Airframes – Instructor Training Manual

Chapter 3 – MANUFACTURING TECHNOLOGY

Learning Objectives

1. The purpose of this chapter is to discuss in more detail, the tools and processes technology that is utilised in the manufacture and assembly of an airframe.

2. By the end of the lesson you should have an understanding of some of the processes, techniques and tools used in the manufacture of the component parts of an airframe.

So what is Manufacturing Technology?

3. Manufacturing technology (or 'Man Tech') provides the tooling required to enable the production of all manufactured goods. These magnify the effort of individual workers and provide the power to turn raw materials into finished and functioning products.

4. Production tools include machine tools and other related equipment and their accessories and tooling.

5. Machine tools are non-portable, power-driven manufacturing machinery and systems used to perform specific, whilst Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM) as well as assembly and test systems are often used in modern manufacturing to create a subassembly or final product.

6. For the purposes of this subject, Manufacturing Technology can be broken down into the following sub-sets.

- Material removal and tooling
- Material forming
- Additive processes
- Controls/Software
- Plastics technology

Material Removal and Tooling

5. The vast majority of tools and techniques within Manufacturing Technology fall within 'machining processes' and perhaps form the basis of the public perception of 'Manufacturing'.

This can range from the simple hand saw through to laser cutters. The tools and techniques most likely to be used in the manufacture of aircraft structures are;

- Turning

- Boring
- Cutting
- Broaching
- Milling
- Grinding
- Drilling
- Electrical Discharge Machining

Cutting

8. Cutting is the most common material removal and machining processes and is typically achieved using a cutting blade with heat treated hardened teeth to cut through (or 'Saw') the workpiece.

9. Cutting can also be achieved through the use of a high velocity jet of ionised gas that conducts electricity. This technology is referred to as a '*Plasma Cutter*'.

The plasma locally heats the workpiece, melting material and allows the operator to produce complex cut-outs.

Drilling

10. Like cutting, drilling is one of the most common material removal and machining processes. It is estimated that over two-thirds of all metal-cutting material removed comes from drilling operations.

11. Drilling is an operation that uses a heat treated hardened rotating tool to produce a round hole in a workpiece. This is accomplished most typically by using a twist drill and is generally performed before machining operations such as boring, reaming, tapping, counterboring, countersinking and spotfacing.

Turning & Boring

12. Turning is another of the basic machining processes and produces solids of revolution which can be tightly toleranced because of the specialized nature of the operation and the machinery used.

13. The process of turning is accomplished on a machine called a *'Lathe'* in which the work piece is mounted on the chuck, which rotates relative to the stationary tool to be used. Turning machines can be used to enlarge drilled or cored holes – this process is referred to as *'Boring'*.

Grinding

14. Grinding is a *'finishing'* process used to improve the surface finish, abrade hard materials, and tighten the tolerance on flat and cylindrical surfaces by removing a small amount of material.

15. In grinding, an abrasive material rubs against the component to remove material and is typically on the surface of a wheel or belt. As this process relies on friction, excessive heat is produced during the grinding process, which requires the use of fluid within the cutting area to prevent the workpiece becoming damaged or distorted.

Milling

16. Milling is as fundamental as drilling among the powered metal cutting processes and uses a rotating cutter that is moved laterally to remove material from the workpiece.

17. Milling is versatile for a basic machining process, but because the milling set up has so many degrees of freedom, milling is usually less accurate than turning or grinding. For manual machining, milling is essential to fabricate any object that is not *'axially symmetric'*.

18. In airframe manufacture, a number of the components will be milled from a solid billet of aluminium – this includes wing ribs and machined wing skin.

Broaching

19. Broaching uses a toothed tool, to remove material from the workpiece. The process is used when precision machining is required, especially for odd shapes as 'Broaching' finishes a surface in a single pass, which makes it very efficient.

20. Commonly machined surfaces include circular and non-circular holes, splines, and flat surfaces. Typical workpieces include small to medium sized castings, forgings, screw machine parts, and stampings.

Even though broaches can be expensive, broaching is usually favorable to other processes when used for high-quantity production runs

Electrical Discharge Machining

21. Electrical Discharge Machining (EDM) is also referred to as spark machining, spark eroding, burning, die sinking or wire erosion and is a manufacturing process whereby the desired shape of the workpiece, is obtained using electrical discharges (or sparks).

22. The material removal from the workpiece occurs by a series of rapidly recurring current discharges between two electrodes, separated by a dielectric liquid and subject to an electric voltage.

Material Forming

23. Not all components can be manufactured through the use of Material Removal tools & techniques.

It is often advantageous to use Material Forming techniques, where it is easier to manufacture more complex components whilst maintaining the desireable material properties.

24. Material forming techniques include;

- Casting
- Pressing
- Extrusion
- Forging
- Bending

Bending

25. Another of the basic manufacturing processes, bending is one of the most common material forming processes.

If a bend is required in a workpiece (be it sheet metal, bar or tube), a *Bending Machine* is used to apply a strain at the desired location to form the designed bend.

Forging

26. Forging is the term for shaping metal by using localised compressive forces.

27. Cold forging is done at room temperature or near room temperature, whilst Hot forging is done at a high temperature, which makes metal easier to shape and less likely to fracture, whilst warm forging is done at an intermediate temperature between room temperature and hot forging temperatures. Forged parts can range in weight from less than a kilogram to 170 metric tons.
Forged parts usually require some further processing to achieve the finished part.

28. There are many different kinds of forging processes available, however they can be grouped into three main classes:

- Drawn out: Increases the length but decreases the cross-section
- Upset: Decreases the length and increases the cross-section
- Squeezed in closed compression dies: produces multidirectional flow

29. Common forging processes include roll forging, swaging, cogging, open-die forging, impression-die forging, press forging, automatic hot forging and upsetting.

30. Forged items are commonly found all around us in our everyday lives – typical example would be the rails used for train tracks, which are produced using the drawn-out method from billets.

Casting

31. Casting is a process by which a liquid material is poured into a mould, which contains a hollow cavity of the desired shape, and then allowed to solidify. The solidified part is known as a *casting*, which is ejected or broken out of the mould to complete the process. Casting materials can be metals or various cold setting materials that cure after mixing two or more components together; examples are epoxy, concrete, plaster and clay.

Casting is most often used for making complex shapes that would be otherwise difficult or uneconomical to make by other manufacturing methods.

32. There are lots of examples of cast products about us – typical examples for use include the alloy wheels of cars and the cylinder blocks of piston engines.

Pressing

33. Pressing is a manufacturing process that allows flat sheets of metal to be formed into three dimensional workpieces. It can also be used to shear the sheet metal in order to cut out forms, press holes or other features using special punches and dies

Pressing machines have a stationary bed and a slide (ram) which uses a controlled reciprocating motion toward and away from the bed surface.

34. Typical example of items produced through pressing are car body panels

Extrusion

35. Extrusion is a process used to create objects of a fixed cross-sectional profile, where the base material is pushed or drawn through a die of the desired cross-section.

36. The two main advantages of this process over other manufacturing processes are;

- Its ability to create very complex cross-sections and work materials that are brittle, because the material only encounters compressive and shear stresses.
- It also forms finished parts with an excellent surface finish.

37. The extrusion process may be continuous or semi-continuous and can be done with the material hot or cold. Typical examples of extruded products include the legs of chairs, as well as aluminium double glazed window frames.

Additive Processes

38. Additive processes are otherwise known as ‘Rapid Prototyping’ and are a manufacturing process for the rapid and flexible production of sample parts for demonstration, evaluation and/or testing.

They typically use advanced layer manufacturing technologies that can quickly generate complex three dimensional objects direct from computer based models

39. Rapid prototyping techniques include;

- Fused Deposition Modelling
- Stereolithography
- Selective Laser Sintering
- Laminated Object Modelling

Fused Deposition Modelling

40. Fused Deposition Modelling is a process which forms three-dimensional objects from CAD-generated solid or surface models. The patterns are generally used when an acroylonitrile-butadiene-styrene thermal plastic part is required for use in a working prototype.

Laminated Object Modelling

41. Laminated Object Modelling is a process that created models from inexpensive, solid-sheet materials.
The process is similar to that of Sterolithography in that it slices a three-dimensional electronic file from the computer to the Laminated Object Modelling machine to produce parts for use in visualisation models, casting patterns and designs.

Selective Laser Sintering

42. Selective Laser Sintering is a flexible technology that uses a CO2 laser beam to fuse (sinter) layers of nylon, metal or trueform powdered materials into a three-dimensional model.

This is a leading rapid prototyping technology as it provides more choices of materials for flexibility and has more applications than the other technologies.

Stereolithography

43. Stereolithography is a manufacturing technology where the layers are formed using a laser to cure the surface of a bath of photo-sensitive polymer resin in order to produce the desired shape.

The process takes a CAD design and produces a solid three-dimensional prototype model using a combination of laser, photochemistry, optical scanning and computer software technology.

Controls / Software

44. A feature of modern manufacturing technology, computer software has improved not only the accuracy of the design process, but also the material output.

45. Often, the more complex machining operations with tight engineering tolerances can only be achieved using tooling controlled by computer.

Typical processes encountered include;

- Computer Aided Design
- Computer Aided Manufacturing
- Computer Integrated Manufacturing
- Numerical Control

Computer Aided Design

46. Computer-aided design (CAD) is the use of computer technology to assist in the design of components and assemblies, both real or virtual.

47. As in the manual drafting of technical and engineering drawings, the output of CAD must also convey symbolic information such as materials, processes, dimensions, and tolerances, so that they can be used to both manufacture and assemble components to an agreed standard.

48. CAD may be used to design curves and figures in two dimensional space or curves, surfaces and solids in three-dimensional objects. This way designs can be visualised before manufacture – ensuring that manufacture and assembly issues are minimized.

Computer Aided Manufacturing

49. Computer-aided manufacturing (CAM) is the use of software tools in the manufacture of product components.

50. It's primary purpose is to enable a faster production process and produce components with more precise dimensions (tighter tolerances) and material consistency. In some cases, this is an efficient process that uses only the required amount of raw material (thus minimizing waste), while simultaneously reducing energy consumption.

51. With CAM it is possible to manufacture physical models using CAD programmes, creating real life versions of components designed within a software package.

Computer Integrated Manufacturing

52. Computer-Integrated Manufacturing (CIM) is a closed-loop method of manufacturing in which the entire production process is controlled by computer, with minimal human intervention.

53. The traditional separated process methods are joined through a computer by CIM. This integration allows the separate processes to exchange information with each other to initiate actions. Through this integration, the manufacturing of components can be accomplished faster and with fewer errors.

The main advantage in utilising this method is the ability to create complex automated manufacturing processes.

Numerical Control

54. The term Numerical Control refers to the automation of machine tools that are operated by means of predetermined programmed commands, as opposed to machine tools that are manually controlled via handwheels or levers.

55. This method of manufacturing can be found in the following forms;

- Computer Numerical Control (CNC): Control of the machine tool is performed by a software programme executed by a computer.
- Direct Numerical Control: Control of a number of CNC machines by a large centralised host computer.
- Distributed Numerical Control: Hierarchical control of all machine tools controlled by a central plant computer, where the controllers are themselves CNC units.

Plastics Technology

56. Plastics technology is the collective term for the processes used to turn a wide range of synthetic or semi-synthetic organic amorphous solid materials (ie, plastic) into a final product.

A number of processes are available, but for the purposes of this subject the following processes are considered further;

- Blow Moulding
- Injection Moulding
- Co-Injection Moulding
- Compression Moulding
- Die
- Plastics Extrusion
- Thermoforming
- Curing

Blow Moulding

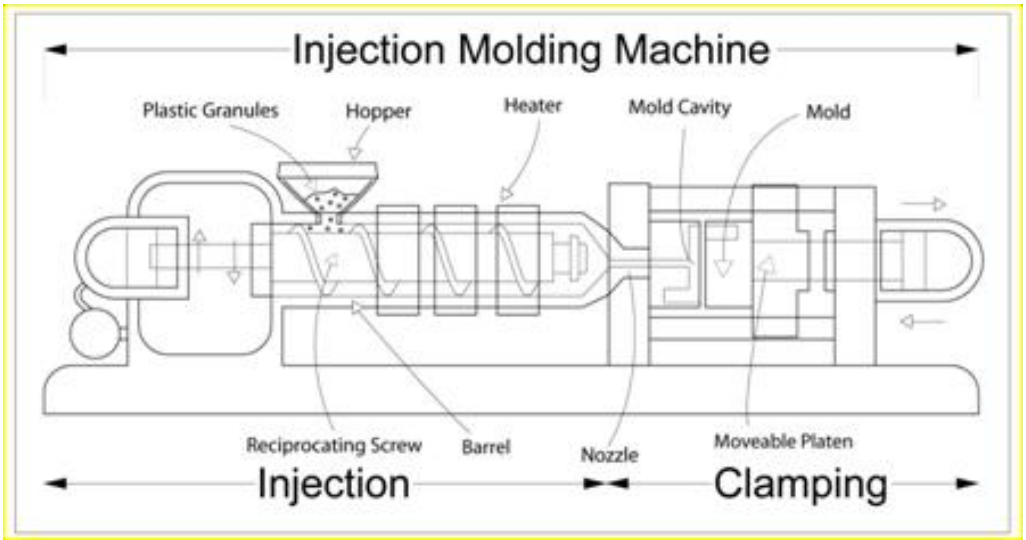
57. Blow Moulding is a manufacturing process by which hollow plastic parts are formed from thermoplastic materials.

58. Three main types of blow moulding are used, these are;

- Extrusion Blow Moulding: produces a hollow plastic tube from the die head and then expanded within the cavity by air pressure to produce a blown object.
- Injection Blow Moulding: supported by a metal core pin to produce blown objects.
- Stretch Blow Moulding: is used in both of the above types to produce odd blown shapes, referred to as Bi-oriented (e.g. orange juice bottles)

Injection Moulding

59. Injection Moulding is a manufacturing process for producing parts from both thermoplastic and thermosetting plastic materials. The raw material is fed into a heated barrel, mixed, and forced into a mould cavity by the reciprocating screw, where it cools and hardens to the configuration of the mould cavity.



Co-Injection Moulding

60. The Co-Injection Moulding process is very similar to that used for Injection Moulding process.

The key difference is that the mould cavity is first partially filled with one plastic and then a second shot is injected to enclose the first shot. This process is often used to produce components with plastics to two different properties and / or colours.

There a two types, Machine Based and Mould Based.

Compression Moulding

61. Compression moulding uses plastic material, generally preheated, that is first placed in an open, heated mould cavity. The mould is closed and a pressure is applied to force the material into contact with all mould areas. Heat and pressure are maintained until the moulding material has cured.

62. The process employs thermosetting resins in a partially cured stage and advanced composite thermoplastics can also be compression moulded with unidirectional support material.

63. The main advantages of compression moulding is it's ability not only to mould intricate parts, but it also produces fewer knit lines and less fibre-length degradation than found in components produced by injection moulding.

Die

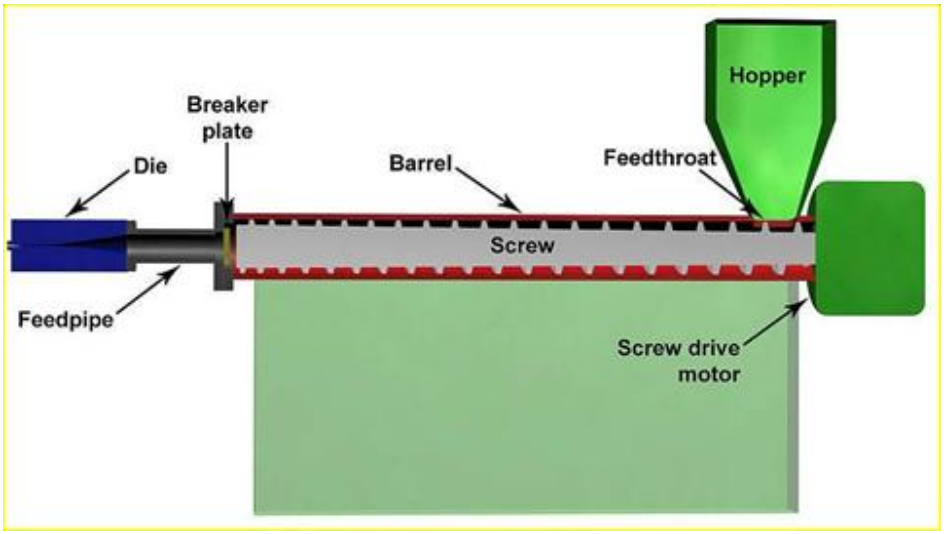
64. Within the context of Plastics Technology, the term die, mould and tool are sometimes considered the same.

This is considered true in that they have a female or negative cavity through, or into, which the molten plastic moves under heat and pressure.

Plastics Extrusion

65. Plastics extrusion is a high volume manufacturing process in which raw plastic material (often in bead form) is melted and forced through a die to form a single continuous profile (e.g. plastic window frames).

The process is similar to that of Metal Extrustion.



Thermoforming

66. Thermoforming is a manufacturing process where a plastic sheet is heated to a pliable forming temperature, formed to a specific shape in a mould, and trimmed to create a usable product.

The plastic sheet is heated to a high-enough temperature, so that it can be stretched into or onto a mould using a vacuum and cooled to a finished shape.

Curing

67. Curing is the process that refers to the toughening or hardening of a polymer material by cross-linking of polymer chains, brought about by the use of chemical additives, ultraviolet radiation, electron beam or heat.

In rubber, the curing process is also called vulcanization.

68. With composite materials, the final process involves curing the assembly using heat in an ‘Auto-clave’ or large oven.

Conclusions

69. Manufacturing Technology covers a wide variety of tools, techniques and processes – all utilised to transform raw materials into finished products.

70. Although not all tools, techniques and processes applicable to airframe manufacturing have been covered within this chapter, you should now be familiar with the basics of manufacturing technology.