CI922 Occurrence Investigation

Executive Summary

On May 30th, 2019, China Airlines scheduled passenger flight CI922, an Airbus A330-302, registration number B-18352, took off from Hong Kong International Airport (VHHH) to Taiwan Taoyuan International Airport (RCTP) at 08:36 (UTC+8) with 2 flight crew members, 10 cabin crew members, 243 passengers, a total of 255 persons onboard. During climb, around 88 nm south-east from VHHH and as passing through 26,672 feet, the aircraft experienced an in-flight left (No.1) engine fire. The flight crew responded by performing the abnormal procedures declaring an emergency, and initiating a turn back toward VHHH. At 09:31, the aircraft safely landed at VHHH airport without further incident.

The Captain of this flight who occupied the left seat was the pilot flying and the First Officer who occupied the right seat was the pilot monitoring. The flight crew received the “ENGINE HIGH VIBRATION” advisory on the ECAM display when the aircraft was climbing through 25,568 feet and heading toward waypoint ENVAR at 0852:34. After checking the system pages, the Captain realized that the reading of N2 vibration of ENG1 indicated 7.5 and kept rising, thus he requested the First Officer react per QRH, and reduced engine thrust at 0853:12. The reading of N2 vibration of ENG 1 dropped to 7 momentarily but again it increased up to 9.

At 0853:35, as the First Officer was performing the abnormal

procedures, the flight crew heard a “bang” and felt a shake, followed by the “ENG 1 FIRE” master warning triggered at 0853:39. The Captain commanded to perform ECAM action, the First Officer retarded the power lever of ENG1 to idle position under Captain’s supervision, turned off ENG1 master switch, and then discharged No.1 fire extinguisher of ENG1.

The Captain declared a Mayday, notified engine one failure, and requested to descend to FL250 to Hong Kong ATC at 0854:56. The First Officer subsequently discharged No.2 fire extinguisher of ENG 1 per QRH. The Captain requested to return to VHHH and obtained clearance and assistance from Hong Kong ATC. The ENG1 fire master warning stopped at 0856:50.

The flight crew commenced a normal approach to VHHH and landed the aircraft on runway 07L at 0931 safely. As the aircraft vacated runway, the flight crew canceled the emergency declaration after inquiring by the tower controller. The passengers disembarked as normal after the aircraft had parked, no one was hurt on board.

According to the Transportation Occurrence Investigation Act of the Republic of China (ROC), and the content of Annex 13 to the Convention on International Civil Aviation, the Taiwan Transportation Safety Board (TTSB), an independent transportation occurrence investigation agency, was responsible for conducting the investigation. The investigation team also included members from US National Transportation Safety Board (NTSB), France Bureau d'Enquêtes et d'Analyses (BEA), AIRBUS, GE Aviation, China Airlines and Taiwan Civil Aeronautics Administration

(CAA).

The 'Draft Final Report' of the occurrence investigation was, by the procedures, reviewed at TTSB's 28th Board Meeting on August 6th, 2021 and then sent to relevant organizations and authorities for comments. After comments were collected and integrated, the Final Report was reviewed and approved by TTSB's 32nd Board Meeting on November 5th, 2021.

There are 7 findings from the Final Report as follows.

I. Findings as the result of this investigation

Findings related to probable causes

1. The no.1 engine of occurrence aircraft experienced high vibration and fire during climb. The root cause was determined to be 4R stationary air/oil seal mis-assembly during the last shop visit for a performance restoration (heavy repair). The incorrectly seated 4R stationary air/oil seal caused ovalization of the seal inner diameter which reduced the clearance between 4R stationary and rotating air/oil seal. During normal operation, it initiated heavy rubs and generated overheat between the 4R rotating and stationary air/oil seals. The 4R rotating air/oil seal deformed radially outward from overheating and centrifugal forces which caused further deep rubs on stationary seals. Eventually both seals were severely damaged and the oil sump cavities lost sealing capability.
2. The liberated debris from damaged 4R rotating and stationary seals impacted the 4R rotating vent seal. After losing the separation of the

vent seal, the high pressure and high temperature HP recoup air entered sump cavities and caused the oil auto-ignition fire. The fire entered and burned through LP recoup tubes and B/C sump vent tubes which caused the engine compartment overheat and fire.

Findings related to risk

1. The installation of 4R stationary air/oil seal without using the gage fixture as prescribed in the latest engine manual revision would compromise the allowable clearance between 4R stationary and rotating air/oil seal.
2. The alternative method of 4R stationary air/oil seal installation of the occurrence engine was deviated from the effective manual revision, however it was accepted by GE Aviation. The work card prepared by the operator did not fully reflect the document and procedure recommended by GE Aviation. This might increase the risk of procedures omission and fail to retain the complete work records.
3. The gage fixture is crucial to check the seal seating during 4R stationary air/oil seal installation. The operator did not acquire the tool in a timely manner, which is not conducive to maintenance personnel to perform the job in accordance with the latest revision of manual.

Other findings

1. The occurrence flight crew were properly certificated and qualified in accordance with the Civil Aeronautics Administrative (CAA) regulations. Records of training and checks show no anomaly related to this occurrence. The rest and activities of flight crew 72 hours

before the occurrence were normal. No evidence indicated any pre-existing medical conditions or alcoholic issue that might have adversely affected the flight crew's performance during the occurrence flight.

2. Reviewing the work card record of 4R air/oil seal installation and relevant document suggested that:

(1) The parts used by the work had no anomaly;

(2) The qualification of mechanics who performed the task complied with company requirements;

(3) The calibration of precision measurement equipment (PME) tools used during the work were normal;

(4) The measurements of minimum radius/ clearance of 4R air/oil seal were within limits according to the applicable manual;

(5) The work was performed according to the previous revision of the process which deviated from the effective revision, however it was accepted by GE Aviation. GE Aviation also required China Airlines to take additional precautions during installation of the seal to prevent any misalignment.

(6) The shop practices taken by China Airlines were similar to the good shop practices recommended by GE Aviation.

II. Safety Actions

During the investigation, TTSB maintained close communication with all relevant organizations. The engine manufacturer, GE Aviation, provided its investigation report on June 1st, 2020. The report included proactive safety actions to address the deficiency discovered during this

investigation with regard to the 4R stationary air/oil seal installation. China Airlines and Taiwan CAA also took corresponding safety actions. Following is a summary of these proactive safety actions.

Safety Actions taken by GE Aviation

1. ***To further ensure that all Maintenance, Repair, and Overhaul (MRO) facilities are incorporating the new 2C18118G01 tool GE Aviation has taken the following actions:***

- *Revised the Engine Shop Manual (ESM) for both the CF6-80C2 & -80E1 sections 72-34-00 to:*
  - *Clearly identify that you "must" use tool 2C18118G01.*
  - *"Tool 2C18118 must be used"*
  - *Addition of CAUTION NOTES stating the consequences if the tool is not used.*
  - *Engine Manual revisions dated April 15, 2020 and can be found on the next slide*

- *Field communications to re-enforce the requirement to use tool 2C18118G01 will include:*
  - *Fleet Highlites article(s).*
  - *Timing is end of 2nd quarter (end of June 2020)*
  - *Regional conferences and / or Working Together Teams (WTT's) calls.*

2. ***Engine Shop Manual 72-34-00 Revisions Dated April 15, 2020***

- *Subtask 72-34-00-220-187*
- ** * SB 72-0349 (INTRODUCTION OF NEW REDUCED-DIAMETER CDP SEAL AND ASSOCIATED HARDWARE)*

AE. Do a check of the No. 4R bearing stationary air/oil seal seating. Use gage fixture 2C18118. Refer to Figure 1026 and as

follows:

CAUTION: TO ASSURE PROPER ASSEMBLY OF THE NO. 4R BEARING STATIONARY AIR/OIL SEAL, THE GAGE FIXTURE 2C18118 MUST BE USED. FAILURE TO USE THIS FIXTURE CAN RESULT IN MISASSEMBLY OF THE NO. 4R BEARING STATIONARY AIR/OIL SEAL AND ENGINE DAMAGE.

CAUTION: USE THE GAGE FIXTURE 2C18118 CAREFULLY TO PREVENT DAMAGE OF THE SEAL INNER DIAMETER SURFACES. INSTALL THE GAGE FIXTURE ONLY ON THE NO. 4R STATIONARY AIR/OIL SEAL POST SB 72-0349 CONFIGURATION.

CAUTION: DO NOT APPLY FORCE TO THE AFT GAGE TO PUT IT IN THE NO. 4R BEARING STATIONARY AIR/OIL SEAL. THE AFT GAGE MUST MOVE FREELY IN THE SEAL WHEN IT IS INSERTED. MAKE SURE THAT ALL TOOL SURFACES ARE CLEAN.

(1) Insert the aft gage in the No. 4R bearing stationary air/oil seal (01-100) to do an inspection of the aft diameter.

CAUTION: DO NOT APPLY FORCE TO THE FORWARD GAGE TO PUT IT IN THE NO. 4R BEARING STATIONARY AIR/OIL SEAL. THE FORWARD GAGE MUST MOVE FREELY IN THE SEAL WHEN IT IS INSERTED. MAKE SURE THAT ALL TOOL SURFACES ARE CLEAN.

(2) Insert the forward gage in the No. 4R bearing stationary air/oil seal (01-100) to do an inspection of the forward diameter.

(3) If one of the gages does not move freely inside the No. 4R bearing stationary air/oil seal (01-100), do an inspection of the seal diameters and do the installation of the seal again.

** * * END SB 72-0349*

Safety Actions taken by China Airlines

On June 16th, 2021, China Airlines provided its safety actions as follows:

1. Before obtaining the special tool, 2C18118G01, the following items are required to confirm during installation of CRF No. 4R stationary air /oil seal:

   1.1 Check seal seating of No. 4R stationary air/oil seal with 0.001" shim after installation.

   1.2 Perform GE SR #00737753 required procedure to prevent any misalignment and measure the diameter of M and N:

   - Use tool 2C14681G02 (Gage- concentricity) and high accuracy gage (1/10,000 inch) to measure No.4R stationary air/oil seal (Dia. M / Dia. N) runout.
   - After removing the concentricity tool, measure the diameter (ID) of No.4R stationary air/oil seal (Dia. M / Dia. N) to make sure the runouts are within limits and without excessive deformation due to installation.
   - Finally calculate the minimum radius (Min. radius) based on the measured value to ensure that there will be appropriate gaps between the No.4R rotating air/oil seal.
   - After installing the heat shield, perform the same measurement and calculation of the minimum radius as described above again, and record the relevant value in

the work cards according to the manual requirements.

2. In the second half of 2019, China Airlines had rented the gage fixture, 2C18118G01, and performed CRF assembly according to the latest engine manual. The training and reminder were made to the maintenance personnel about the CAUTION notes described in the relevant engine manual and work cards to ensure that the installation of 4R stationary air/oil seal meets the requirements of the engine manual.

3. In the second half of 2020, China Airlines engine shop found that the size of the tool 2C18118G01 purchased from the engine manufacturer was beyond the tool specification, and the runout was also higher than the normal limit. It was reported to the engine manufacturer and received a reply that G01 material will absorb moisture which would cause ovalization. Engine manufacturer provided an alternative method before obtaining the modified tool G02, temporarily allowing the repair shop to in-house turning G01 tools to meet the specifications, and regularly check to ensure that the G01 tool size is within limits. China Airlines engine shop has issued EON and revised work cards that require the G01 tool size to be measured and recorded when assembling CRF. Subsequently, the engine manufacturer released the engine manual 2021/Jan revision which introduced the modified tool 2C18118G02. China Airlines ordered the G02 tool in 2020/Oct and received it in 2021/Feb. China Airlines engine shop had completed the CRF assembly of three E1 engines since the revision of the work cards on October 6, 2020. The procedures have all met the requirements of

the engine manual and work cards, and no assembly abnormalities have been found.

Safety Actions taken by Civil Aeronautics Administrative, Taiwan

1. CAA has required and supervised China Airlines Engineering and Maintenance Department to revise the "Procedure of Engineering Order / EO Work Card Establishment" (QP08ME099) on April 21st, 2021, and implement it accordingly. The New revision added a requirement that when an alternative procedure (deviation from the latest manual) is accepted/received from the manufacturer, China Airlines shall issue a supplemental work card (Ad-Hoc Task) as a basis for work execution and documentation.

2. CAA also has required and supervised China Airlines Engine Shop to revise the "Procedure of Engine Shop Technical Documents (Maintenance Manuals and Technical Bulletins) Revision and Control" (QP07MH008) on February 2nd, 2021, and implement it accordingly. The new revision prescribes that when an up-to-date maintenance manual requires new tools or equipment, a list of new tools and equipment must be made. The list must be reviewed in the routine Department Meeting until the acquisition of new tools/equipment is completed. The items of reviewing include purchasing, renting, and relevant efficiency assessments.

III. Transportation Safety recommendation

Arising from the conclusions of the investigation, the following safety recommendations are issued to relevant organizations.

To China Airlines

1. Enhance the integrity of the engine installation work cards. If it is necessary to deviate from the latest engine manual revision, in addition to using the alternative method accepted by the engine manufacturer, the documents and procedures described in the alternative method shall be reflected on the work cards to reduce the risk of procedures omission and to completely document the results of work cards.（TTSB-ASR-21-11-001）
2. Review and evaluate the acquisition process and schedule control of the special tools required for engine maintenance, and obtain the special tools needed in a timely manner to avoid the use of alternative solutions to reduce risk.（TTSB-ASR-21-11-002）
3. Review and evaluate the assembly work order of the engine shop.to designate the items as maintenance significant items for the work which is similar to the installation of the 4R stationary air/oil seal, if it is not completed properly and its failure could endanger the safe operation of the aircraft. （TTSB-ASR-21-11-003）

To Civil Aeronautics Administration, Taiwan

1. Supervise China Airlines engine shop performs engine installation/repair encountering the situation with necessities of

deviation from the latest manual revision for a reason, the alternative method accepted or provided by the engine manufacturer must be used, and the documents/procedures described in the alternative method must be fully reflected on the work order. And supervise China Airlines to review/evaluate the acquisition process and scheduling control of special tools required for engine shop maintenance. Also require China Airlines to review and evaluate the engine assembly work order of the engine shop.to designate the items as maintenance significant items for the work which is similar to the installation of the 4R stationary air/oil seal of this occurrence, if it is not performed correctly and its failure could endanger the safe operation of the aircraft. （TTSB-ASR-21-11-004）