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THE PROBLEMS OF REFITTING AERO-GAS TURBINE ENGINES FOR MULTIPLE USES

by Chen Guang

When aero-gas turbine engines (including turbojets, turbofans, turboprops and turboshafts) are changed into gas turbines for use other than in aviation (industry and ships) most of the time the aero-gas turbine engine, the prototype, is transformed into a gas generator and linking the gas generator and power turbine are a diffuser box and air-intake device. In order to adapt to the changes of industrial conditions, it is necessary to make relevant modifications of the structural and important cyclical parameters in the refit. This article will address itself to many of the present refitting problems encountered abroad concerning the multiple uses of aero-gas turbine engines.

Influence of the Prototype Model

When the prototype is a turbojet, they eliminate the jet nozzle and it then becomes a gas generator. When the prototype is a turbofan, the following method can be adopted to obtain a gas generator:

1. Eliminate the fan and low pressure turbine, for example the derived industrial model of the RB211, and the derived ship models LM2500 and LM500 of the TF39 (or CF6-6) and TF34. This is the simplest method. Because the fan is eliminated, the air enters directly into an intermediate or high pressure compressor and therefore the number 1 and number 2 blades in front must be

redesigned so as to accommodate the changes of the inlet flow field. When the TF34 is refitted, they eliminate the fan and refit on a drive gear, directly use a low pressure turbine as the power turbine, and change the low pressure turboshaft into a power output shaft. The shortcoming of this type of refit is that both the total boost ratio and heat efficiency drop.

2. After cutting off the top of the fan (eliminating the outer part), it is changed into a low pressure generator. At this time, it is necessary to modify the low pressure turbine so that it adapts to the requirements of a decreased driving load. For example, when the "Sibei" RB168-66 was changed for use in industry and on ships, the top cut 3 fans and original 2 intermediate pressure compressors composed 5 low pressure compressors and the low pressure turbine's guide exhaust area and number of blades were changed accordingly. The thermal efficiency of this refitting was higher than the previous one.

3. Eliminate the large fan and replace it with several low pressure compressors so as to fundamentally maintain the total boost ratio of the prototype generator. When the CF6-50 was remodelled into ship model 5000, this method was used. Moreover, the four original low pressure turbines of the transmission fan were refitted into one and an exhaust stator blade was added.

Selection of Operating Point

When aero-gas turbine engines are refitted into gas turbines for use other than in aviation, the operating point (i.e. rotating speed and gas temperature in front of turbine) of the gas generator should be selected well. At this time, it is necessary that the use of the unit, the size of the output power, the life of the gas turbine and operating costs (rate of gas consumption) be fully considered. When used in a generating device with peak load the operating point of the gas turbine is higher than when there is a basic load.

To maintain relatively high boost ratio, most present refitted units maintain the rotating speed of the prototype, for example the industrial model "Aolinbasi." Some lower the rotating speed such as the industrial model "Aiwen." Yet during later development, the rotating speed of the industrial model "Aiwen" was appropriately raised so as to raise efficiency.

To attain longer operating life, the gas temperature in front of the selected turbine must all be much lower than those of the prototype. For example, the temperatures of the LM5000 in peak load and basic load are respectively 140° and 182°C lower than its prototype CF6-50 during takeoff. The gas temperatures in front of the ship model "Aolinbasi", "Sibei", RB211 and LM2500 turbines are respectively 155°C, 150°C, 125°C and 168°C lower than each of their prototypes.

Strengthened Components

Because of the changes of the operating environment and the long periods of continuous motion, when refitting aero-gas turbine engines it is necessary to strengthen or replace materials for the major components in order to prolong operating life.

For example:

1. Replacing Materials. Most cold end components change to use materials which have corrosion endurance properties and are quite strong. For example, the compressor box in the prototype is modified from a magnesium alloy to an aluminum alloy (industrial model ("Aiwen") or titanium alloy (industrial model "Bilinbasi"); the aluminum compressor's rotor vane and stationary vane are changed into titanium alloy and stainless steel ones respectively (i.e. ship model "Aolinbasi" and "Sibei"). The compressor's stationary vane of ship model "Sibei" also has Sermetel protective layers. Materials mainly of hot end components change to use materials with better heat endurance properties. For example, in the ship model "Sibei", the high pressure number 1 and number 2 turbine blades are changed from the prototype's N108 and N115 to INC.799 and furthermore the surface is alumetized; the high pressure number 2 and low pressure number 1 guide vanes are changed from C 1023 to INC.738. The material of the industrial model "Aiwen" 1533's turbine blade is changed from N115 to INC.738; in the "Aiwen" 1534, N115 replaces the N105 for the number 2 turbine blade. The material of the industrial model RB211 turbine blade is changed to surface alumetized INC.738.

2. Improving the Cooling of the Turbine Blade. The British apply aviation model RB211 turbine cooling technology on the number 1 turbine blade and numbers 1 and 2 turbine guide vanes of the industrial model "Aolinbasi." This causes the gas temperature in front of the turbine to rise from the original 942°C

(uncooled) to 1,087°C, the material's temperature to drop about 150°C and the heat efficiency to rise from 26% to 31%. The Americans changed the leading edge holes of the two LM5000 high pressure turbine blades from circular to rectangular, enlarged the heat conduction area, and improved the cooling effects. On the later period's industrial model "Aiwen", the originally uncooled number 1 turbine blade was also changed into a 7 hole air-cooled blade.

3. Strengthened Components. In order to prevent external damage to the industrial model gas turbine when it operates for a long period of time on the ground, it is necessary to strengthen several structures in front of the compressor. For example, they enlarged the leading and trailing edge radii and maximum thickness of the compressors rotor vane. When developing the industrial model RB211, the British newly designed and strengthened the number 1 compressor.

After the aero-gas turbine engines were refitted, when the thrust bearing of the gas generator rotor was placed under a large axial aerodynamic load for a long time, operating life greatly decreased. For this reason, most adopted the following measures: 1) Readjusted the gas effect of the forward axial force of the compressor rotor's back end. This can change the pressure of the rotor's back unloading cavity or enlarge the unloading cavity's sealed comb-toothed radius. 2) Raised the single bearing's bearing capabilities. For example, the bearing capabilities of the thrust bearing on the industrial and ship model FT3 are 60% higher than those of the prototype JT3 turbojet engine. 3) Used parallel double bearings to replace the single thrust bearings. For example, the low pressure rotor of the industrial model "Aolinbasi" and the two rotors of the industrial model 211 are made in this way.

After raising the gas temperature in front of the turbine, the pressure in back of the turbine blade rises a little. This can cause the forward axial force of the entire rotor to increase (this affects the load on the thrust bearing). For this reason, it is necessary to adopt corresponding unloading measures. For example, on an MK1533B foundation, the gas temperature in front of the industrial model "Aiwen" MK1534's turbine rose 60°C and thus its closed radius appropriately enlarged.

After refitting, because aircraft accessories with large consumption power, such as alternating current generators and liquid pressure pumps, were eliminated there was a great decrease of the transmission shaft's bearing load in the accessory transmission box. To prevent this from causing bearing light load sliding friction breakdown the transmission shaft bearing on the ship model "Sibei" was changed to a preloaded elliptical bearing.

An oil extrusion device was added on the ship model "Sibei's" high pressure turbine roller bearing. This can decrease vibration and raise bearing box life. These measures are also effective for preventing the ship's body from transmitting excessive vibration to the rotor.

To decrease serious wear on the contact type sealed devices created by long continuous operation a release pressure slot is added on the industrial and ship model FT3 closed device. This decreased the unit pressure of the closed surface area and at the same time strengthened the cooling lubrication and heat insulation so that the life of the closed device reached to 8,000 hours.

4. Improving the Cooling of the Flame Tube Nose. For example, in the flame tube of the industrial model "Aiwen", the inlet dish of triple gaseous film cooling is used to replace the inlet dish of the prototype's single layer gaseous film cooling. This enlarged the nose's quantity of cooling air.

5. Increasing Coating on Surfaces of Important Components.

The cooling end of the component surfaces on the ship model gas turbines also have protective layers to prevent salt-bearing dampness corrosion. Furthermore, alumetizing on the turbine blade prevents sulphur from corroding the blade surface. After the industrial and ship models FT3 and FT12 (the FT12 is derived from the JT12 aero-gas turbine engine) operates for a long time, the flame tube support surface area has excessive wear due to aerodynamic vibrations. For this reason, the flame tube support surface area and nozzle support surface area are sprayed with friction endurance materials. The ship model "Sibei" also carries out a similar process.

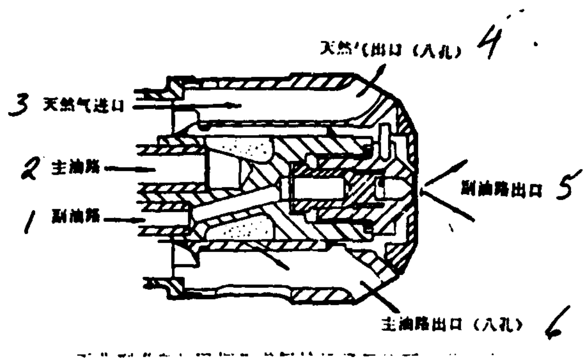

Fig. 1 Two Phase Fuel Nozzle Used in the Industrial MOdel "Aolinbasi" Gas Turbine

Key: 1. Auxiliary oil path
2. Main oil path
3. Natural gas inlet
4. Natural gas outlet (8 holes)
5. Auxiliary oil path outlet
6. Main oil path outlet (8 holes)

Various Inexpensive Fuels for Operation

From the gas turbines refitted from the aero-gas turbine engines for industrial and ship use, they hoped to change to using inexpensive light diesel oil natural gas and even heavy diesel oil. Because the kerosene in ships easily catches fire, it is necessary to change fuels. Due to the change of fuels the fuel supply system and regulating system must both be modified accordingly. At present, some refitted sets such as the industrial model "Aolinbasi", RB211 and "Sibei" need to be able to burn natural gas, liquid fuels and must at the same time burn two types of fuel (the ratio of the two types of fuel can change within 10% to 90%)or during the operation process change from one type of fuel to another. For this reason, a two phase (liquid phase and gas phase) fuel nozzle was used on the "Aolinbasi." The central part of this type of nozzle is divided into a mechanical centrifugal type atomized auxiliary oil path nozzle. There are 8 main oil path nozzles and 8 gas fuel nozzles on its outer periphery. The liquid fuel of the main oil path nozzle first flows to the outer passage and combines and vaporizes the radial inflowing air, which is afterwards discharged from the nozzle. This type of nozzle can spray liquid phase or gas phase fuels and at the same time can also spray out two phase fuels. Moreover, it can also realize the exchange of two phase fuels under conditions where the set has a load. During the fuel switch process, the power change of the set's output is not larger than 5%.

Because gas fuel is used, the hydraulic pressure mechanical type regulator used in aero-gas turbine engines must be changed to an electronic regulator.

Aside from this, among the inexpensive heavy fraction fuels and natural gas, the quantity of sulphur can be higher than in aviation kerosene. Thus, it is necessary to adopt anti-sulphur corrosion measures for the turbine blade and guide blade such as alumetizing and chromizing.

Improving Component Performance and Raising Thermal Efficiency

To raise the thermal efficiency of the aero-gas turbine engine refitted set, some sets increase the zero level in front of the compressor to improve the front few levels of blade design. Others improve the turbine's cooling technique so as to raise the gas temperature in front of the turbine.

After the refitted set was put into operation, they still continuously made improvements so as to raise their performances. The table below lists the improvement process for the industrial model "Aiwen".

1 型号	2 功率, 马力	3 热效率	4 改进措施	8 投入使用的日期
MK1533A	17,800	27%		1964年 9
MK1533B	19,590		5 提高转速	1967年 10
MK1534	21,690		6 提高涡轮前燃气温度60°C	1971年 11
MK1535	23,800	28.8%	7 再提高温度42°C	1976年 12

Table 1 Improvement Process of Industrial Model "Aiwen"

Key:
1. Model number
2. Power, horse power
3. Thermal efficiency
4. Improvement measure
5. Raised rotating speed
6. Raised gas temperature 60°C in front of turbine
7. Further raised temperature 42°C
8. Time put into operation
9. 1964
10. 1967
11. 1971
12. 1976

Reducing Degree of Smoke in Combustion Chamber

In gas turbines refitted during the early period, the degree of smoke in the combustion chambers was relatively large, for example, the industrial model LM1500 derived from the J79 aviation turbojet engine. To reduce the degree of smoke, over the last few years the Americans made relatively large improvements on the flame tube of the LM1500 including changing the flame tube's nose inlet cone from a plate material weldment to a mechanically processed component, strengthening the cooling of the nose, and changing the eddy-flow instrument into outside to inside radial admission so as to impel fuel vaporizing to guarantee full combustion of the fuel and to eliminate visible smoke.

When the "Sibei" was changed from an aviation to ship model, a reflection type air vaporizing nozzle was used so that the fuel would intensely mix with the eddying air prior to entering the flame tube nose to form a well vaporized gas mixture. This guaranteed full combustion and eliminated visible smoke.

Gas Admission and Discharge Processing

Gas turbines refitted from aviation to industrial use should adopt silencing measures in their admission and exhaust passages. For example, porous sound absorption bushings are installed on the airflow pipe wall to reduce the noise pollution of the admission and exhaust passage on the surrounding environment.

To prevent ground dust and sand from entering the gas turbine and destroying inner components or being deposited on the blade and thus causing efficiency to drop, a dustproof filtering device was also installed on the set's admission passage.

For refitted sets operating on the ocean or along the coast, it is necessary to filter the air entering the gas turbine so that the salt content will be lower than 0.01-ppm. The use of a three level filter is an inertia separator with a vertical shutter structure which first separates out the free water drops in the air. The second level of the filter is a fiber shaped condensor which condenses the mist in the air into relatively large water drops and also causes the water drops to be eliminated from the bottom part of the condensor. The structure of the third level of the filter is the same as that of the first. It separates out the remaining water drops in the air.

It is also necessary to frequently clean the inner parts of gas turbines used in industry and in ships so as to raise their operating efficiency. Aside from regular cleaning, when there is a 5% decline in the set's output power or when the exhaust temperature rises 5-10°C this shows that there is a possible accumulation of dirt in the compressor and thus it should be cleaned.

During the early period, hard fragmented particles such as walnut shells, candy shells and coke were often sprayed into the compressor during slow movement and so it was necessary to clean out the pollutants inside the passage. Because the fragmented particles of the substances used for cleaning can sometimes block the small gas drawing hole, thus at present there have been many changes in the use of liquid detergents. The cleaning process is generally as follows: when a compressor has rotation, a detergent of 50% detergent and 50% pure water (when atmospheric pressure is lower than 0°C, a small amount of ethyl alcohol should also be added in) is pressurized and sprayed into the compressor from the liquid spray ring in the admission passage to wash it for several minutes and afterwards pure water is used to wash it for several minutes. This is repeated several times. The number and time of washings is determined by the cleanliness. After washing is completed, the turbine is started in a slow state and rotates for a period so as to dry the inside of the gas turbine.

When using cleaning fluid to wash the set, it is best to wash when the compressor is rotating after the turbine has stopped. This is because when the turbine is on, the washing can wash away the salt particles in the compressor passage which can also create negative results for the high pressure components on the turbine.

Several Special Problems of Ship Model Gas Turbines

When weapons are launched on ships, hull vibrations are very large and can cause rusty substances to shake off, enter the turbine through the air flow and possibly block the small air flow passages. Therefore, it is best that the turbine blades of ship model gas turbines not use air film cooling structures.

When a ship encounters underwater explosion, the hull can sustain more than 150g impact acceleration in the vertical direction. At this time, the set should still be able to maintain normal rotation. Most of the adopted measures are flexible vibration absorbing cushions installed on the seat at the bottom of the set's mounting which can absorb 120g. Later, flexible mounts were used to support the set. For example, there are 22 longitudinal and transverse flexible vibration absorbing cushions on the bottom seat of the ship model "Aolinbasi". and 14 similar vibration absorbing cushions installed on the bottom seat of the ship model "Taijun."

To reduce the possibility of being discovered by the other side's infrared missiles, it is also necessary to lower the exhaust temperature of the ship model gas turbine as much as possible.

SUCCESS OF DYE FORGING TITANIUM DISCS ON A GUNPOWDER HAMMER

by Li Chenggong

The use of titanium alloys as well as their processing is an important problem in modern aircraft production. Titanium alloys possess a series of strong points including high strength and occupy an important position in the development of aircraft engines. The discs and blades of compressors are the main objects for the application of titanium alloys. Among these, the compressor disc is also the key large scale forging. In foreign nations, the dye forging of titanium discs, besides being carried out on hydraulic presses, are also done on hammers with anvils and without anvils. China mainly forges discs on 30,000 ton hydraulic presses. In view of the fact that the cost of forging titanium discs on large hydraulic presses is very high, we carried out test forging on a new forging pressure device we developed - a 40·ton meter gunpowder hammer, and attained success.

This 40 ton·meter gunpowder hammer is a dye forging device which uses gunpowder as the power source. Its hitting speed is higher than that of the common dye forging hammer. Basically, it does not waste electric energy and only the hydraulic system requires the use of a 7.5 kilowatt electric motor. This type of device possesses the advantages of saving energy, having a simple structure, being inexpensive to manufacture, having good forming performance, having small vibration, and not having special basic requirements. See fig. 1 for its exterior.

Fig. 1 Exterior of Titanium Disc Dye Forging on a Gunpowder Hammer

To investigate the possibility of dye forging a titanium disc on a gunpowder hammer, we first carried out simulated tests and on the basis of the results obtained from these simulated tests we were successful in dye forging tests of full sized titanium discs. See fig. 1 for the exterior of the titanium disc forging successfully test forged on a gunpowder hammer. When compared to a hydraulic press dye forging, it has distinct outlines, precise measurements, and the quality of the surface is good. The results of examining the dye forgings macroscopic and microscopic metallographic structures completely matched the technical conditions and related standard requirements. See fig. 2 for a metallographic photograph of the macrostructure.

Fig. 2 Macrostructure of Titanium Disc Forging on a Gunpowder Hammer

When compared to hydraulic press dye forging, its flow line is distinct and complies with the external distribution of the forging and unrough large indistinct crystalline grains. See fig. 3 for the microstructure of samples examined cut from different places in the forging.

图 3 火药锤上钛盘锻件的显微组织
(a) 轮缘 (b) 轮辐 (c) 轮毂 ×500

Fig. 3 Microstructures of Titanium Forgings on Gunpowder Hammer

(a) Felloe
(b) Spoke
(c) Hub
X 500

It is formed from an equiaxial newborn α plus β transformed structure. When compared to a hydraulic press forging, it does not exist in a continuous or semi-continuous grain boundary α phase, and its newborn α content is about 50%.

According to the requirements of technical conditions, see table 1 for the measurements of the mechanical properties of the titanium disc dye forging and a comparison of the measurement results and hydraulic press with similar titanium disc forging on a common dye forging hammer.

性能 / 工艺	室温性能						500°C性能				热稳定性 500°C×100小时后室温		
	σ_b 公斤/毫米²	$\sigma_{0.2}$ 公斤/毫米²	δ %	ψ %	a_k 公斤-米/厘米²	H_{Rd} 毫米	σ_b 公斤/毫米²	δ %	ψ %	τ_{100} 公斤/毫米² 小时	σ_b 公斤/毫米²	δ %	ψ %
火药锤钛盘锻件	107.6	98.6	13.5	41.2	5.7	—	78.8	20.1	49.1	440	108.3	13.9	37.1
	108.0	98.8	15.6	41.6	6.2	—	80.3	18.6	50.2	405	110.7	14.6	37.1
模锻锤钛盘锻件	110.0	100.0	13.5	46.5	5.85	3.36	74.5	16.5	53.5	>100	110.0	18.0	40.5
	109.0	98.5	14.0	46.5	5.25	3.42	76.0	17.0	57.0	>100	110.0	16.5	40.5
液压机钛盘锻件	114.0	104.0	13.0	24.5	4.2	3.5	78.0	12.4	45.0	>110	112.0	16.0	24.0
	110.0	105.5	10.0	28.0	4.4	3.6	75.0	19.6	41.0	>110	114 0	10.6	17.0
技术条件	105/125	>95	>9	>25	>3	3.2/3.7	>70	>12	>40	>100	>105	>8	>20

Table 1 Mechanical Properties of Titanium Disc Dye Forging

Key:
1. Technique
2. Property
3. Gunpowder hammer titanium disc forging
4. Dye forging hammer titanium disc forging
5. Hydraulic press titanium disc forging
6. Technical conditions
7. Room temperature properties
8. kg/mm^2
9. kg/mm^2
10. kg-meter/cm^2

11. mm
12. 500°C properties
13. kg/mm^2
14. kg/mm^2 hours
15. Thermal stability, room temperature after 500°CX 100 hours
16. kg/mm^2

It can be seen from this table that the properties of each item of the gunpowder hammer titanium disc dye forging matches the technical condition requirements and when the blank supply conditions are the same, their property levels are the same as those of the common hammer dye forging. When compared to a hydraulic press forging, its room temperature strength is close to the lower limit, its plastic reserve is relatively high, its thermal stability is excellent, its high temperature tensile strength is relatively good, its endurance strength is good, its various data are relatively stable, and its fluctuation range is small.

It can be seen from the above comparison of the technical indices for each item that although there were few test forgings of titanium discs on 40 ton·meter gunpowder hammers, forging quality and its technical superiority were still quite obvious.

In analyzing the economics of titanium discs dye forgings on gunpowder hammers, because to date there have been few tests and there is also a lack of production examination data, comparisons are mainly carried out by using the old prices of equipment and by energy consumption. The selected comparison plan is the

·already used plan or plan for possible use in similar present day titanium disc production tests. The comparison results of economic analysis are given in table 2.

	对比指标 2 / 工艺方案 1	8 设备价格		16 电能消耗	
		9 锻压设备出厂价格，元（总重，吨）	15 比值	17 锻压设备电能消耗，千瓦（安装功率）	18 比值
3	30000吨水压机模锻方案	10 4000万(8000吨)	160.0	1,360	181.3
4	10吨锤模锻方案	11 108万（312吨）	4.3	550	73.3
5	25吨·米无砧座锤模锻方案	54万（150吨） 12	2.2	550	73.3
6	100吨·米高速锤模锻方案	73万（110吨） 13	2.9	350	46.6
7	40吨·米火药锤模锻方案	25万（80吨） 14	1.0	7.5	1.0

Table 2 Economic Analysis Comparison of Several Types of Titanium Disc Dye Forging Plans

Key:
1. Technical plan
2. Comparison index
3. 30,000 ton hydraulic press dye forging plan
4. 10 ton hammer dye forging plan
5. 25 ton·meter non-anvil hammer dye foreign plan
6. 100 ton·meter high speed hammer dye forging plan
7. 40 ton·meter gunpowder hammer dye forging plan
8. Cost of Equipment
9. Producer price of forging press equipment, dollars (total weight tons)
10. 40 million dollars (8,000 tons)
11. 1,080,000 dollars (312 tons)
12. 540,000 dollars (150 tons)
13. 730,000 dollars (110 tons)
14. 250,000 dollars (80 tons)
15. Specific value
16. Electric energy consumption
17. Electric energy consumption of forging press equipment, kilowatts (installed power)
18. Specific value

It can be seen from this table that if the forging raw materials, mould, labor, heating and other costs are approximately the same then the costs of a titanium disc forging is mainly divided between equipment costs and electric energy consumption. If we use gunpowder hammer dye forging as the basis for comparison we then obtain the results shown in table 2. The comparison index can differ several fold and even up to several hundred fold. It is especially necessary to point out that the gunpowder hammer dye forging plan has the least electric consumption because the source of the equipment's hitting energy is the chemical energy of gunpowder. In actual use, because the gunpowder hammer can use certain properties of extremely different or expired gunpowder its cost can be overlooked. Even if we use quality gunpowder, the cost of gunpowder for each hit using total energy is only about 1 dollar Renminbi.

To sum up, the technical and economic superiority of the titanium disc forging on a gunpowder hammer technical plan is very obvious. Although this is only a preliminary analysis, incomplete and lacking concrete production examination data, yet we can predict from this analysis that the gunpowder hammer titanium disc forging technique will become a new technique created by China which will coincide with the Central Committee's spirit of tapping resources, innovation and transformation. It will also coincide with our national conditions and is thus a new type of technology with a broad future. It will constantly be improved and perfected in future practical use and gradually have its application extended in production.

THE GENERAL ASSEMBLY AND PAINTING
OF THE YIER - 86 PASSENGER PLANE

by Wang Zhongzhi

The structures of wide body aircraft have many special features and these greatly influence assembly techniques. The major features are:

1) There are no separation surfaces in the joining area of the wing and fuselage nor in the joining areas of many other components;

2) The measurements of the assembly unit contour is large (component length reaches 55 meters);

3) Most of the assembly units have complex moving systems and rotating segments (such as the nose-slot wing, wing flap, landing gear, cabin door and radiator flap);

4) There are a large number of various decorative plate parts in the passenger cabin and there are many varieties of these. For example, ceiling and window frame wall plates are made of aluminum decorative plates, the intermediate and side wall plates have honeycomb structures and there are also the protective plates and luggage racks.

Because of the special structural features of wide body planes mentioned above, there is a large quantity and grear variety of components, segment parts, sectional parts and modules and thus there is a great deal of assembly work.

1 工作种类	10 劳动量, %
2 毛坯生产	10.2
3 切削加工	23.7
4 钳工装配	6.0
5 部件装配	33.0
6 焊接装配	2.3
7 总　　装	17.8
8 试　　验	5.0
9 其　　他	2.0
	100.0

Table 1 Labor Distribution in Different Technical Processes for the Yier - 86 Passenger Plane

Key:
1. Type of work
2. Blank production
3. Cutting process
4. Benchwork assembly
5. Component assembly
6. Welding assembly
7. General assembly
8. Testing
9. Other
10. Amount of labor, %

From table 1 we know that assembly work occupies about 60% of the total amount of labor for producing an entire plane. Therefore, to a large extent, the technical level of the assembly work determined the technical level in manufacturing an entire aircraft.

When the contour measurements of the components is very large, the use of the standard sample coordination method is technically unsuitable in many situations or is not economically worthwhile. The Yier - 86 aircraft widely used the mathematical description method for the component surface and used the numerical control machine tool and laser fixed center measuring systems. Moreover, on this foundation, they resolved the assembly and exchange precision problems of the modules and components. Fig. 1 is a sketch of the matching, assembly and examination of a non-standard sample of an Yier - 86 passenger plane wing-fuselage abutment joining apparatus.

To guarantee the abutment joining of the wing and fuselage, it is necessary to match bearing frame positions nos. 40, 45 and 50 so that their plane shifts in the wing and fuselage assembly frame will not exceed ± 0.5 mm.

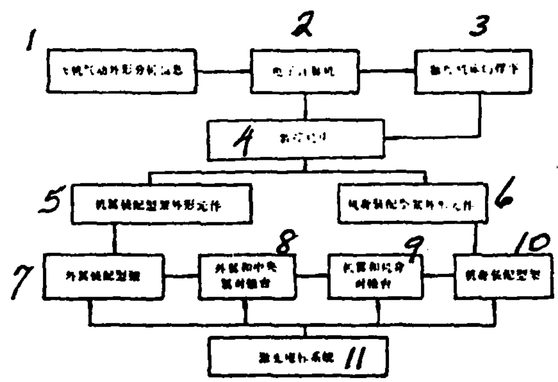

Fig. 1 Sketch of the Marching, Assembly and Examination of a Non-Standard Sample of Yier - 86 Aircraft Wing-Fuselage Abutment Joining Apparatus

Key:
1. Analysis information of aircraft's aerodynamic contour
2. Electronic computer
3. Program of numerically controlled machine tools
4. Numerically controlled machine tools
5. External unit of wing's assembly frame
6. External unit of fuselage's assembly frame

7. Outer wing assembly frame
8. Outer wing and middle wing abutment joining platform
9. Wing and fuselage abutment joining platform
10. Fuselage assembly frame
11. Laser coordinate system

The fuselage of the Yier - 86 passenger plane is divided into two sections for abutment joining (fig. 2):

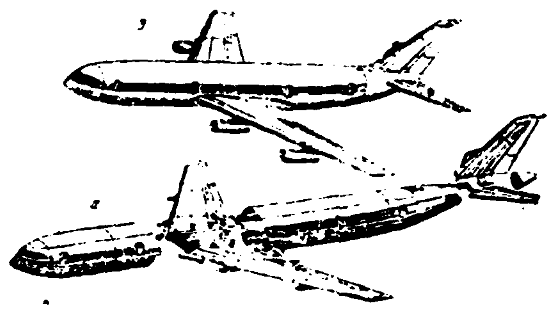

Fig. 2 Total Abutment Joint Diagram of Yier - 86 Passenger Plane

a - Wing and fuselage abutment joint

b - Aircraft component abutment joint

The Front Section of the Fuselage (frames no.1-40). The landing gear suspended joint of this section of the fuselage undergoes precision machinery, the fixed tracks of the passenger seats have been installed, and based on the level measuring chart we drew corresponding level measuring points.

The Tail Section of the Fuselage (frames no. 40-101). The main landing gear suspended joint of this section of the fuselage has been precisely machined, the utilized abutment joint surface is joined to vertical stabilizing surface and finally milled, the bolt holes of the fixed vertical stabilizing surface have been precision machined, the fixed tracks of the passenger seats have been installed, and based on the level measuring chart we drew corresponding level measuring points.

The front section and tail section of the fuselage are placed on a special vehicle with a band cradle and sent along the slideway to the general assembly shop. Afterwards, a bridge crane is used to place the two sections of the fuselage on the adjustable cradle of the abutment joining platform vehicle.

The two platforms of the bridge crane and special hangar are used to transport the assembled and sealed wing to the abutment joining platform and place it on an adjustable cradle.

Prior to abutment joining, we first use a laser instrument to place the wings and two sections of the fuselage (front and tail sections) in a flight condition according to the level measuring points (the deviation of the measuring points is $\pm$ 1 mm), and afterwards carry out abutment joining.

On the abutment joining platform, the holes of the front and main landing gear suspended joints also need to use special machine tools and standard drill for precision machining.

The joined wing and fuselage are pushed out from the abutment joining platform and moved to the work stage outside the frame for tail surface abutment joining as well as the mounting of the nose-slot wing, brake plates, inside flap, engine hangar and nacelle, landing gear, slide-rail fairing, cabin door suspended joint, hatch, radiator flap etc. (see fig. 2).

To shorten assemble time and raise the mechanization level of the assembly work, we fully used the technical separation surface in the general assembly of the Yier-86 aircraft. The maximum limitation of the Yier-86 aircraft's components is their division into segment parts, separated segment parts, wall plates and modules. The mounting of these parts have made wide use of the assembly hole method and coordinate fixed position method.

The mounting of the long truss of the wing rib parts, spar parts, flap, airleron parts, fuselage wall plates as well as the bulkhead parts and fuselage beams all use the assembly hole method.

The mounting of the large beams of the wing, flap and airleron, the slide-rail and slide of the nose-slot wing and flap, the force endurance frame of the fuselage, the wall plate parts and segment parts all use the coordinate fixed position hole method.

To adjust moving structures such as wing lift equipment, landing gear and the cabin door, we used ten special test platforms, and provided three balanced platforms for control parts, seven abutment joining platforms and other equipment.

The fuselage has a large number of doors, windows and hatches. Experience has shown that it is best for these openings to be cut out of the assembled fuselage skin. The use of a mechanized method for making openings on the assembled fuselage skin did not require the advanced making of openings on the wall plates and also did not require adjustment during general assembly after mounting the side frame on the single clamping apparatus. In this way the amount of labor for machining and assembling side frames can be reduced greatly.

The parts in the Yier-86 aircraft which use this method to make openings include the fourteen openings of the entrance-exit cabin door, emergency cabin door, freight compartment door, and kitchen door.

The machining of making openings uses special machining equipment. Among these are the milled clamping apparatus and the pneumatic mill which is mounted on the guide clamping apparatus. The milled clamping apparatus is mounted on the fuselage according to standard where an opening is to be made and bolts are used to fix it on the special technical frame. The underseat of the clamping apparatus is made by placing glass cloth soaked with resin on a molding bed, in the four mounts of the underseat there are rubber strips and it is absorbed on the fuselage skin by a vacuum. The pneumatic mill is quick stripped and can be used along with various clamps (the pneumatic mill has a slide frame and is mounted with a milling head and feed mechanism). The machining of making openings is generally carried out in two steps (preliminary milling and precision milling) and the largest millable layer thickness is 10mm. The shape of the opening is checked by the clamp's standard limiter.

To guarantee position accuracy (opposite openings) when the cabin door and hatch are closed and movement accuracy when they are opened, it is necessary to carry out meticulous matching of the complete set of manufactured and assembled cabin doors. Fig. 3 is a typical coordination chart of manufacturing cabin door parts, and the equipment used for assembling cabin doors (hatches) and making their openings.

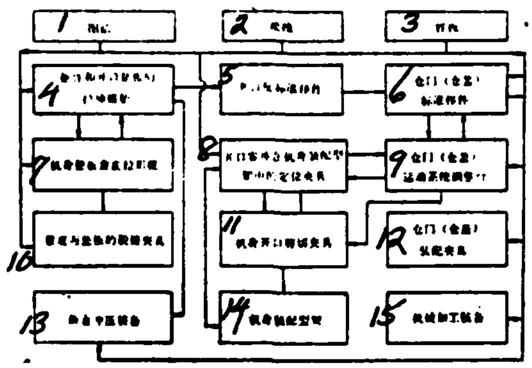

Fig. 3 Coordination Chart of the Manufacture of Cabin Door Parts and the Equipment Used For Assembling Cabin Doors (Hatches)

Key:
1. Graph paper
2. Modular line
3. Template
4. Tensile mould tire of frame and opening backing
5. Opening non-standard sample
6. Cabin door)hatch) standard sample
7. Fuselage wall plate skin drawn contour
8. Fixed position clamp of the opening parts in the fuselage assembly frame
9. Adjustment platform of cabin door (hatch) moving system
10. Rubber clamp of skin and backing
11. Shearing clamp for fuselage opening
12. Cabin door (hatch) assembly clamp
13. Sheet metal ram equipment
14. Fuselage assembly frame
15. Machining equipment

To guarantee the necessary precision of matching equipment, we used a moving system processing platform of a standard sample and non-standard sample and coordinated them with a standard hole system. In order to mount the fixed parts of the frame in the assembled equipment and mount the clamp used for shearing openings, we used a laser collimation measuring system.

Following the appearance of wide body aircraft, the mounting of decorative plates in the cabin became even more complex. The old method of using template, drawing lines and making repairs and supplying replacements cannot guarantee the mounting accuracy of the decorative plates and during the assembly process it is very difficult to prevent the decorative plates from being damaged. Moreover, the amount of labor for mounting the decorative plates is also very large. During the production of the Yier-86 aircraft, we used a new technical process and facilities for mounting the decorative plates. To guarantee the mounting precision of the decorative plate components and tracks, we used the same standard during mounting, the laser beam standard system and the commonly used rigidity coordinate carrier for the mounting case and coordinatograph. The mounting case can move along the special technical tracks and we use the mounting case to be able to accurately position and fix the suspended joint of the decorative plate components along the contour inside the fuselage. By using the coordinatograph, we can position and fix the seat tracks on the stipulated location. This guarantees the precision mounting of cabin seats in accordance with altitude and guarantees the mutual positions of the seats and their positions relative to the aircraft's symmetrical axis.

The pipelines of the narrow body aircraft do not generally carry replacement quick mounting joints on the seperation surface. However, there does not seem to be this type of joint on wide body aircraft which makes the coordination work of pipeline abutment joining complex. Moreover, not until after all of the parts are completely assembled and before all of the hole drilling work is finished can mounting and test work be carried out. In this way, the main assembly work load is transferred to the general assembly shop causing production to become more complex. Thus, we must set up abutment joining and mounting intermediate shops.

The internal installations of aircraft use unitized structures which can reduce the amount of work in the general assembly shop. In the Yier-86 aircraft, the large sections such as the kitchen, dining room, lavatories and ceiling are all last finished unitized structures which are delivered to the general assembly shop. The amount of labor for the mounting of these types of unitized structures is very small.

The mounting and testing of the wide body aircraft's conduit system is very complex and a large amount of labor is required. The technical procedure of the mounting, examination and testing of the Yier-86 aircraft's hydraulic system is as follows:

1. Preparation before mounting hydraulic system's finished pipelines and parts, and mounting;

2. Conduct presealed tests (using nitrogen) of the mounted pipe joined pipelines;

3. Use working liquid - NGZh -4 hydraulic oil to examine the seal of the pipe joined pipelines;

4. Clean the pipelines (first cleaning) and let out the working liquid;

5. Carry out unit tests and processing of hydraulic system;

6. Seal examinations after hydraulic system is assembled;

7. Use working liquid to clean hydraulic system (second cleaning) after assembly is complete;

8. Hydraulic system function tests;

9. Pour hydraulic oil into hydraulic system;

10. Carry out function tests for entire hydraulic system.

To complete this work, it is necessay to use a large amount of test equipment including moving test platforms for cleaning pipelines, pipeline seal examination platforms, separate system unit test platforms, mobile cleaning platforms, mobile work platforms for washing and testing the entire hydraulic system and seal examinations, fixed test platforms for washing and testing the hydraulic system, and mobile oiling platforms.

The area occupied by the wide body aircraft paint spraying shop is very large. The shop is equipped with a hot air supply system (a large amount of hot air flows from top to bottom and is used for drying the layers of paint), an air purification system and drainage pipe system (drains the scattered paint, primer and other pollutants).

Use of the above mentioned systems can automatically guarantee the necessary work conditions for spray painting. Before spray painting, meticulous preparation work must be carried out on the surface of the aircraft. In the spray paint shop of a Boeing Aircraft Company plant, a special type of washing liquid is used to eliminate the protective layer on the surface of the aircraft, a special type of degreasing agent is used to degrease the surface, and water is used to check the degreasing quality (if the surface is washed clean, water can then flow smoothly down from the surface without having "cut off water").

After the surface is cleaned, a layer of primer is sprayed on and after the primer dries three layers of paint are sprayed on, aech layer having to dry. Spray painting is carried out by hand spray painting with a spray gun on a special lifting platform. The platform can be controlled by workers. There are six (three for each side of the aircraft) or eight of these platforms. A sensor is mounted on the platform which can prevent the platform from colliding with the spray painted surface. The lifting controllable platform has four degrees of freedom of movement in space. Furthermore, it has a special mounting platform for spray painting the wings and two positions of building block type lifting platforms for spray painting the vertical tail.

In the plant of the MacDonald-Douglas Company, the cleaning of the surface of the DC-10 aircraft is carried out in a separate room of the spray paint shop. After the surface is cleaned, two layers of primers are sprayed on and after they dry two layers of paint are sprayed on. Following this, the surface is polished (to raise the surface shine) and finally a last layer of paint is sprayed on.

A spray painting shop must use special ventilation measures to guarantee the technical needs of spray painting, to prevent paint poisoning, and to guarantee anti-detonation safety and spray painting quality. Sray painting shops are equipped with high energy air conditioning equipment to guarantee that there are eight changes of air in the shop each shift, that the room temperature during spray painting is maintained at 18°C, the humidity at 75-80%, and the room temperature is maintained at 60° C when drying the paint. These temperature ranges are automatically controlled by air conditioning equipment.

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