Introduction of Aircraft Door Center that Applies Epoch-making Flexible Production System

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The volume of orders received for the production of doors for civil aircraft is increasing along with their diversity of types. In order to successfully overcome competition for such orders, an epoch-making concept that departs from the conventional assembling method had to be introduced. Various consultations were held with specialists, production plants and other parties concerned, and the idea for an integrated line called a Door center characterized by flexible manufacturing was adopted. Notable characteristics of such an approach include mixed production and increased efficiency in handling as well as flexible layout, producing from the assembly of small parts to the packaging of products. At present, two models and three types of base flexible assembling lines have been built. The basic concepts and beneficial effects of these lines are introduced here.

1. Introduction

Orders for the doors of civil aircraft received by Mitsubishi Heavy Industries, Ltd. (MHI) in recent years include the entrance doors and cargo doors (**Fig. 1**) for Boeing B767 and B777 as well as Airbus A330 and A380 aircraft. The types and sizes of the doors ordered are quite diversified. A brief overview of conventional door assembly operation is first presented before the epoch-making concept of flexible assembly is explained.

2. Conventional door assembly operation

2.1 Flow of operations

The first step in door assembly operations consists of constructing of a framing for the door. The framing is manufactured by setting several pieces of frames passing in the vertical direction and several beams passing in the longitudinal direction in a lattice shape and joining the intersections of each piece to each other with rivets. Next, the framing is moved to next, and a skin is located onto the completed framing. This is done by drilling some 2 000 or more joining holes into the skin and the framing from the skin side, and then joining skin to the framing with rivets. After the skin is joined to the framing, inner skins are installed onto the inner surface of the framing. The inner skins are also joined to the frame with rivets. This completes the main steps in the assembly of the basic door structure.

Next, the completed structural assembly is moved to the painting area, for paint operations. After painting has been completed, work begins on the installation of the various mechanical parts that comprise the final door system. Here handles, hooks, rods, shafts for releasing the door lock and other door components are installed in the door. Finally, a dimensional inspection is performed of the entire door before it is shipped. This is the general flow of the door assembly operation.

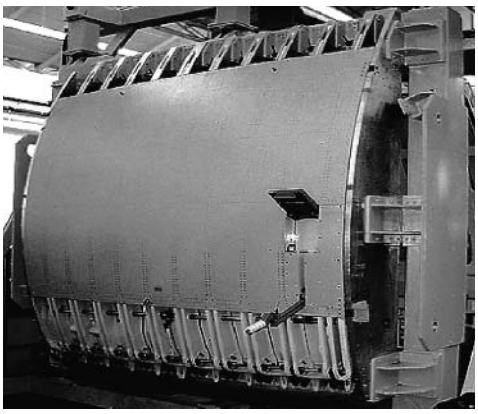

Fig. 1 A330 cargo door
Typical product produced with the door center

2.2 Problems with the conventional assembly method

In the conventional assembly method, a new production line is required each time the number of new door models is increased, because a special production line for each type of aircraft and type of door needs to be set based on the particular specifications for each door assembly operation. Further, if variation in the number of aircraft produced occurs, the number of jigs must be increased or decreased and the arrangement of the jigs needs to be changed, accordingly. The amount of investment necessary to fabricate and maintain such lines is quite large.

Aside from equipment, since workers perform operations for a specified time on a given dedicated line, there is a limit to how much operation time can be successively reduced. In order to compete with worldwide low labor cost, a new assembling method has become necessary. In addition, another factor contributing to an increase in the overall amount working time is handling work using general-purpose cranes and dollies.

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3. Three basic concepts of aircraft door center

To address the above problems, a variety of measures were examined from various angles such as manufacturing method, layout, jigs, and equipment. As a result, MHI finally arrived at the idea of developing a flexible production line (aircraft door center) having three basic concepts.

3.1 Increase in efficiency through flexible production

The first of the three basic concepts is to increase the efficiency of production through the effective application of flexible production.

Generally, the total number of man-hours needed to produce a given product decreases as workers become more proficient and accustomed to producing the product. In small lot production such as for aircraft, however, the length of time needed for workers to become proficient and accustomed to the manufacture of each product becomes longer.

As a result, similar increases in effectiveness in terms of shortened production man-hours cannot be expected in a short period as can be realized for other mass-produced products. Accordingly, in the flexible production approach, similar steps were unified and similar operations are performed at the same position on each line.

As a result, the amount of time needed for workers to produce products of similar types as they became more proficient and accustomed to producing each model could be shortened to 1/2 for the second model and 1/3 for the third model. Significant reductions in cost could thus be realized as production could become more stabilized.

For example, when a worker performed an operation for one type of product in four days, the worker would become accustomed to a production cycle of four days. (If two types of products were moved down the same line at the same time, the worker would learn the operation in four days.)

However, if the operation was divided into two parts with operations performed by two workers, the amount of work that must be learned by one worker would be halved, which would be equivalent to work for two days. The operation time can be thus reduced earlier with a cycle of two days.

In this case, however, a major point is the similarity of the two products. Since the line cannot be applied to a range of operations with significantly different design concepts for each door such as the installation of an opening/closing mechanism, the operations performed at the flexible position must be carefully examined before being incorporated in the line.

3.2 Increase in efficiency and automation of handling

The second concept is an increase in efficiency and automation of handling.

Generally, moving the position of a product does not provide added value to the product. Thus, if a general-purpose crane is used in the category of incidental operations, it is an operation that cannot be neglected as it is performed by four or five workers (five to six times for each product) and comprises about 7 to 8% of the total cost for assembly. In addition, MHI considered that handling operations must be improved since there is a risk of damage to the product in the event that any human error were to occur during handling.

As a first measure, the painting area was positioned adjacent to the plant to join the painting area to the assembly area by a monorail, thereby eliminating the need for dolly transportation of the product to the next stage of production.

Next, automated guided vehicles, monorails, and special cranes according to work characteristics at each position and the layout of the plant building were planned and constructed for complete automation (semi- and full-automation) of operations. As a result, the cost of handling could be reduced to less than 1% of the total cost for assembly.

For reference, the main features of each of the handling equipment used and the reason for why these various pieces of equipment were adopted are briefly introduced below.

- Automated guided vehicle: This piece of equipment reduces the risk of products being dropped, enables unmanned handling, and makes it possible to easily change the layout by replacing a magnetic tape. Accordingly, the vehicle is applied to a commonly used position area where rate variation occurs frequently and the times of changes in layout are expected to occur frequently (**Fig. 2**).

Fig. 2 Automatic guided vehicle
Automatic handling is possible.

Fig. 4 Monorail
Mechanism installation position and dimensional inspection position

Fig. 3 Special crane
Safe rotation of product is possible.

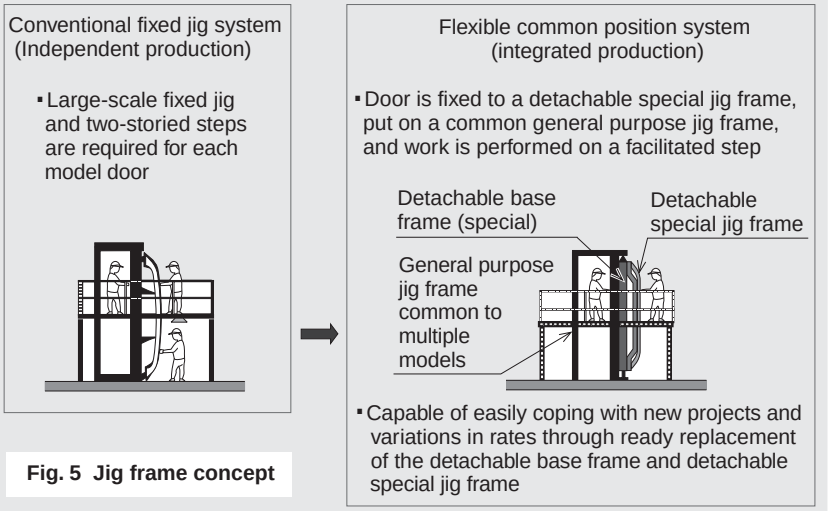

Fig. 5 Jig frame concept

- Special crane: This equipment has the function of rotating products. It is used for loading and unloading items from an automatic riveter (described later), which is difficult and dangerous to do using a general-purpose crane (**Fig. 3**).
- Monorail: This equipment is operated by man. However, it can reduce the number of workers necessary for transportation. Once products are set on the monorail, operations can be performed in that state without loading or unloading items from a support fixture. Accordingly, it is used in areas for painting and mechanism assembly positions (**Fig. 4**).

3.3 Flexibility of layout

The third concept is that flexibility is given to layout. In the production of aircraft, the rate and types of models produced very rapidly. In order to minimize any increases or decreases in the number of jigs and changes in the arrangements of jigs for each production process, which were problems in the conventional production method, the special assembly jig used for framing work was modified to separate the special jig frame designed for each model from the frame used as a base so that it could be readily changed.

Fig. 6 Common support fixture and work step with lifting function

As a result, even if a new door project is started in the future, the jig can cope with it easily merely by replacing the detachable special jig frame (**Fig. 5**).

In addition, a support fixture commonly usable for all models has been prepared in the common position area, and a work step (**Fig. 6**) with a lifting function has been arranged around it. Since the fixture can accommodate all models, it can flexibly cope with a variation in production rates and the receipt of new orders in the future.

4. Introduction of NC automatic riveter

In the design of the door production center, the lines were created aiming at an increase in efficiency. Cost reduction by the latest automatic assembly equipment was also considered to be critical factors, and was introduced in the basic concept for the production center from the beginning. One of the devices thus introduced was an automatic riveter for panels (skins) (**Fig. 7**).

Due to the complicated structure (shapes of frame and beam) of the components, an automatic riveter was not used for joining the door panels. Accordingly, drilling, deburring, and riveting operations by two workers were performed manually and as such were one of the tasks which took a long time to complete.

The NC automatic riveter, however, can move to a riveting position rapidly with high accuracy by fully numerically controlled operation, drilling in a short time without deburring, and can perform riveting quickly and reliably. Namely, it has the effect of remarkably reducing working time.

In addition, since the quality of riveting is better ensured and consistent, the need for re-riveting which was required by manual operation has been eliminated. The beneficial effects of the device are tremendously large. In particular, it is expected that the riveter will be applied to a wide range of uses in the production of cargo doors for the Airbus.

5. Future of door center

In constructing the door center, MHI set a goal of enhancing price competitiveness to global levels. It aims to remarkably reduce costs less than those associated with conventional assemblies. At present, MHI has been actively moving towards this goal.

MHI is confident that this goal has been achieved by the full operation of the automatic riveter. The concept of the door center has just begun. In the future, MHI plans to continue making every effort to increase the volume of new orders received for the construction of aircraft doors and fill its assembling line with doors that best meet every customer need as early as possible.

Fig. 7 NC automatic riveter

6. Conclusion

This plan was established as a prototype for integrated assembly of similar products. It seemed that doors could be put together easily because they were small products. However, problems arise in the assembly of a variety of doors on the same line. Quantities demanded may be larger than expected, and consultations could not be performed in many cases to the extent considered beforehand. However, a base flexible manufacturing line capable of assembling two models and three types of products could eventually be established.

A brief overview of the line concept and equipment have been explained above. However, it is true that cost reduction relying on them is limited. MHI considers that it is more important to create an easy-to-manufacture product from the design phase and make full use of its effect. It can be said that, in the severe cost competitiveness in the future, the manufacturer and designer must work more to create low cost products in cooperation with each other.

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