STUDENT SECTION

DEVELOPMENT OF AIRCRAFT PRODUCTION ENGINEERING DISCIPLINE AT IIT, BOMBAY

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ABSTRACT

The task of building a modern aircraft can be fulfilled only if there is a powerful technology to back up design innovations. Though aircraft production engineering is a branch of manufacturing engineering, it is distinguished by some important features. In a country like India where the emphasis is on aircraft production, our aeronautical engineering graduates should be thoroughly trained in these areas. Keeping this in mind an "Aircraft Production Engineering Discipline" has been started in "Aeronautical Engineering Department, I. I. T., Bombay". The fundamentals of aircraft production and the other activities are discussed.

1.0 Introduction

Rapid advances in manufacturing methods have taken place during recent years in the aircraft industry. This progress was necessary to keep pace with the increasing complexity of the product, greater performance, and the large number of models, accentuated by military design requirements. Development of the modern complex aircraft has proceeded at such a rapid pace that projects are obsolete by the time they are in production. New concepts are in preliminary design by that time. The lessons learned from a new model in use are converted to design changes, and the remaining units are made to conform. The customer requires his supplier to update his product continuously. Design progress in this fashion has been rapid.

A producer of aircraft is building such a large and costly product that it is necessary to expend large sums of money at the very beginning of design which cannot be tied up for indefinite periods. The customer wants delivery as soon as possible. There is competition from other aircraft producers also. This is the reason why design-to-delivery time spans are shortening and will tend to decrease even more. The aircraft industry is never static except in war or periods of emergency, and static in this case means merely that the design is frozen. The aircraft is built to move someone or something from one place to another in the shortest time, at the lowest cost, and with the greatest safety.

Since unit output of the aircraft industry is small, it does not function on a mass production basis. It seems full of contradictions, needlessly strict in requirements, and slow to follow the mass production methods of the general engineering industry. The cost of aircraft production is very high compared to the other components the reasons being:

1) Small batch production,
2) Use of high quality expensive materials,
3) Laborious character of component manufacture to achieve the required accuracy,
4) Need of a large number of special tooling, and
5) Changes in design.

2.0 Aircraft Production Engineering Discipline

Though aircraft production engineering is a branch of manufacturing engineering, it is distinguished by some important features. A unified system of lofts, templates, master tools, master models, jigs and fixtures is the basis of production. Critical accuracy requirements are met using "loft-template method".

The task of building a modern aircraft can be fulfilled only if there is a powerful technology to back-up and the engineers and the other personnel engaged are conversant with the recent

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developments in aircraft production techniques. In a country like India where the emphasis is on aircraft production and maintenance, our aeronautical engineering graduates should be thoroughly trained in these areas. Keeping this in mind an "Aircraft Production Engineering Discipline" has been started in "Aeronautical Engineering Department, I.I.T., Bombay" a few years ago.

In order to appreciate the work being done in Aeronautical Engineering Department, I.I.T., Bombay in aircraft production engineering discipline, the fundamentals of aircraft production are discussed.

Aircraft production engineering mainly consists of airframe production, engine production and production of components of various systems. The following discussion is mainly confined to the airframe production.

3.0 Fundamentals of Aircraft Production

Airframe parts can be distinguished as rigid and non-rigid. All the rigid parts are made by providing definite tolerances according to the requirement and subsequently assembled into the sub-assemblies. But the non-rigid parts are associated with spring back and consequently distortion of shape after the forming pressure is released. Hence a system of lofts and templates is used as the basis for the manufacture of these parts, and their subsequent assembly into sub assemblies.

Aircraft production is dependent on the following two fundamental systems:

1) Limits and tolerance system,
2) Loft-template method.

Since the loft-template method is a specific feature of aircraft production, the following discussion is confined to it.

4.0 Loft-Template Method

The loft-template method is a unified system of the process planning, production of tooling, parts and units and inspection. The principal scheme of the loft-template method used in aircraft production is shown in Fig. 1.

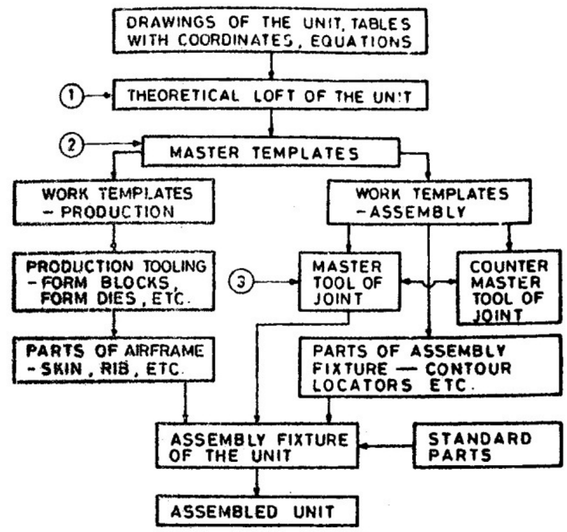

Fig. 1. Principal scheme of the loft-template method used in aircraft production

A theoretical loft is a full scale unit drawing performed at various stations on sheet metal covered with special coating. The loft group draws the theoretical loft for the given drawings of the unit, tables of coordinates and equations of the part contour. Corrections, if any, are introduced at this stage in consultation with the design group.

The master templates or design lofts are made taking the theoretical loft as reference. The master templates are made of sheet metal and the external contour represents the loft contour, and also carry a system of reference holes and lines. The master templates made of plastic sheet with non-worked contours that are to be reproduced on parts are called design lofts. In the design lofts all the theoretical outlines, reference lines and holes are drawn. The cross sections of all the parts in the flat section of the unit are also drawn. The design lofts can be made by direct photo-copying of the theoretical loft on photo-sensitive plastic sheets. These are not used directly in the production shops, but either the master templates or the design lofts are used as the reference for the fabrication of various work templates. The reference holes are reproduced in all the work templates and they serve as a unified reference system during the fabrication of tooling, manufacture of parts and their subsequent assembly into subassemblies and units. With the help of work templates production tooling and assembly fixture components are made.

The master tool reproduces all the mating surfaces of unit joints and provides their proper location with respect to reference lines and external contours. It is the dimensional authority for the construction and control of production tools, thereby establishing the relationship between reference holes, surfaces and contours of a specified part, mating part or assembly or a portion thereof."

Finally the parts are assembled on the assembly fixture and the assembled unit is obtained. The master tool of joint is used for relative positioning of different parts, sub-assemblies and sections during assembly.

This is a coordinated system of production and a relatively high accuracy is obtained.

The scheme of tooling coordination for the production of the skin, rib and the assembly fixture component - contour locator - is shown in Fig. 2. The skin and the rib are assembled on the assembly fixture taking the internal contour of the contour locator as reference.

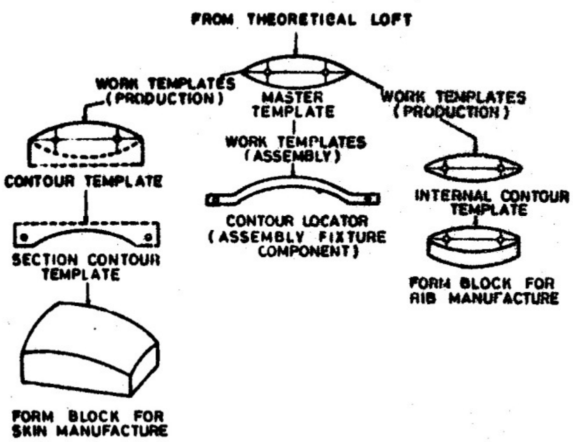

Fig. 2. Scheme of tooling coordination

4.1 Loft-Template Master Method

The templates are essentially two-dimensional masters. Hence for achieving the critical accuracy requirements three-dimensional master models are made.

A master model is a full-scale, three-dimensional structure which establishes the complete outside (or inside) surfaces of the part or assembly, as defined by design engineering data and/or loft lines, and may carry other coordinating data such as trim lines and reference holes.

Purposes of a master model are:

1. To make casts for dies, form blocks, etc.
2. To control contoured areas not defined by any other media.
3. To coordinate detail and assembly tools.

The master models are made of plaster or plastics and the finished surface is faired by splining over the shapes of two or more templates.

These master models are expensive and initial production cycle is extended. But once the master model is made, various form blocks and assembly fixture components are made easily by cast method.

4.2 Geometrical Coordination

There are three main groups of geometrical parameters to be coordinated in aircraft production:

1) External contours of the units which form smooth working surface of an aircraft are coordinated by drawing theoretical loft. If the theoretical loft is taken as the reference for further operations, the possible errors $\Delta_1, \Delta_2, \ldots$ can be either minimized or eliminiated, Fig. 3.

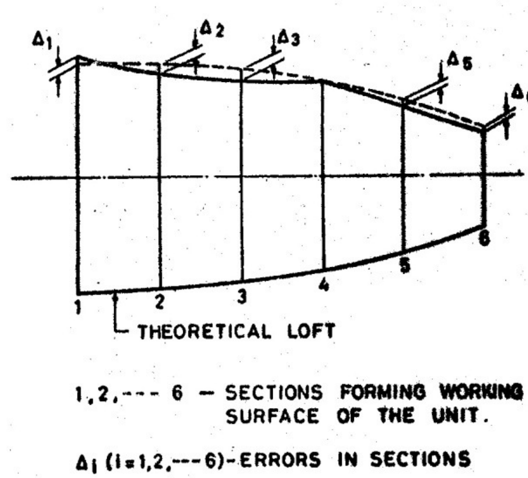

Fig. 3. Coordination of external contours by drawing theoretical loft

2) Geometrical parameters of the structural elements in each flat section of the unit are coordinated with the help of master templates or

design loft. The error of coordination $\Delta_{1,2}$, $\Delta_{2,3}$,... can be reduced if master templates or design lofts are taken as reference for further operations, Fig. 4.

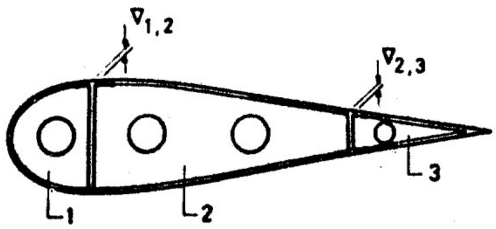

Fig. 4. Coordination of structural elements in each flat section

3) Master tool of joint serves for the coordination of mating surfaces and provides the required location of joints of the units with respect to reference lines or surfaces. Using the master tool of joint, the parameters such as d, D, α, θ can be coordinated, Fig. 5.

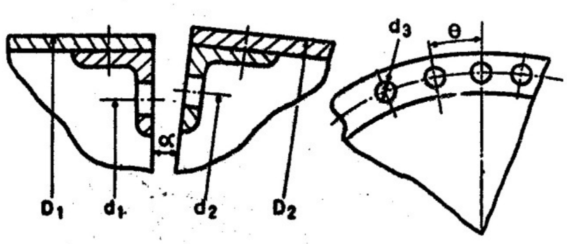

Fig. 5. Coordination of mating surfaces - for a flange joint

The production and assembly of all non-rigid components can be coordinated using the loft-template method.

When there is change in design, the corresponding changes should be introduced in al' the tooling required. It will involve a lot of additional expenditure. In the loft-template method the tooling are made using either templates or master models as reference. With a rational analysis, the same tooling can be made use of with a little of rework and recasting.

5.0 Theory Courses Offered

To acquaint the students with the required theoretical knowledge the theory courses are offered in the following areas:

1) Principles of engineering production
2) Metrology
3) Loft-template method
4) Aircraft manufacturing processes
5) Aircraft assembly processes
6) Aircraft materials
7) Jig and tool design
8) Analysis of manufacturing and assembly processes.

Limits and tolerance system and loft template method as the basis of aircraft production engineering are discussed in detail. Conventional machining and forming processes, metrology modern machining processes, high-energy rate forming, flexible die forming, stretch-wrap forming processes, assembly processes, jig and tool design techniques are taught to the undergraduate and post-graduate students with a specific reference to aircraft production. Students are introduced to the analysis of manufacturing and assembly processes. Design and fabrication of tooling and assembly fixture components are taught. Students are exposed to aircraft assembly, erection and equipping processes.

The other courses of general engineering interest are taught in production engineering section, mechanical engineering department.

Various B. Tech homepaper projects and M. Tech dissertations are completed on aircraft production engineering.

6.0 Laboratory Development

To supplement the theory courses on aircraft production and assembly techniques, a well equipped laboratory is developed. The following are the major facilities available:

1) Loft jig and tooling dock

Loft jig and tooling block are the two-dimensional and three-dimensional coordinate tool-stands respectively. Fabrication of form-block frames, assembly fixture components such as contour locators, beams etc. is done

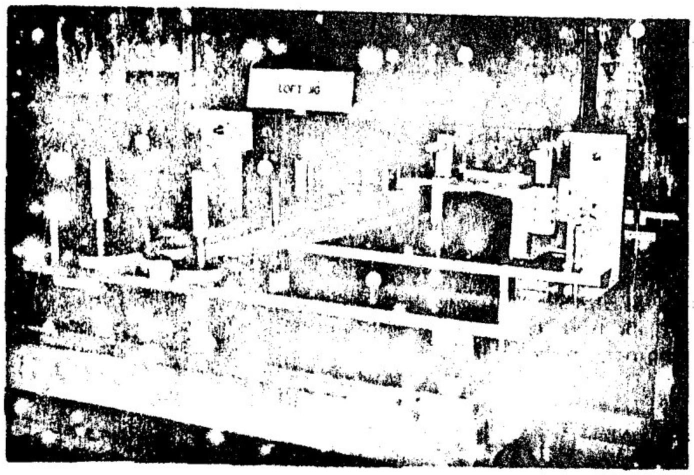

Fig. 6. Loft-jig

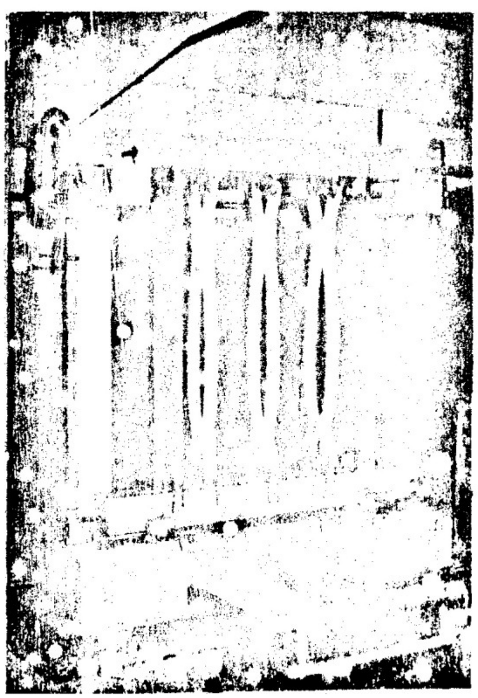

Fig. 7. Fixture for wing assembly

Fig. 8. Stand for the study of assembly techniques and assembly datum surfaces.

Fig. 9. Inspection device

Fig.10. Rubber-pad forming set-up

with the help of loft jig, tooling dock and optical tooling, Fig. 6.

ii) Fixture for wing assembly

Techniques of erection of assembly fixture components are studied on this fixture. Optical tooling is made use of for the erection of various components, Fig. 7.

iii) Stand for the study of assembly techniques and assembly datum surfaces

Every dimension must originate at a reference point, line, or plane which must first be transferred or established relative to the workpiece. Depending on the reference used the complexity of assembly technique, accuracy, cost and productivity may vary. On this stand the study can be carried out with skin external surface as datum, with frame/rib external surface as datum and with assembly holes as datum surface, Fig. 8. Assembled torsion box of wing can be inspected on the inspection device designed and fabricated for this purpose, Fig. 9.

iv) Rubber-pad forming

Since the cost of dies is an important consideration in sheet metal forming, the question arises whether it would be possible to replace either the punch or the die by a different material and in a different shape. On example, is in which the lower die is replaced by a rubber pad which conforms to the geometry of the tool.

Rubber pad forming, also known as the Guerin Process, forms the work piece over an inverted punch by the action of a pad of rubber in a container attached to the ram of a standard hydraulic press. The die (also called formblock) is laid on the bed of the press. The rubber pad, completely encased in a container on all the four sides and top is suspended from the ram of the press over the workpiece on the formblock. As the ram descends over the bed encompassing the formblock and the blank and pressure is applied, the rubber flows inside the container forcing the workpiece and forming it into a finished part, Fig. 10.

Analysis of rubber pad forming and tooling design considering the springback can be carried out on this set-up.

v) Tightening of threaded joints

Determination of preload and the control of it are the important aspects in bolted joints. On this set-up the methods to control the preload can be studied. The preload can be controlled by controlling the external torque applied, angle of rotation and the nut and the deformation in the bolt.

vi) Study of fibre-reinforced plastics

The pultrusion process set-up and the filament winding machine are being developed in our department.

vii) Other facilities

There are facilities for the study of adhesive bonding, honeycomb core expansion, deep drawing, blanking and piercing, ultrasonic machining, chemical machining etc.

The other facilities on general engineering are available in mechanical engineering department.

7.0 Closure

In our country the study of aircraft production engineering in educational institutes is not given due importance.

Since the emphasis is on aircraft production in our country, our aeronautical graduates should be trained thoroughly in production technology. Keeping this in mind the Aeronautical Engineering Department, I. I. T., Bombay has been training the aeronautical graduates in these areas.

Apart from the courses discussed above, courses on N/C machines and automation and mechanization techniques are being planned to be offered to the students.

With this background of aircraft production engineering, our graduates are well equipped to take-up the challenging jobs.