Large Engine Maintenance Technique to Support Flight Operation for Commercial Airlines

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Original Equipment Manufacturer (hereafter OEM) and Maintenance, Repair and Overhaul providers (hereafter MRO) are making stiff competition for receiving orders in the field of maintenance of large engines of commercial airlines, aiming at expanding their shares. The outline of large engine maintenance work is described below, with the introduction of on-wing engine performance analysis system and new repair technologies (viz. borescope blend repair, powder-feed weld repair and HVOF coating) developed by Mitsubishi Heavy Industries, Ltd. (MHI) as the high-reliability, low-cost and short turn around time (hereafter TAT) as demanded by the commercial airlines.

1. Introduction

With the OEM including Pratt and Whitney, General Electric Company. and Rolls-Royce positively making their way into the field of large engine maintenance together with the keen attention paid by MRO including Lufthansa Technique Co., etc., this field has become a hot spot of tough competition in the aircraft maintenance industry. As the engine maintenance covers 30% of the total cost of the aircraft maintenance, how to deal with this problem is becoming an important factor in the operation of commercial airlines.

MHI has so far carried out maintenance of large engines PW4000 mounted on A300 of Japan Air System Co., Ltd. and on MD-11 of Japan Airline Co., Ltd., with the record of maintenance amounting to more than 100 units. The PW4000 large engine is a latest model large turbofan engine developed by Pratt and Whitney, calling for a high-level technique for its maintenance. In order to comply with this need, MHI has mustered up all its technologies from Engine Maintenance Department, Parts Production Department, Design Department and Research & Development Center to realize high reliability, low cost and short TAT.

This paper describes the undertakings of MHI regarding large engine maintenance.

2. Outline of PW 4000 engine and engine maintenance process

Launched for operation in June 1987, a total of 2 194 units of PW4000 engines have so far been produced, with 2 050 of them still in operation, boasting of our extremely high reliability. The PW4000 engine is a twin spool turbofan engine equipped with 16-stage compressor and 6-stage turbine. **Fig. 1** shows the structure of the engine.

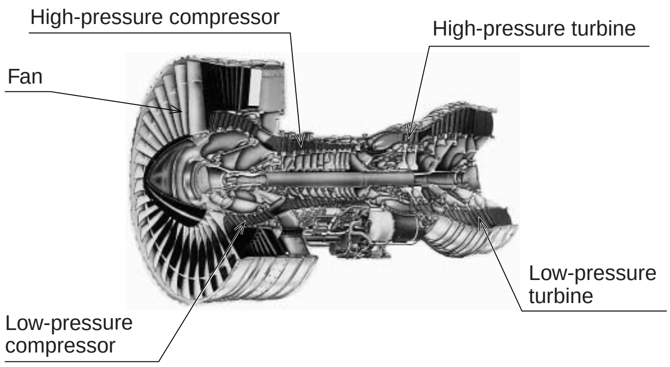

Fig. 1 Structure of engine PW4000
Maintenance of the engine is carried out per unit component parts called modules such as fan, low-pressure compressor, high-pressure compressor, high-pressure turbine, low-pressure turbine, etc.

The maintenance of PW4000 engine involves overhaul, cleaning/inspection, repair, assembly and test running processes after the engine is brought into the plant and is finally delivered to the airline as shown in **Fig. 2**.

3. Aircraft operational cost

It has been a conventional important problem for commercial airlines how to reduce operational (flight) cost of the aircraft. The operational cost is divided into two items: airframe-related cost and engine-related cost (**Fig. 3**). The engine-related cost includes cost for purchasing the engine, engine maintenance cost, fuel cost and so on. Of these engine maintenance cost occurs repeatedly, with the shop (plant) maintenance cost covering the larger part. Consequently reduction of shop maintenance cost is extremely important for reduction of the operational cost of an aircraft. Compared with the other aircraft maintenance costs, the shop maintenance cost of an engine features in that the cost of replacement parts remarkably stands out (approximately 50-60% of the to-

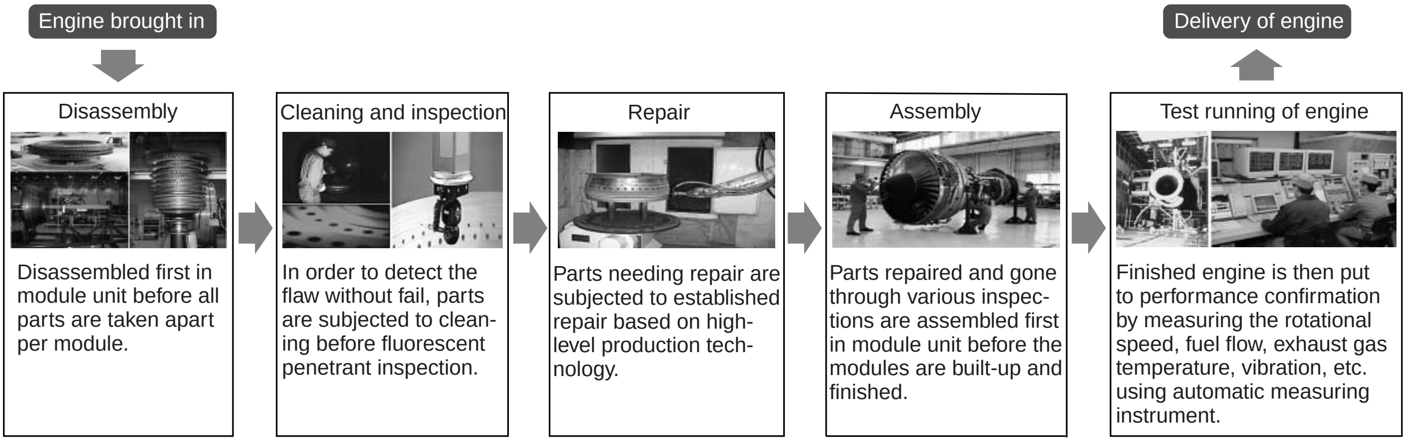

Fig. 2 Engine maintenance processes
Indicates the flow of maintenance processes from bringing into the workshop (plant) to delivery.

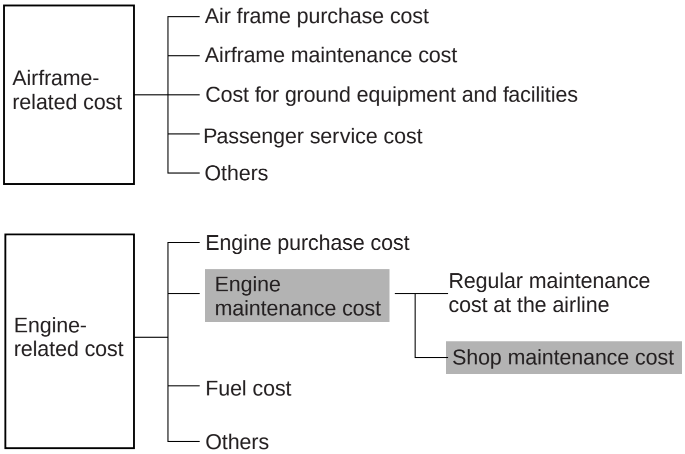

Fig. 3 Itemized aircraft operation cost

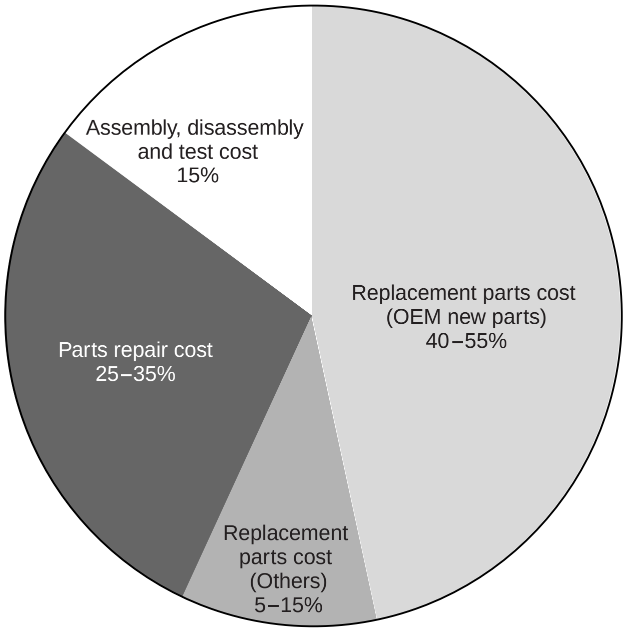

Fig. 4 Itemized engine maintenance cost

tal cost) (**Fig. 4**).

In addition, the prices of OEM new parts (products) show a high-rate annual rise of 3-5% on average, especially with the prices of the parts produced by Pratt and Whitney and Rolls-Royce soaring to 50% high in these nine years. In other words, it has become compulsory to reduce the annually increasing cost of replacement parts in order to reduce the engine maintenance cost.

4. MHI measures for engine maintenance cost reduction

Based on the experience of maintenance of more than 100 units of PW4000 engines, MHI is taking various measures given below to reduce the engine maintenance cost (**Fig. 5**). First, MHI sets an appropriate engine maintenance time and maintenance range. The parts, such as combustor, blades and vanes, exposed to severe load conditions and high temperature, can no longer be repaired if they exceed a certain deterioration level. Hence, setting an appropriate time for engine maintenance and carrying out engine maintenance while the parts can still be repaired leads to the longer life of parts and reduces the parts scrap rate. Further, setting an appropriate engine maintenance range enables to minimize the engine overhaul range, leading to the prevention of increase in 100% replacement parts bound to occur at the time of overhaul. With this purpose, MHI adopts a system of monitoring the performance data per engine to set the appropriate maintenance time and maintenance range. The system is described in detail in Section 5.

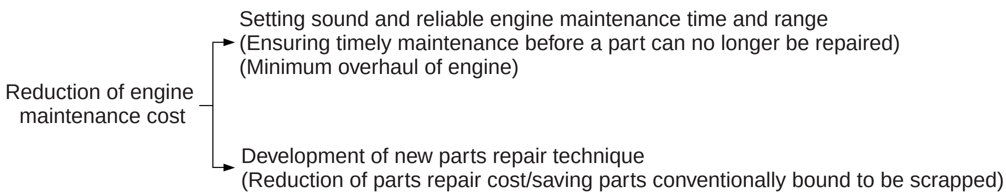

Fig. 5 Measures for reducing engine maintenance cost

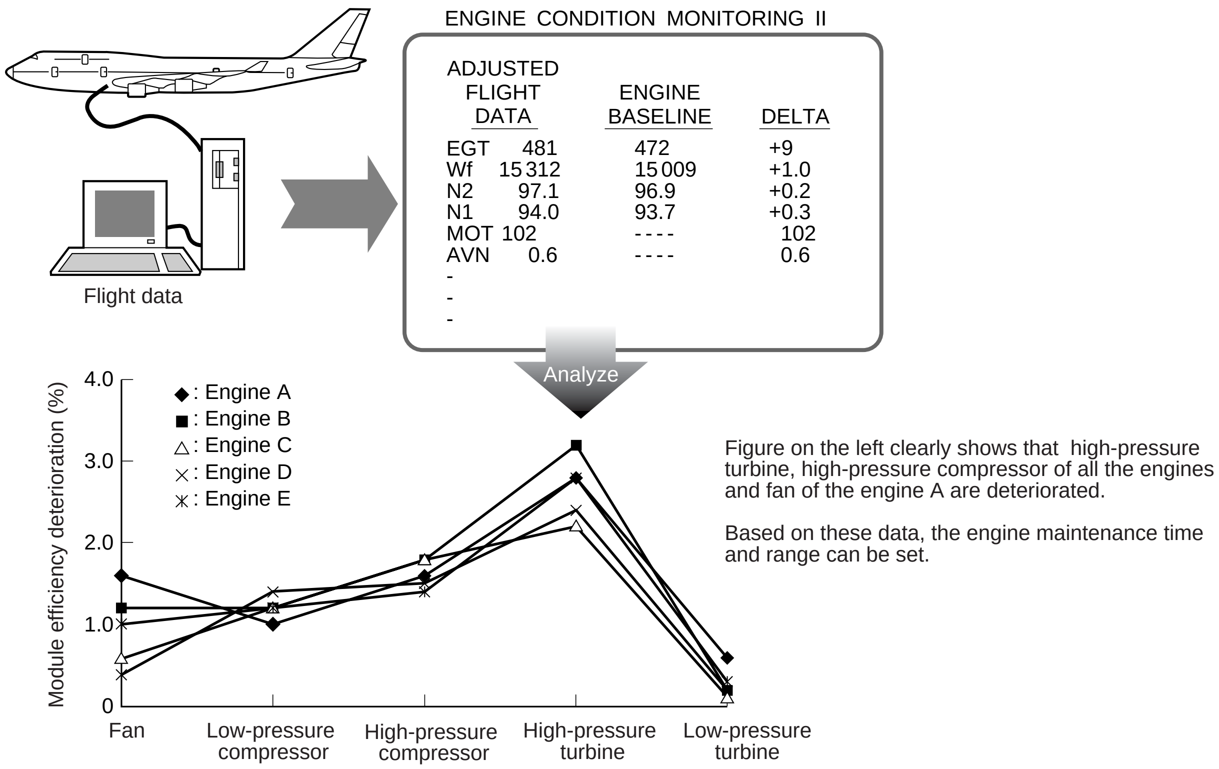

Fig. 6 Setting the engine maintenance time/range using on-wing performance analysis system

Table 1 Repair techniques for main parts & examples of newly developed and applied techniques in MHI

Division	Content	Parts repair technique: Application example of conventional technique	Parts repair technique: Application example of MHI newly developed technique
Removal	Removal of damaged part	Hand finishing, cutting and grinding	Borescope blend
Cladding	Repair material is adhered to the base material in order to recover the dimension.	TIG welding, plating, plasma welding and frame welding	Powder feed plasma welding, powder feed laser welding and HVOF coating
Bonding	Bonds the repair parts	Brazing, TIG welding, laser welding and electron-beam welding	Diffusion bonding and linear friction welding
Renewal	Reapplication of treating processes same as in the case of new parts (coating, honeycomb brazing, shot peening, etc.)	(Removal technique for deterioration treatment) Chemical solution processing and grid blasting	

Secondly, MHI develops and applies new parts repairing techniques. The application of new parts repairing techniques contributes not only to the reduction of parts repair cost but also to a drastic reduction in replacement parts cost because of the recycling of the repaired parts conventionally subjected to be scrapped. However, some of the OEM are leaning towards monopolization in recent years by keeping the repairing method secret, which has led the MRO to develop their own repair techniques. In case of MHI, it makes use of the partnership with Pratt and Whitney (a member of OEM), and has the repair technique developed by MHI acknowledged as the repair technique of OEM. The various repair techniques currently applied by MHI are described in detail in Section 6.

5. Setting the engine maintenance time and maintenance range

As mentioned above, MHI applies on-wing engine performance analysis system for PW4000 engines in order to set the appropriate time and range of maintenance (**Fig.6**).

This system provides on regular basis the on-wing engine performance data from each commercial airline, and by analyzing the obtained data the performance degradation tendency of the entire engine and of each component module can be monitored.

The appropriate maintenance time of engine is determined by means of timely comprehension of the engine performance degradation, while the appropriate maintenance range can be set by using the analytical result of the module performance data.

6. Development of new parts repair technique

Parts repair technique can be broadly divided into four divisions. (**Table 1**) MHI develops and applies new techniques in each division in addition to using the

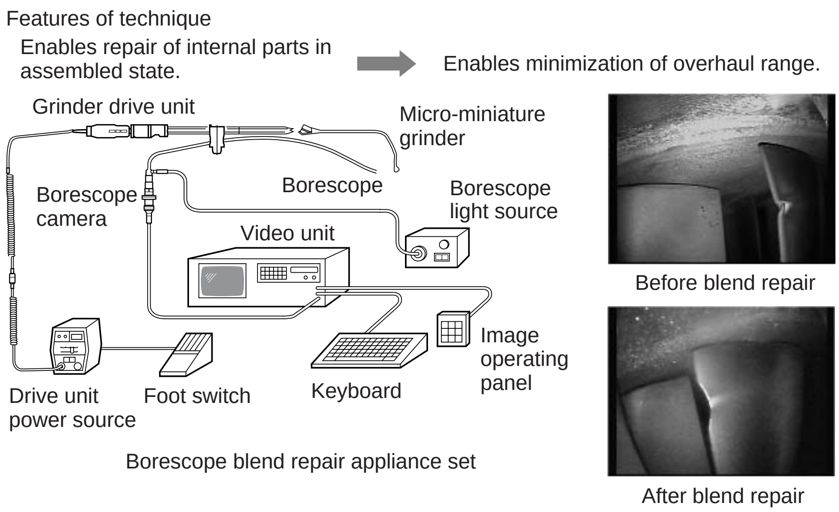

Fig. 7 Borescope blend repair technique for blades and vanes

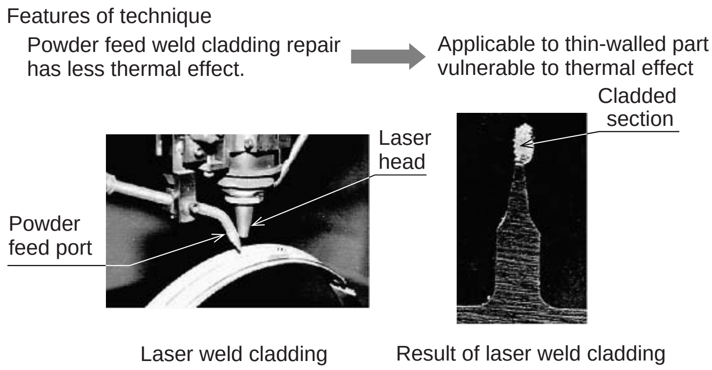

Fig. 8 Powder feed weld cladding repair process

conventional techniques, so as to reduce the replacement parts cost. These techniques are described below.

6.1 Borescope blend repair technique

The borescope blend repair technique is a technique for repairing the parts in assembled state in order to minimize the overhaul range during engine maintenance. In case the blades and vanes inside the engine are found to be damaged beyond the standard levels, the engine normally has to go through overhaul to get the parts repaired. If the borescope blend repair technique is applied, however, repair can be done without having the engine to go through overhaul. Supposing the blades and vanes of a compressor inside the engine are found to have defect, this technique can be used by inserting a borescope and a micro-miniature grinder into the engine to carry out blend repair of the defective blades and vanes without overhauling the engine. This minimizes the engine overhaul, contributing to the reduction of 100% replacement parts cost caused by overhaul (**Fig. 7**).

6.2 Powder feed weld repair process

This is a new technique applied to saving the parts conventionally subjected to be scrapped. The worn-out portion of a thin-walled part vulnerable to thermal effect can not be subjected to conventional cladding weld repair because of the deformation and deterioration of base material texture caused by the heat. In order to solve this problem MHI has developed the powder feed weld repair process (powder feed plasma welding/powder feed laser welding) with less thermal effect, enabling the cladding weld repair of a thin-walled part (**Fig. 8**).

6.3 HVOF (High Velocity Oxygen Fuel) coating repair technique

Because of the inadequate bonding strength, the conventional plasma coating repair cannot be applied to the cladding weld repair where strength is required. Hence, MHI has developed the HVOF coating repair technique with greater bonding strength than the conventional plasma coating and capable of high-density coating, enabling coating clad repair where strength is required. Further, unlike the welding, the HVOF coating does not inflict any thermal effect to the base material (**Fig. 9**).

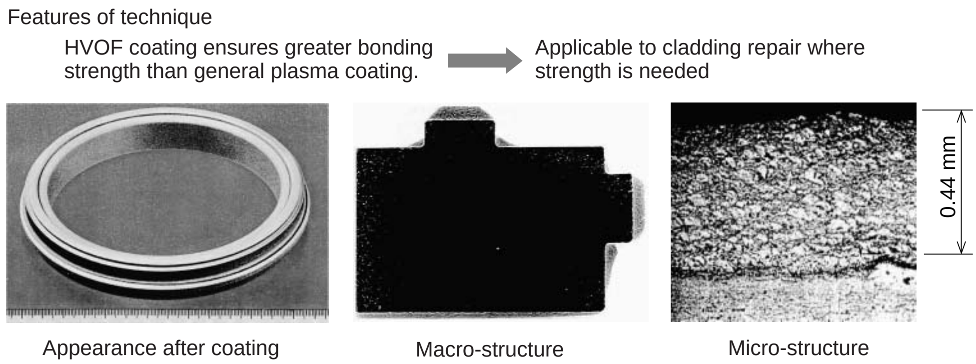

Fig. 9 HVOF coating repair technique

7. Conclusion

Substantial support for engine maintenance, one of the important factors in flight management of commercial airlines, is an important topic for large engine maintenance business. Commercial airlines have been demanding for reduction in engine maintenance cost in order to reduce the aircraft operation (flight) cost. The determination of appropriate time and range of maintenance together with the development and application of new techniques as introduced in this paper can play a key role in meeting such demand (or cost reduction).

In addition to the long amassed experiences of Engine Maintenance Department, MHI is determined to muster up the techniques of Large Engine Parts Manufacturing Department (not available in other companies), Design Department and Research & Development Center in realizing higher reliability, lower cost and shorter TAT in order to satisfy the commercial airlines.

References

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