and it is useful to know some of the key differences.

Material Extrusion: This well-known method is often though of as '3D printing', however the term also applies to several other process as well. Usually a polymer is stored on a spool and fed or drawn through a heated nozzle, depositing melted material onto a bed. The nozzle is mounted to an arm which moves in either 2 or 3 axes and the bed may also move or indeed be heated too.

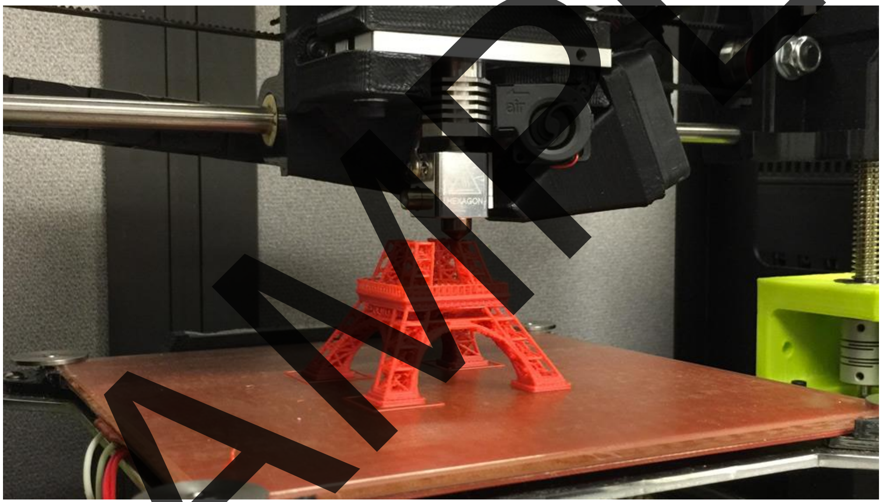

Figure 1.8: *3D Printing the Eiffel Tower*

Directed Energy Deposition: This is a similar method to material extrusion, however normally it can be used with a wider selection of materials, such as ceramics and metals. Additionally, the stock material is melted by an electron beam gun or laser.

Sheet Lamination: There are two common sheet lamination methods, ultrasonic additive manufacturing (UAM) and laminated object manufacturing (LOM). With UAM, thin metal sheets are bonded using ultrasonic welding, whereas with LOM, layers of paper and adhesive are alternated. There are advantages to each method, LOM is very quick and relatively inexpensive, ideal for aesthetic modelling and UAM itself is actually relatively low temperature and can be used with several different metals.

Vat Polymerisation (Stereolithography): This method uses a vat of liquid resin to create a 3D object, each resin layer is cured using ultraviolet light directed via mirrors, which causes a process called polymerisation to occur, resulting in precisely controlled cured microfine layers.

Powder Bed Fusion (Sintering): There are some subcategories of the powder bed fusion technique, each one uses either thermal, electron beam or laser print heads to either partially or fully melt material in a 3D space, one very fine layer at a time.

Figure 1.9: *Gear Produced via Metal-Sintering*

Material Jetting and Binder Jetting are similar processes which are loosely based on a 2D inkjet printer head, the head moves in three axes and the layers harden as they are cured by UV light or just cool naturally. Binder Jetting maintains the distinct difference of layering powder material with a liquid binder.

All of these additive manufacturing processes are sometimes used to produce end-use products, however they are currently more often utilised in rapid prototyping applications, due to the speed at which they can be applied and their flexibility. However, structural and surface finish properties of products produced via additive manufacturing are improving, meaning that they are becoming more common processes for end-use products.

Additive manufacturing negates the need for moulds, forming, pressing and other labour-intensive processes, common to traditional manufacturing techniques. As the technology is improving, its range of application widens, and many speculate that we may even be able to print human tissue one day.

1.2.2 3D Printing

At this moment in time printing people is not quite a reality, however there are many useful applications for 3D printing in general. There are many effects that 3D printing is having on manufacturing currently, both positive and negative:

Advantages:

When making a prototype part manually, there are associated risks that come with this, consider the PPE that must be worn when machining a block of material, bending a tube. With 3D printing, the human element of manufacture is severely reduced, meaning that their chances of injury are also severely reduced.

With any new technology and process, comes the demand for qualified workers to design, use, maintain and repair the associated machines. Other demands for product and engineering designers will also increase, as the demand for 3D-printed products increases, as well as associated services.

Video

Some examples of automation in industry can be seen below:

https://www.youtube.com/watch?v=cLVCGEmkJs0

https://www.youtube.com/watch?v=otE6CnFUXDA

https://www.youtube.com/watch?v=vv1mFAMz0PE

The following video gives an excellent overview of the current wave of automation currently occurring in industry, focusing specifically on China in this example:

https://www.youtube.com/watch?v=HX6M4QunVmA

1.2.4 Types of Application & Industry

There are many areas of industry which use advanced manufacturing processes, many utilise additive manufacturing and its usage by industry can be seen below:

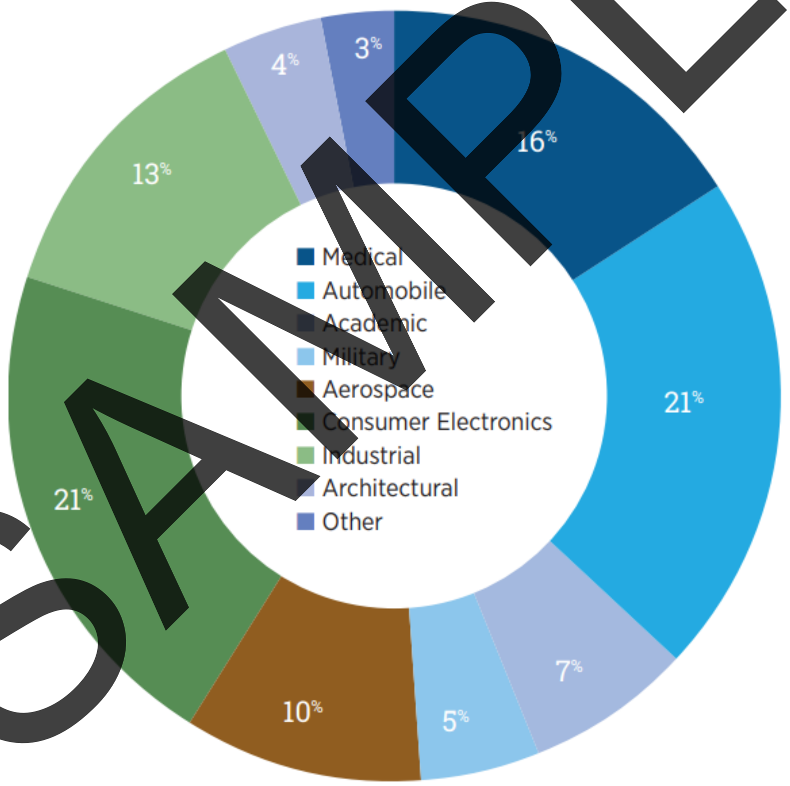

Figure 2.6: *Revenue Split of A.M. Equipment Customers.*

(Source: Wohlers Report, 2013).

Some typical examples of advanced manufacturing will be examined below:

Aerospace: Within this industry there are several advanced manufacturing technologies usually employed. Firstly, additive manufacturing (A.M.) is a very useful technique because of the complicated and unusual geometries that can be produced, as well as the advanced materials which can be used.

In aerospace, weight is an incredibly important issue and therefore additive manufacturing can offer another advantage by producing lattice-type structures which maintain strength and reduce weight compared to traditional processes.

Additionally, A.M. is capable of producing only one part whereby other methods may need to produce more than one in order to suit the application. This reduction in the number of parts helps to simplify assembly and means that the potential number of failure points is reduced.

Figure 2.7: *Aerospace Component Produced using A.M.*

Aerospace also tends to use advanced composite materials, because of their superior strength-to-weight properties compared to traditional materials. Robotics are commonly used in aerospace manufacturing for a variety of tasks, including lifting and handling, inspection, drilling, dispensing, sealing, fastening, painting and welding. Whilst, laser welding and machining is also deployed robotically as an efficient and low waste alternative to other labour-intensive processes.

Figure 2.8: *Laser-Beam Welding*

Automotive: As in the aerospace industry, automotive companies are beginning to use additive manufacturing to offer complicated geometries, light-weight components and faster development cycles. There are many real-life examples of 3D printed metal parts, one can be found on the 2020 Ford Shelby Mustang GT500, this car actually includes two 3D printed brake components as standard. The BMW i8 Roadster also uses 3D printing to produce a window guide rail, which is used on its current vehicles.

Figure 2.9: *3D Printed Window Guide Rail for BMW*

There are other examples of the technology being used as well, both Porsche and Mercedes-Benz have used 3D printing to produce some obscure replacement components.

Many of the large automotive companies are currently investing heavily in additive manufacturing, and some have actually been using the technology for several years but have not disclosed any details. BMW, Ford, Honda, Volkswagen, Porsche, Toyota, and many others have all been focusing on developing their in-house A.M. operations. Car production plants commonly use robotics for certain tasks such as painting, spot welding and assembly. As discussed throughout this unit, there are many advantages of using robotics in place or as well as human workers: safety, quality and capacity being the main factors.

Figure 3.1: *Spot-Welding in Car-Assembly*

Healthcare: Within this industry, there are some very well documented cases of additive manufacturing being utilised, advantages are similar to within other industries however there are additional factors to be considered. Artificial limbs are being produced using 3D printing, the most common types being hand and arms, whilst legs and even facial portions are possible.

Figure 3.2: *3D Printed Prosthetic Leg*

These prosthetics are essentially passive supports; however, it is possible through the use of advanced robotics to produce bionic limbs and body parts which can be controlled through electrical brain impulses. (See the video below).

Video

https://www.youtube.com/watch?v=sk1NkWl_W2Y

Electronics: Again, additive manufacturing is a popular area of development in this industry too. It is actually possible to 3D print electronic circuit boards through the use of a particular substrate which contains conductive ink.

One of the other key advances in technology in electronics, as well as other industries, is Graphene, this two-dimensional substance is an allotrope of carbon, which is approximately 200 times stronger than steel, very thin, flexible, lightweight, as well as being an excellent heat, light and electrical conductor. There are several other new materials and substances which are under development in the electronics industry, such as smart-glass, biochips, carbon nanotubes, silicon carbide, quantum dots and flexible batteries.

Fashion: Within the fashion and textiles industry, there are several advances in manufacturing and technology which have led to new and innovative approaches. Wearable technology is a growing sector,