AI2020-3

AIRCRAFT SERIOUS INCIDENT INVESTIGATION REPORT

JAPAN AIRLINES CO., LTD.
JA8980

July 30, 2020

JTSB Japan Transport Safety Board

The objective of the investigation conducted by the Japan Transport Safety Board in accordance with the Act for Establishment of the Japan Transport Safety Board (and with Annex 13 to the Convention on International Civil Aviation) is to prevent future accidents and incidents. It is not the purpose of the investigation to apportion blame or liability.

TAKEDA Nobuo
Chairman
Japan Transport Safety Board

Note:

This report is a translation of the Japanese original investigation report. The text in Japanese shall prevail in the interpretation of the report.

AIRCRAFT SERIOUS INCIDENT INVESTIGATION REPORT

THE CASE EQUIVALENT TO DAMAGE TO ENGINE
(LIMITED TO SUCH A CASE WHERE FRAGMENTS PENETRATED THE CASING OF SUBJECT ENGINE)
JAPAN AIRLINES CO., LTD.
BOEING 767-300, JA8980
AT ALTITUDE OF ABOUT 7,500 FT
ABOUT 6 KM SOUTHWEST OF KUMAMOTO AIRPORT
AT AROUND 15:55 JST, MAY 24, 2018

June 19, 2020
Adopted by the Japan Transport Safety Board
Chairman TAKEDA Nobuo
Member MIYASHITA Toru
Member KAKISHIMA Yoshiko
Member MARUI Yuichi
Member MIYAZAWA Yoshikazu
Member NAKANISHI Miwa

1. PROCESS AND PROGRESS OF THE AIRCRAFT SERIOUS INCIDENT INVESTIGATION

1.1 Summary of the Serious Incident	On Thursday, May 24, 2018, a Boeing 767-300, registered JA8980, operated by Japan Airlines Co., Ltd. had noise accompanied by vibration as well as reduced rpm of No. 1 engine (left side) indicated on instrument panel during the climb after the take-off from Kumamoto Airport. The Aircraft therefore set engine thrust idle and returned to the Airport for landing after air traffic control priority was granted. The post-flight inspection revealed that high-pressure and low-pressure turbines of the engine were damaged in several stages and a hole was generated in the engine casing. Besides, fragments of inner parts exhausted from the engine damaged windows and roofs of buildings and windshield of vehicles on the ground.
1.2 Outline of the Serious Incident Investigation	The occurrence covered by this report falls under the category of Item 17, Article 166-4 of the Ordinance for Enforcement of the Civil Aeronautics Act of Japan (Ordinance of Ministry of Transport No. 56 of 1952), as the case equivalent to “Damage of engine (limited to such a case where fragments penetrated the casing of subject engine)” as stipulated in Item 6 of the same Article, and is classified as a serious incident. Besides, the engine was damaged and a hole was confirmed in the engine casing; however, penetration of fragments was not confirmed. The Japan Transport Safety Board (JTSB) designated an investigator-in-charge and two investigators on May 24, 2018 to investigate this serious incident. Another investigator was additionally designated on May 28, 2018.

An accredited representative and an adviser of the United States of America, as the State of Design and Manufacture of the Aircraft involved in this serious incident, participated in the investigation.

Comments were invited from parties relevant to the cause of this serious incident and the Relevant State.

2. FACTUAL INFORMATION

2.1 History of the Flight

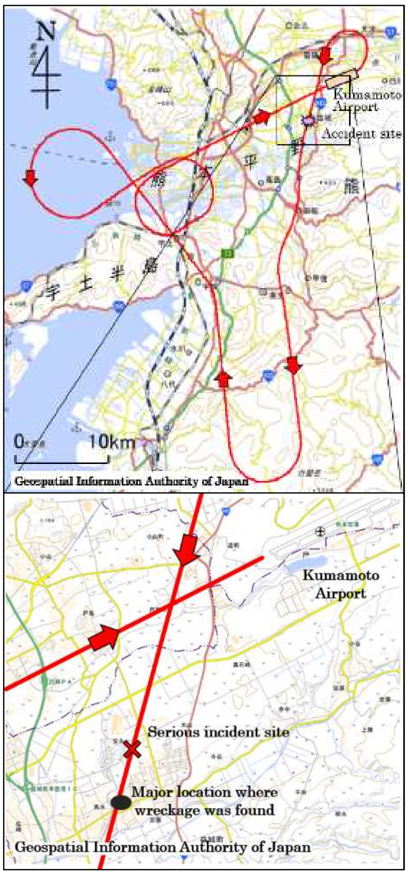


Figure 1: Estimated flight route

On Thursday, May 24, 2018, at 15:52 JST (UTC+9 hours; unless otherwise noted, all times are indicated in JST in this report on a 24-hour clock), a Boeing 767-300, registered JA8980, operated by Japan Airlines Co., Ltd. (hereinafter referred to as "the Company") as a scheduled flight 632, took off from Kumamoto Airport for Tokyo International Airport with 217 persons on board, consisting of a captain, seven crew members and 209 passengers.

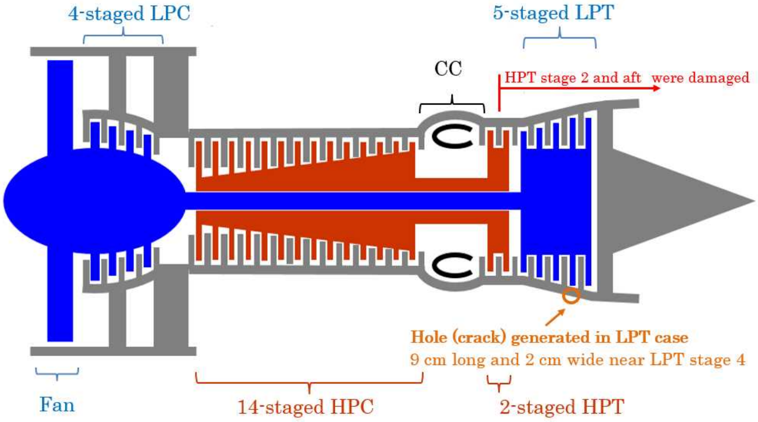
In the Aircraft, the captain sat in the left pilot's seat as PM (mainly responsible for monitoring flight status of aircraft, cross-checking PF's maneuvering and other non-operational tasks of aircraft) and the FO (First Officer) on the right pilot's seat as PF (mainly responsible for maneuvering of aircraft).

During the climb at an altitude of about 7,500 ft at an airspeed of about 250 kt after the take-off from Runway 07 at the Airport, an abnormal noise accompanied by vibration occurred, and the instrument panel indicated reduced rpm of No. 1 engine (left side) and the increases in exhaust gas temperature (EGT) and engine vibration; therefore, the captain switched over to the PF from the PM and conducted the items to deal with Engine Limit or Surge or Stall on the non-normal check list after setting engine thrust idle.

When doing this, the captain and the FO confirmed that the engine's instrument panel indicated that figures were reduced to the normal, and the vibration and abnormal noise became lower after reducing engine thrust.

As the captain slowly increased engine thrust accoording to the procedure in the check list, the vibration and noise were increased, therefore, he immediately returned engine thrust to idle.

Although the vibration and abnormal noise from the engine became lower, the vibration still continued; and besides, as there was an available departure aerodrome for landing, the Aircraft returned to the Airport after air traffic control priority was granted, and landed at the Airport at 16:17.

	At the time of the occurrence of this serious incident, the Aircraft was climbing at an altitude of about 7,500 ft about 6 km southwest of the Airport (32°47’59” N, 130°48’ 41” E) and the time of the occurrence was at around 15:55 on May 24, 2018.
2.2 Injuries to Persons	None
2.3 Damage to Aircraft	(1) Extent of Damage: Slightly damaged Marks of rubs and dents were generated on inboard flap, outboard flap, horizontal stabilizer and fairing located at No. 1 engine aft. (2) Damage to the Engine The Aircraft was equipped with a two-spool turbofan engine that consists of a fan, 4-staged low-pressure compressor (LPC), 14-staged high-pressure compressor (HPC), combustion chamber (CC), 2-staged high-pressure turbine (HPT) and 5-staged low-pressure turbine (LPT). HPT stage 2 and aft of No. 1 engine were fractured, condition of which is as shown in Figure 2.  Figure 2: Structure and fractured sections of Engine i) HPT Among total 74 blades on HPT stage 2, blade #13 was fractured at the shank. Besides, blade #12 was fractured at the position of about half of the airfoil. Furthermore, the blade #11 and #10 were fractured near the tip of the blades. Other blades had tips chipped along the entire circle (see Figure 3).  HPT stage 2 blades (74 blades in total) Damage initiating from HPT stage 2 blade #13 Figure 3: Condition of damaged blades of HPT stage 2

ii) LPT

A great portion of blades and nozzles of LPT was damaged.

iii) LPT Casing

There was a hole (crack), which was about 9 cm long and about 2 cm wide, generated near LPT stage 4 (in the direction of around three o’clock if seen from the engine aft).

Besides, the core cowl[*1] outside the hole generated on LPT casing was free from damage.

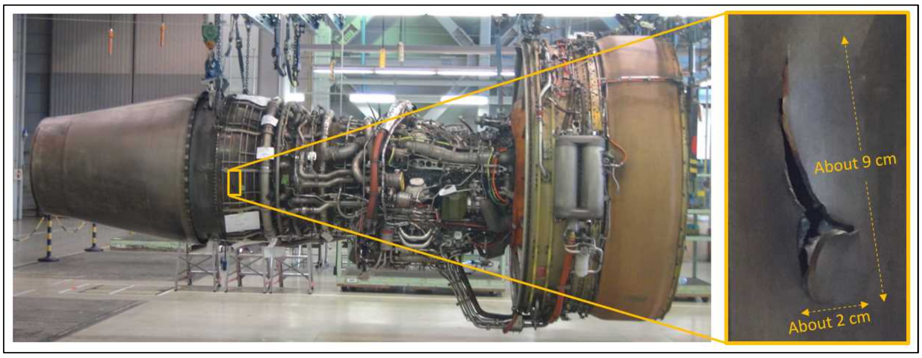


Figure 4: Hole (crack) generated on LPT casing

2.4 Personnel Information

(1) Captain Male/Age 50

Airline transport pilot certificate (Airplane)	November 12, 2002
Type rating for Boeing 767	October 16, 2013
Class 1 aviation medical certificate	
Validity	September 21, 2018

(2) FO Male/Age 43

Commercial pilot certificate (Airplane)	August 1, 2001
Type rating for Boeing 767	March 11, 2003
Instrument flight certificate	April 19, 2002
Class 1 aviation medical certificate	
Validity	August 25, 2018

2.5 Aircraft Information

(1) Aircraft

Type:	Boeing 767-300
Serial number:	28837
Date of manufacture:	August 22, 1997
Certificate of airworthiness:	No. 2009-115

Validity: During the period in which the aircraft is maintained in accordance with the Maintenance Management Manual approved based on Civil Aeronautics Act

Total flight time	53,100 hours 51 minutes
Flight time since the last periodic check (C maintenance on November 24, 2017)	1,242 hours 00 minutes

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[*1] “core cowl” denotes a metal cowling that covers the outside of engine casing that covers compressor, combustion chamber and turbine of engine.

(2) Engines

Attached position	No. 1 Engine (on the left)	No. 2 Engine (on the right)
Type	General Electric CF6-80C2B4F	
Serial number	702858	702418
Date of manufacture	December 16, 1992	September 27, 1990
Total time in service	70,802 hours	68,168 hours
Total cycles in service	32,805	34,165

2.6 Additional Information

(1) Damage to the Ground

Windows and roofs of buildings and windshield of vehicles on the ground near the serious incident site were damaged from fragments of inner parts exhausted from No. 1 engine. About 400 exhausted fragments were gathered, and the heaviest one among them weighed about 70 gram.

Besides, LPT of same type of engine weighs about 726 kg and the pertinent LPT after the damage weighed about 653 kgs. When comparing the weights, the weight reduced by exhausted fragments was calculated equivalent to about 73 kgs.

(2) Engine Data Recorded in FDR and QAR

Analysis of FDR and QAR revealed that abnormality or its indication was not recorded until the occurrence of the serious incident.

At 15:55 when the Aircraft was climbing, the vibration level[*2] on N2[*3] side of No. 1 engine abruptly increased reaching the upper limit of measurement (4.99 unit) (see "a" in Figure 5), immediately followed by abrupt increases of the vibration level on N1[*4] side reaching the upper limit of measurement (see "b" in Figure 5) and EGT[*5] up to about 950° C (see "c" in Figure 5).

Then, rpm on N1 side was abruptly decreased, and the same on N2 side was almost simultaneously reduced as well. Thrust lever was reduced to idle five seconds thereafter (see "d" in Figure 5). Engine rpm (N1 and N2) was still maintained near idle position until landing, and vibration level on N1 and N2 sides remained high (see "e" in Figure 5). Besides, figures of EGT record after EGT sensor was damaged associated with the damage to HPT may not be accurate.

[*2] "vibration level" denote a vibration level of fan, LPC, LPT, HPC and HPT of engine, and the highest level of which is displayed on EICAS (Engine Indication and Crew Alering System) display unit both in analog form and figures (unit).

[*3] "N2" denotes rpm of HPC and HPT of engine. The pertinent engine indicates 9,827 rpm, which is close to the maximum engine thrust, as 100%.

[*4] "N1" denotes rpm of fan, LPC and LPT of engine. The pertinent engine indicates 3,280 rpm, which is close to the maximum engine thrust, as 100%.

[*5] "EGT" denotes exhaust gas temperature of engine, which is measured in between HPT and LPT.

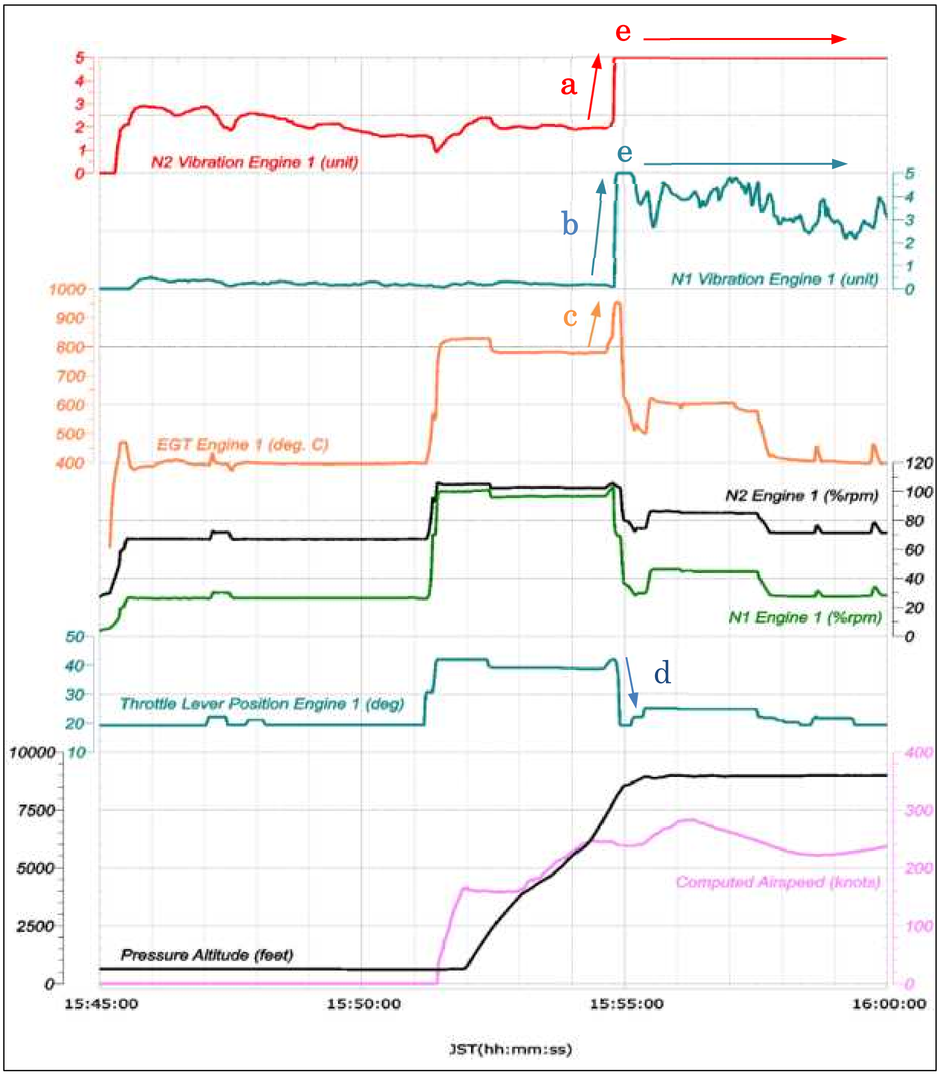


Figure 5: QAR record

(3) Flight Logbook and Maintenance Record

According to flight logbook of the Aircraft and maintenance records of the Aircraft and the engines, there occurred no malfunction that could involve in the damage to the engine before this serious incident.

(4) History of Blade #13 on HPT Stage 2

History of the fractured blade #13 on HPT stage 2 is as follows:

Part number: 2118M77P03 (hereinafter referred to as “P03 Type”)

The part number at the time of manufacturing was 1881M52G05 (hereinafter referred to as “G05 Type”), and thereafter was altered to P03 Type by implementation of coating modification based on the Service Bulletin SB72-1271 issued by the engine manufacturer. Due to this, G05 Type and P03 Type have different part numbers, but they are dimensionally identical.

Serial number: PCM80CH8

Total time in service: 56,772 hours (4,568 hours after overhaul)

Total cycles[*6] in service: 15,397 cycles (3,395 cycles after overhaul)

[*6] “cycles” used in this report denotes a number of a complete sequence of take-off and landing that is counted as one cycle.

(5) Metallurgical Investigation into Blades on HPT Stage 2

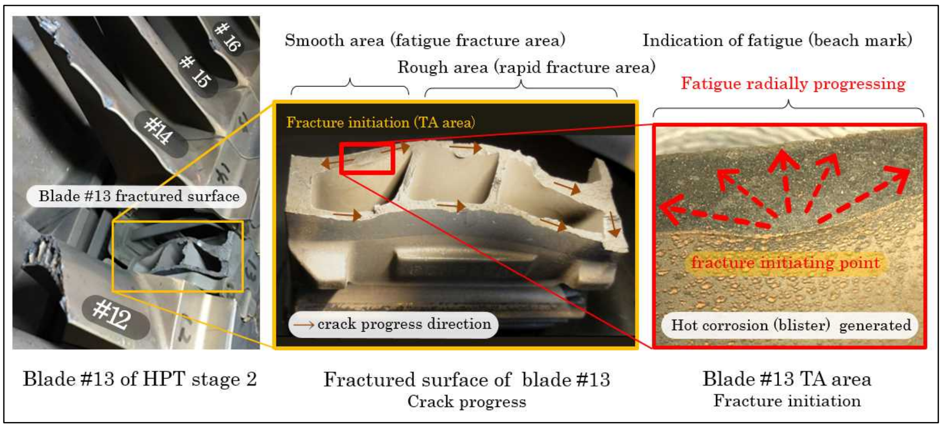
Metallurgical investigation into the blades on HPT stage 2 was conducted at the facilities of the designer and manufacturer of the engine.

i) Fracture initiating point of blade #13

There existed two different areas on the fractured surface of blade #13, a smooth area (fatigue fracture area) and a rough area (rapid fracture area). The fracture progressed from TA (Turning Around: branching and turning around of cooling air flowing inside blades) area as an initiating point in the air passage 1 in the smooth area, and the mark (beach mark) of indication of fatigue was observed.

Besides, cracks were generated on aluminide coating layer*7 near the initiating point (see Figure 7), and corrosion (blister)*8 swollen in hot bubble was generated near the cracks. Detailed investigation into the fractured surface of the blade with Scanning Electron Microscope revealed the marks of low-cycle fatigue*9 that progressed from TA area. (See Figure 6 and 7) Blade shape and coating layer thickness met the design and manufacturing requirements.

Besides, investigation into the elements contained in the base materials of blade and the coating layer by X-ray analysis detected ingredients of oxygen as a mark of oxidizing phenomenon and sulfur as a mark of sulfurizing phenomenon from the portions in which the hot corrosion and the cracks of the coating layer existed. Ingredients of coating layer of the blade and the base materials met the design and manufacturing requirements.



Blade #13 of HPT stage 2

Fractured surface of blade #13
Crack progress

Blade #13 TA area
Fracture initiation

Figure 6: Fractured surface of the blade #13

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*7 "aluminide coating layer" denotes a thin membrane layer of aluminum compound coated on the surface of base metals to protect them from heat and oxidization, and thereby prevents them from deteriorating.

*8 "blister" denotes corrosion swollen in bubble that is generated in high temperature condition.

*9 "low-cycle fatigue" denotes fatigue generated in case that a metallic material is given plastic deformation by relatively large repetitive stress of about 10,000 cycles or less.

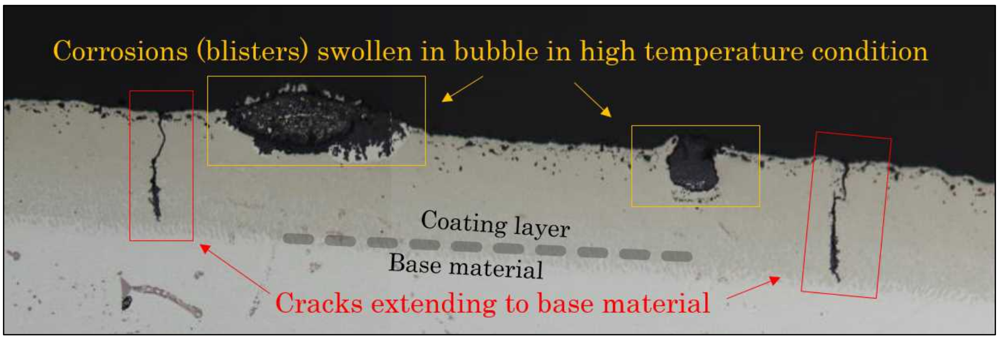


Figure 7: Coating layer near the fracture initiating point of blade #13 (cross sectional view)
(condition of cracks and corrosions of coating layer)

ii) Condition of blades on HPT stage 2

HPT stage 2 consisted of 8 blades of P03 Type, same as blade #13, 54 blades with a part number 1881M52G14 (hereinafter referred to as "G14 Type") and 12 blades with a part number 1881M52G15 (hereinafter referred to as "G 15 Type").

Investigation into the condition of the TA area of blade #3, 5, 7 and 9, all of which are of the same type to blade #13 (fractured blade), by cutting them revealed that all blades had hot corrosion. Cycles in service of these blades were 15,397.

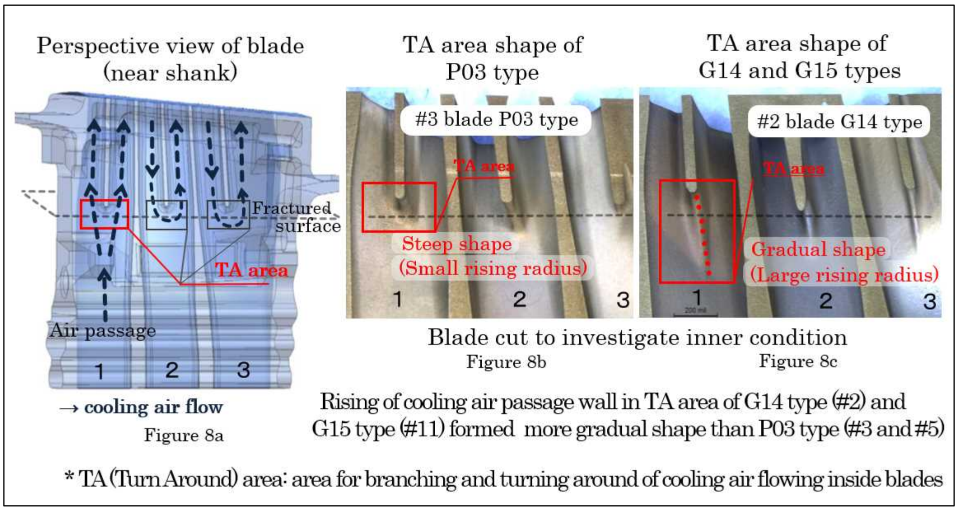
Measuring the coating layer thickness verified that these blades met the design and manufacturing requirements; however, blade #3, 5 and 13 were relatively thicker with cracks generated in the coating layers.

Besides, the coating layer of the blades was aluminide coating, which has a low thermal ductility, and therefore, is prone to generate cracks easily at lower temperatures when the coating layer is thick.

TA areas of G14 Type and G15 Type had a thinner coating layer than P03 Type forming a gradual shape, which is prone to resist stress concentration. G14 Type and G15 Type were free from hot corrosions and cracks, which were generated in P03 Type.

Table 1: Comparative verification of TA area of blades on HPT stage 2

Blade #	Type	Cycles in service	Existence of hot corrosion on coating layer	Coating layer thickness (1/1000 inches)	Existence of cracks on coating layer
13	P03 Type	15,397	Yes	2.41	Yes
3	P03 Type	15,397	Yes	2.51	Yes
5	P03 Type	15,397	Yes	2.46	Yes
7	P03 Type	15,397	Yes	0.82	None
9	P03 Type	15,397	Yes	1.63	None
2	G14 Type	3,395	None	1.61	None
11	G15 Type	7,205	None	0.86	None



Rising of cooling air passage wall in TA area of G14 type (#2) and G15 type (#11) formed more gradual shape than P03 type (#3 and #5)

* TA (Turn Around) area: area for branching and turning around of cooling air flowing inside blades

Figure 8: TA area condition of P03, G14 and G15 types

(6) Similar Case Occurred in the Past with the Same Type of the Engine (Case of JA767B)

The serious incident occurred on December 1, 2005 with JA767B (Boeing 767-300) (incident category: “Flame within an engine fire-prevention area” as per Aircraft Serious Incident Investigation Report AI-2009-1-1 issued by the JTSB) was such that the engine was damaged from fractured blade #58 on HPT stage 2 of the right engine, the fuel supply tube was also ruptured by vibration of the engine, and subsequently leaked fuel caught fire leading to the outbreak of flame.

In the JA767B serious incident investigation, the cause of the cracks generated on blade #58 could not precisely be determined, and the conclusion was made that it is somewhat likely that combined factors described below contributed to generation of the cracks:

i) because the TA (Turning Around) curvature radius of the cooling air passage inside the blades was smaller, the stress was prone to concentrate on that area and thereby it became prone to cause cracks, and later, the cracks progressed due to low-cycle fatigue,

ii) because sulfur was detected from the fractured surface, the blade was in the condition that it became prone to have cracks came by hot corrosion.

iii) thinner LE passage (corresponding to Air passage 1 in Figure 8a) wall of the shank created the high stress on the entire blades (due to variation in blade manufacturing although LE passage wall of the shank stayed within the nominal values).

After the JA767B serious incident, the engine manufacturer made modification by thinning coating inside the shank of the fractured type of the blade, and simultaneously, re-designed the curvature radius of TA area, which was incorporated in the Service Bulletin CF6-80C2 (SB) 72-1283 (HPT Rotor New Stage 2 Blade) dated February 12, 2008 and was issued and the new type of the blades were provided to operator.

Besides, the Service Bulletin 72-1283 described that replacement with the re-designed blade was to save costs that incurred associated with maintenance because previous type of blades were disposed of due to corrosion, and the timing of the replacement was at customers' discretion, but did not describe the detailed background of this re-designed blade.

In addition, as for the type of blade such as blade #13 whose part number was G05 Type at the time of manufacturing and thereafter was altered to P03 Type by implementation of coating modification, the engine manufacturer did not include in the parts to be replaced.

(7) Similarities Between JA8980 and JA767B Serious Incidents

Blade #13 on HPT stage 2 of JA8980 was manufactured under the same part number as blade #58 on HPT stage 2 of JA767B, both of which had similar conditions in hot corrosion generated in the coating layer, cracks and fracture.

At the time of this serious incident, replacement with the new type of re-designed blade was not mandatory; however, deteriorated blades were replaced with the new type of blade in overhaul work.

Table 2: Blades initiating engine fractures in JA8980 and JA767B

	Blade #13 on HPT stage 2 of JA8980	Blade #58 on HPT stage 2 of JA767B
Part number	P03 Type (G05 Type*) *altered to P03 Type by modification of coating after shipment as G05 Type	G05 Type
Serial number	PCM80CH8	PCM82JM4
Date of manufacture	July 15, 1999	October 19, 1999
Time in service	56,772 hours	11,513 hours
Cycles in service	15,397	9,546

(8) Same Type of Blades as Blade #13

According to the engine manufacturer, about 300,000 in total of the same type of blades to #13 were manufactured from the period of January 1999 to April 2002.

Besides, this serious incident was the second case originating from the fracture of the same type of blade after the JA767B serious incident. In either case, multiple turbine airfoils were fractured; however, fragments did not lead to penetrating LPT casing.

(9) Investigation by the Company

In view of the fact that blade #13 of JA8980 is the same type as blade #58 of JA767B and manufacturing date of both blades was close, the Company, as an interim safety action, replaced 90 blades of same type and same period manufactured as these with the re-designed new type of blades. When replacing these 90 blades, another 168 blades of the same type, which were installed in the pertinent engine and manufactured in a different period, were replaced with the re-designed new type of blades making a total of 258 blades replaced.

The Company's investigation into the condition of TA area of the replaced 226 blades among the total 258 blades replaced by cutting them revealed that two blades had cracks that progressed from the coating layer to the base materials.

Besides, these two blades had a total time in service of 26,232 hours

	and total cycles in service of 14,579.

3. ANALYSIS

3.1 Involvement of Weather	None
3.2 Involvement of Pilot	None
3.3 Involvement of Aircraft	Yes
3.4 Analysis of Findings	(1) Engine Fracture Initiating Point Turbine blades were fractured at various radial locations from HPT stage 2 and aft. HPT stage 2 had four fractured blades of #13, 12, 11 and 10 in the order of having less remainder. Among these, fractured surface of blade #13 had marks of low-cycle fatigue initiating from the TA area. From this, it is highly probable that the engine was damaged initiating with the fractured blade #13. (2) Cracks Generated on the TA Area of Blade #13 It is somewhat likely that the cracks on the TA area of blade #13 were generated by low-cycle fatigue initiating with the damage generated on the coating layer because swelling (blister) caused by hot corrosion and cracks were generated on the coating layer (see Figure 6). It is somewhat likely that cracks generated on the coating layer of blades, which progressed to the base materials and finally led to fracture of #13 blade, were involved by complex factors of increased cycles in service, steep rising shape of cooling air passage wall in the TA area (small curvature radius of TA area) (see Figure 8) and the thick coating layer (see Table 1). i) Cycles in service Generally, the more cycles in service increase, the more quality of coating deteriorates, thereby leading to generation of and progress to hot corrosion and cracks. Accordingly, it is somewhat likely that increased cycles in service affected generation of cracks on the coating layer as well as progress to the base materials. i i) Rising Shape of Cooling Air Passage Wall in TA area Blade #2 (G14 Type) and #11 (G15 Type), which had more gradual shape of cooling air passage wall in TA area than #13 (P03 Type), were free from generation of cracks on the coating layer (see Table 1 and Figure 8). Accordingly, is it somewhat likely that the steep shape of cooling air passage wall in the TA area of the blade generated stress concentration to the pertinent area and affected generation of cracks on the base materials. iii) Thickness of the coating layer Comparative investigation into the condition of TA area of blade #3, 5, 7 and 9, all of which are P03 Type, same as #13, revealed that cracks were generated in the coating layer of #3 and #5 only, which

had a relatively thicker coating layer (see Table 1 and Figure 8). It is somewhat likely that the thicker coating layer affected generation of cracks on the base materials because aluminide coating of blades has a low ductility with tendency to be prone to generate cracks when coating layer is thick.

(3) Damage to LPT Casing

It is probable that damage to HPT stage 2, LPT and LPT casing was initiated by the fractured blade #13 of HPT stage 2, followed by a chain of fractures of blades and stator vanes of aft stages, fragments of which collided with LPT casing near LPT stage 4 and generated a hole.

Although the hole was generated on LPT casing, it is probable that fragments of the engine did not penetrate LPT casing because the inner surface of core cowl covering LPT casing was free from marks of collision with the fragments.

It is probable that fragments of the engine dropped on the ground were exhausted from exhaust nozzle of the engine, not from the hole of LPT casing.

(4) Replacement of the Same Type of Blade

About 300,000 in total of the same type of blade as #13 were manufactured over the period of 1999 to 2002, and this serious incident was the second case originating from the fracture of the same type of blade after the JA767B serious incident.

In view of the fact that #13 blade of JA8980 is the same type as #58 blade of JA767B and manufacturing date of both blades was close, the Company, as an interim safety action, replaced 90 blades, which were manufactured during the same period of time (July through October 1999), and another 168 blades of the same type, which were installed in the pertinent engine, with the new type of blades. When replacing the blades, another 168 blades of the same type, which were used in the engine in which the 90 blades were installed and manufactured in a different period from the above manufacturing period, were replaced with the new type of blades as well (making a total of 258 blades replaced).

Investigation by the Company into the condition of TA area of the replaced 226 blades among the total 258 blades replaced by cutting them revealed that two blades with 14,579 cycles in service had cracks that progressed from the coating layer to the base materials.

From this, it is probable that cracks, apart from the two blades, were already generated on the base materials of the same type of blades or may be newly generated later, and it is somewhat likely that such cracks progress to engine fracture as in the case of this serious incident over the period of time in service.

From aircraft airworthiness standpoint, in the event that fragments of fractured HPT blade generated by damaged engine do not penetrate casing as in the case of this serious incident, the fragments do not lead to damaging aircraft outside engine such as oil and hydraulic system, electrical wiring or

	electronic devices, and therefore, it is probable that possibility of leading to situations in which safety flight or landing of aircraft is put at risk is low. On the other hand, from standpoint to prevent damage to the ground, in the event that the turbine flow path hardware of the engine is damaged, it is somewhat likely that fragments are exhausted from exhaust nozzle and drop on the ground resulting in damage to the ground as in the case of this serious incident. Therefore, it is required that the same type of blades (G05 Type and P03 Type that was altered by modifying G05 Type) installed in engine probably having cracks in base material be removed and replaced with the new types of blades, such as G15 Type, which was issued through the Service Bulletin SB72-1283 (issued on February 12, 2008), G14 Type, which was issued through the Service Bulletin SB72-1457 (issued on November 21, 2013) and Part No. 1881M52G31, which was issued through the Service Bulleting SB72-1519 (issued on October 20, 2015). The engine manufacturer is required to continuously gather malfunction information from operators and maintenance companies, investigate and analyze such information in order to identify blades with possibly having cracks and recommend replacement of such blades with these new types of blades.

4. PROBABLE CAUSES

It is highly probable that this serious incident was caused by the fractured blade #13 on HPT (high pressure turbine) stage 2 of No. 1 engine (left side), when the Aircraft was climbing, that damaged blades and stator vanes of aft stages, fragments of which collided with LPT (low pressure turbine) casing and generated a hole (crack).

It is highly probable that the fractured blade #13 was caused by cracks that were generated on TA (Turning Around (branching and turning around of cooling air flowing inside blades)) area and progressed thereafter.

It is somewhat likely that cracks generated on TA area were caused by hot corrosion swelling (blister) generated on the coating layer of the blades and low-cycle fatigue initiating from the cracks.

5. SAFETY ACTIONS

(1) Japan Civil Aviation Bureau of the Ministry of Land, Infrastructure, Transport and Tourism (JCAB, MLIT)

Upon the announcement on May 29, 2018 from the JTSB that the Borescope Inspections (BSIs) confirmed that turbine blades were fractured and damaged from HPT stage 2 toward LPT side, the JCAB, MLIT instructed domestic aviation companies operating the aircraft such as those equipped with the same type of the engine to make an inspection on the blades on HPT stage 1 and stage 2 on the same day.

(2) Safety Actions Taken by the Company

In view of the fact that blade #13 of HPT stage 2 of the Aircraft is the same type as #58 blade of JA767B and manufactured during the same period, the Company, as an interim safety action, replaced 258 blades in total including 90 blades (7 engines), which were manufactured during the same period of time (July through October 1999), and another 168 blades of the same type, which were installed in the pertinent engine, with the new type of blades by November 2018.

Besides, as a final safety action, the Company replaced all blades of the same type used in all other engines with the new type of blades by March 2020.

Besides, the Company conducted an additional 200-cycle check (BSIs conducted on the blades of HPT stage 1 and stage 2) in addition to the conventional 400-cycle check (BSIs conducted on the combustion chamber and the high-pressure turbine) until the same type of blades were replaced with the new types of blades.

(3) Providing Information and Continuing Monitoring by the Engine Manufacturer

i) Continuously monitoring cycles in use

In order to identify blades, which are similar to blade #13 and probably have cracks in base materials, the engine manufacturer is set to investigate cycles in use of parts or components, which probably may not meet design intent, and cope with such circumstances as needed. The engine manufacturer is set to monitor cycles in use of the same type of blades and continuously verify events confirmed in flight or in maintenance.

ii) Issuance of product support information (Fleet Highlight)

In an effort to identify blades of the same type as blade #13 probably having cracks in the base materials and recommending replacement of such blades with the new types of blades, the engine manufacturer is planning to provide information on the number of occurrences of fractures and malfunctions of the same type of blades, recommended measures and Service Bulletins (SB) issued in the past in relation to major repairs or improvements with operators and maintenance companies.