SERIOUS INCIDENT

Aircraft Type and Registration: Boeing 757-28A, G-STRY

No & Type of Engines: 2 Rolls-Royce RB211-535E4 turbofan engines

Year of Manufacture: 1996

Date & Time (UTC): 25 August 2010 at 0025 hrs

Location: En route over Mauritania

Type of Flight: Commercial Air Transport (Passenger)

Persons on Board: Crew - 7 Passengers - 96

Injuries: Crew - None Passengers - None

Nature of Damage: None

Commander's Licence: Airline Transport Pilot's Licence

Commander's Age: 34 years

Commander's Flying Experience: 8,662 hours (of which 2,820 were on type)

Last 90 days - 181 hours Last 28 days - 79 hours

Information Source: AAIB Field Investigation

Synopsis

The aircraft was in the cruise at FL370 when the flight crew noticed an increase in both engine vibration levels. They selected the Engine Anti-Icing (EAI) ON but the vibration levels continued to increase gradually. The crew decided to carry out an ice shedding procedure, which was described in their operations manual (OM). As thrust was reduced on the left engine its vibration increased rapidly to the maximum level shown on the EICAS. The crew attempted to restore the thrust but the engine did not respond normally to the thrust lever movement. A descent was made to a lower level and a diversion to Nouakchott was initiated. The engine recovered at some time during the descent and a normal two-engine approach and landing was made.

The left engine is considered to have entered a surge or stall condition following the action of retarding the thrust lever and then increasing thrust. There was no damage evident within the engine and the vibration condition was attributed by the engine manufacturer to an asymmetric ice build-up under the spinner fairing. The manufacturer's Fan Ice Removal procedure as described in the OM was found to be inappropriate for the prevailing conditions.

Three Safety Recommendations are made.

History of the flight

The aircraft was operating a scheduled service from Freetown Airport, Sierra Leone, to London Heathrow

Airport. The aircraft took off at 2343 hrs and climbed directly to FL370. En-route there were some significant areas of convective weather activity, which the crew identified on their weather radar and altered course to avoid

One hour and forty minutes into the flight the crew noticed a sustained increase in both engine vibration levels to approximately 2.3 units. Looking for a possible reason, the commander shone a torch onto his windscreen wiper and noticed a thin layer of ice present. The Static Air Temperature (SAT) was

-47°C. The crew selected the EAI ON. The vibration continued and increased to between 3 and 3.5 units over a ten minute period. The Quick Reference Handbook (QRH) non-normal checklist for engine vibration was consulted and the crew decided that, as icing conditions were present, no further action was required. Note: normally in icing conditions in the climb or cruise, with SAT below -40°C, the EAI is not required.

The vibration could now be felt through the airframe by both the flight crew and the cabin crew. The commander decided to perform the manufacturer's

ENGINE VIBRATION Condition: Vibration indication is in the amber band. If in icing conditions: Note: Vibration levels in amber band on either or both engines not accompanied by other failure indications are considered normal. If not in icing conditions: AUTOTHROTTLE ARM SWITCH.....OFF [Allows thrust levers to remain where manually positioned.] THRUST LEVER..... RETARD Operate at a thrust level which will maintain vibration below amber band. If vibration remains in amber band with the thrust lever at idle: Accomplish ENGINE FAILURE OR SHUTDOWN checklist.

Figure 1

QRH Engine Vibration non-normal checklist

CAUTION: Avoid prolonged operation in moderate to severe icing conditions.

If moderate to severe icing conditions are encountered: Increases in engine vibration above 2.5 units may occur due to fan icing. After a short period of time, this ice will normally shed and vibration will return to normal. If desired, do the following procedure on both engines, one engine at a time; quickly reduce thrust to idle for 5 seconds then restore the require thrust. If vibration persists, advance thrust lever to 90% N1 momentarily.

Note: Under all but very severe icing conditions, ice will shed when thrust is reduced to idle, eliminating the need to subsequently apply higher than desired thrust.

Figure 2

Fan Ice Removal procedure

Fan Ice Removal procedure detailed in their OM, in an attempt to reduce the vibration (see Figure 2).

The autothrottle was disconnected and the thrust lever was retarded on the left engine. As the thrust reduced, the crew observed an immediate increase in vibration on the left engine, which they recollected as 5 to 6 units. Thrust was reapplied but the engine power did not correspond to the thrust lever movement and the EGT increased to an observed peak of 803°C. The crew reduced the thrust again to 1.2 EPR, to prevent an EGT exceedence, whereupon the vibration stabilised at around 2.5 units. The right engine, while still indicating a vibration level of 3 units, was operating as expected. A MAYDAY was declared and the aircraft descended to FL250 and altered course towards Nouakchott. The right engine was kept at a medium power level during the descent. Several more attempts to increase power on the left engine were made, again resulting in increased vibration and high EGT. The crew decided not to shut down the left engine in case a similar problem should occur with the right engine. Later on, during the descent the left engine started to respond normally to thrust lever movement.

At 0229 hrs a normal two-engine landing was made at

Nouakchott. Subsequent examination of both engines on the ground, both externally and internally, did not reveal any damage.

Meteorological information

For their pre-flight planning, the crew had available an Africa High Level Significant Weather Forecast chart. This showed several areas of isolated cumulonimbus cloud along the route, with tops reaching up to FL500. The upper level winds for the first two hours of flight were generally from an easterly direction.

En route, the crew were able to monitor the conditions ahead of track using the aircraft weather radar. They made several deviations to the east of the flight planned track to avoid flying into areas of strong convective activity. In the process of the investigation a colour enhanced infrared satellite image, timed at 0100 hrs, with the track of the aircraft superimposed upon it, was constructed. This image showed the height of cloud, based on a colour coded scale, with the white areas being the highest level. The commander subsequently sketched the approximate position of the weather activity he had observed on the weather radar onto this image (see Figure 3).

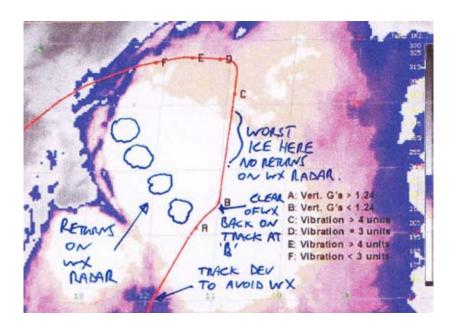


Figure 3

Infrared satellite image with sketch of en-route weather (for scale, each vertical graticule is 60 nm ie the distance from A to C is approximately 120 nm)

An analysis of the weather radar identified two Mesoscale Convective Systems¹ (MCS) along the route flown by the aircraft. The total distance the aircraft flew within one of the two systems was more than 500 nm, over a two hour period.

Flight recorders

The aircraft was equipped with a Flight Data Recorder (FDR), a Quick Access Recorder (QAR) and a 30-minute Cockpit Voice Recorder (CVR). Whilst at Nouakchott Airport, the operator had made preparations to remove the FDR. However, following confirmation from its engineering department that the QAR system would record the same data as the FDR, the operator secured the QAR data and decided not to replace the FDR. The QAR

Footnote

Mesoscale Convective Systems (MCS) are thunderstorm regions which may be round or linear in shape, with a horizontal extent of 100 km (54 nm) or more. MCS form when clouds occurring in response to convective instability amalgamate into a single cloud system with a very large upper cirriform cloud structure. data was successfully replayed by the operator following the aircraft's return to the UK. The operator advised that it did not remove the CVR, as it understood that the period containing the peak engine vibrations would have been overwritten prior to landing. At the time of the incident, the operator did not have a formal procedure for the preservation of the FDR or CVR. The operator has since addressed this.

Salient parameters from the QAR included the selection of EAI, thrust lever position, engine EPR, EGT and vibration. For each engine vibration parameter only the shaft (N₁, N₂ or N₃) with the highest vibration level was recorded at any one time. The thrust lever and engine EPR parameters were recorded once every second, and engine EGT and vibration once every 64 seconds. Figure 4 provides a plot of the flight, with shaded areas A to G identifying periods flown whilst in the two MCSs. Figure 5 is a satellite image containing the two MCS areas, planned waypoints and flight track; the flight track

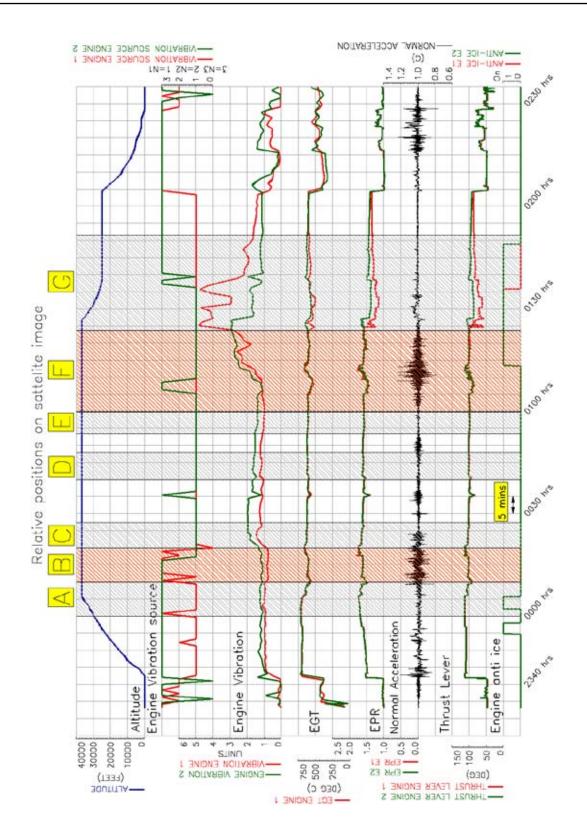


Figure 4
Flight from Lungi Airport (Sierra Leone) to Nouakchott Airport (Islamic Republic of Mauritania)

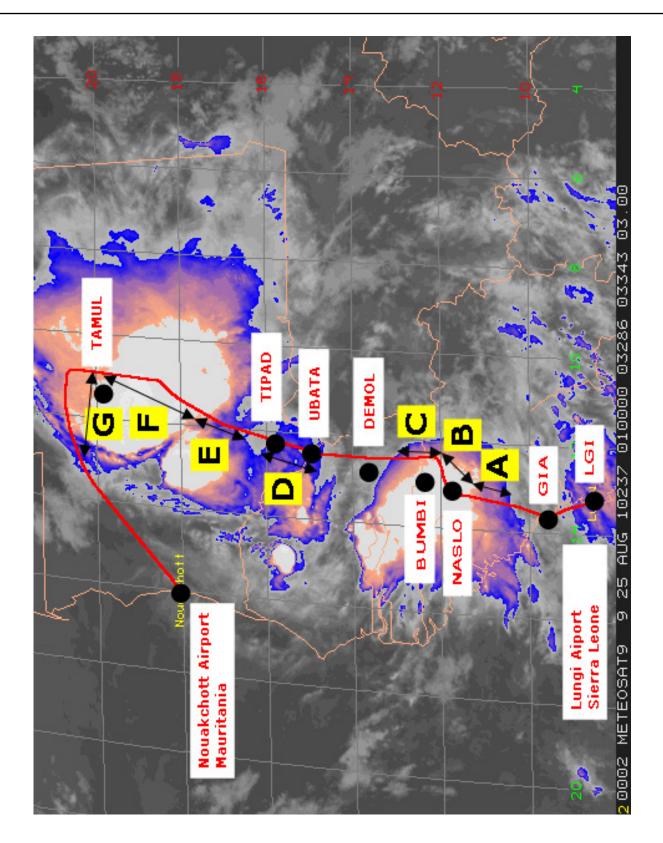


Figure 5
Satellite image of MCS areas over Africa and G-STRY flight track and waypoints (Points A to G refer to the relative aircraft positions detailed in Figure 4)

is annotated with sections A to G for cross reference with those detailed in Figure 4. Figure 6 is a plot of the left engine response to manual thrust lever commands whilst in the cruise.

The takeoff was uneventful, with the aircraft initially tracking northwards along the west coast of Guinea, to waypoint GIA, before routing inland to waypoint NASLO. During the climb, EAI was selected ON between FL227 and FL270 and then again between FL320 and FL365. As the aircraft climbed through FL290, it entered the first MCS (see Figures 4 and 5). The first MCS was approximately 230 nm in length and 170 nm wide. At 0006 hrs, the aircraft levelled off to cruise at FL370. The SAT had gradually reduced from 25°C, at takeoff, to -48°C. Four minutes later, the aircraft entered the area with the highest cloud tops within the MCS (see Figures 4 and 5 – area B) and there was an increase in normal acceleration activity, indicative of moderate turbulence. Shortly after, as the aircraft approached waypoint NASLO, the flight crew altered track approximately 35 nm to the east, routing away from the core of the MCS.

After the takeoff at 2343 hrs, the engine vibration levels remained at about 0.9 units for the left engine and 1.2 units for the right, with N_1 shaft vibration predominantly recorded for the left engine and N_3 for the right. However, at 0020 hrs, just at the aircraft was resuming its northerly track to waypoint UBATA, the N_1 shaft vibration level on both engines started to increase. The aircraft was still in turbulent air at the time and the EPR on both engines was just reducing from 1.75 to 1.65. At 0028 hrs the aircraft exited the MCS. The left engine N_1 shaft vibration had now stabilised at just less than 1.2 units, and the right engine N_1 shaft vibration at 2 units. The aircraft had flown for about 200 nm whilst in the MCS.

At 0035 hrs, whilst experiencing light turbulence, the autothrottle gradually reduced the EPR settings on both engines from 1.6 to 1.4. At this time, the left engine peak vibration source changed from the N_1 shaft to the N_3 shaft and reduced from 2 to 1.2 units. The EPR on both engines was then progressively increased to 1.6, following which the right engine peak vibration source returned to the N_1 shaft, at a level of 1.7 units. There was no change in left engine vibration during this period, with the N_1 shaft at 1.2 units.

At 0041 hrs, as the aircraft approached waypoint UBATA (situated near to the border between Senegal and the Islamic Republic of Mauritania), it entered the southern tip of the second MCS. The MCS extended to the north by approximately 480 nm and was between 170 nm and 350 nm wide. Twenty minutes later, the aircraft entered the area of the MCS having the highest clouds (see Figures 4 and 5 - area F) and there was an increase in turbulence. Several minutes later, the EPR on both engines was progressively reduced, from 1.6 to 1.4. This was accompanied by a reduction in right engine vibration, with the N₃ shaft becoming the source of maximum vibration at 1.1 units. During the next four minutes, as the autothrottle attempted to stabilise the airspeed, the EPR on both engines was progressively increased to 1.7. As EPR increased, the right engine maximum vibration source changed to the N₁ shaft and there was an increasing trend in both left and right engine N₁ shaft vibration levels. As the left engine reached 2 units and the right 2.5 units, the flight crew selected both EAI systems to ON. Both engine N₁ shaft vibration levels continued to increase, before stabilising at about 2.6 units. The trend over the next five minutes was a slight reduction in the left engine N₁ shaft vibration, before both engine N₁ shaft vibration levels further increased to 3 units. The aircraft was just leaving the highest cloud level within the MCS at this time (see Figures 4 and 5 – area G).

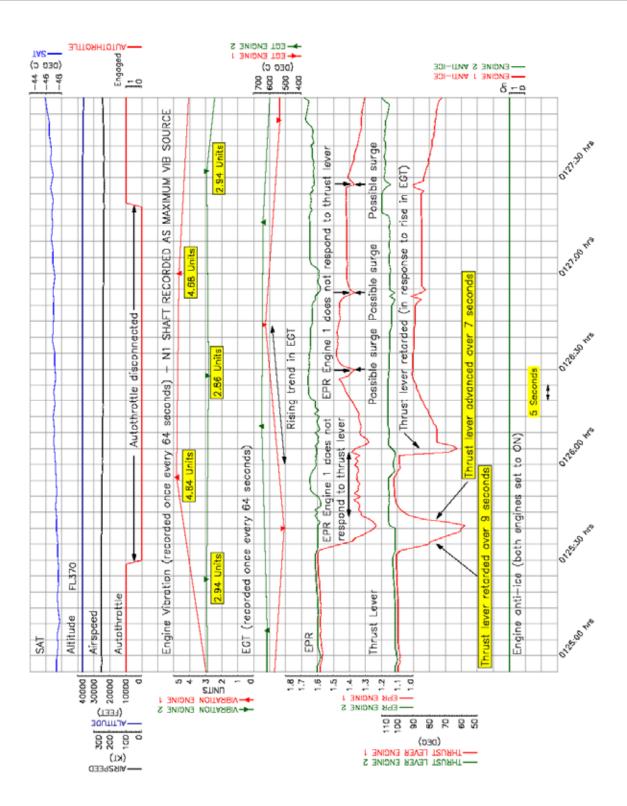


Figure 6
Recorded data during period of manual thrust reduction whilst in the cruise

A few minutes later, at 0125 hrs, the autothrottle was disconnected by the flight crew and over a nine second period, the left engine thrust lever was manually retarded to an intermediate position above idle, with the EPR reducing to 1.2 (see Figure 6). The left thrust lever was then advanced, without delay, to its previous cruise position over a seven second period. The left engine initially responded, before stabilising at about 1.3 EPR, which was below that being commanded. The right engine N₁ shaft vibration had remained stable at about 3 units; however, the left engine N₁ shaft vibration increased to 4.8 units. This was accompanied by a recorded rise in left engine EGT, to a maximum of 630°C2. The left thrust lever was quickly retarded and then gradually advanced over a further 30 second period. The left engine EPR initially tracked the increasing thrust command but the EPR then rapidly reduced before increasing again. During the following minute the left thrust lever was advanced and retarded twice. On both occasions, the left engine EPR failed to respond correctly (see Figure 6). Shortly before the last of these two thrust lever movements, the autothrottle was re-engaged as the flight crew initiated a descent to FL250 and altered track to the south-west, towards Nouakchott Airport. Since entering the cruise, the SAT had remained predominantly stable at about -48°C. As the aircraft descended, the SAT gradually increased.

As thrust was reduced for the descent, there was a slight stagger in the position of the left and right thrust levers, with the right leading the left. The right engine thrust was reduced to 1.4 EPR and its N_1 shaft vibration level subsequently reduced from 3 to 1.7 units. The left engine stabilised at a lower EPR of about 1.2, although its N_1 shaft vibration remained at about 4 units. Over the next

Footnote

² The flight crew reported a maximum left engine EGT of 803°C. This was not captured on the FDR due to the recording rate of EGT, which was once every 64 seconds.

eight minutes, the left engine N_1 shaft vibration level varied between 3 and 4 units, with the right engine N_1 shaft vibration remaining predominantly stable at about 1.7 units. As the aircraft descended through FL265, the left EAI was selected to OFF. It was at about this time that a reducing trend in the left engine N_1 shaft vibration began. By the time the aircraft levelled at FL250, the left engine N_1 shaft vibration level had reduced to about 2.2 units. At this time, the right engine peak vibration was 1.2 units and the source had changed from the N_1 to the N_3 shaft. A few minutes later, the right EAI was selected to OFF.

At approximately 0152 hrs, the aircraft exited the second MCS, having flown in it for approximately 2 hours, over a distance of 460 nm. The left engine N_1 shaft vibration level was now at about 1.6 units. The thrust lever stagger had also slowly started to reduce. As the thrust levers were retarded for the start of the final descent, the left engine dominant vibration changed from the N_1 to the N_3 shaft, with vibration level reducing to less than 1 unit, where it remained.

During the descent and approach, with the thrust levers re-aligned, both engines operated at similar EPR values. During the final approach, there was an increase in both engine N_3 shaft vibration levels, with the right engine increasing to a maximum of 1.4 units – the aircraft was also experiencing turbulence at this time. The subsequent landing and taxi were uneventful.

Preservation of flight recordings (FDR and CVR)

Although the operator had no formal procedure in place to preserve the FDR or CVR data, it had taken steps to preserve a record of the FDR by securing the QAR data. On this occasion, the QAR was successfully replayed; however, it should be noted that neither ICAO Standards and Recommended Practices nor EU-OPS regulations,

concerning the preservation of the FDR following an incident or accident, refer to the QAR being used as an alternative means of compliance. The operator had also considered the removal of the CVR but, aware that the period containing the peak engine vibrations would have been overwritten prior to landing, they elected not to preserve it. Although the event period itself may have been overwritten, AAIB experience is that CVR's may still provide useful information if preserved in a timely manner after landing, with the possibility that post-event discussions in the cockpit may have been recorded.

With reference to UK CAA publication CAP 382 (*The Mandatory Occurrence Reporting Scheme*), the incident was subject to mandatory reporting since an engine had failed to respond correctly to thrust lever commands. The operator subsequently reported the incident to the AAIB on 27 August 2010 and provided a safety report to the CAA.

EU-OPS 1.160, 'Preservation, production and use of flight recorder recordings', requires the following of an operator:

'(a) Preservation of recordings:

(2) Unless prior permission has been granted by the Authority, following an incident that is subject to mandatory reporting, the operator of an aeroplane on which a flight recorder is carried shall, to the extent possible, preserve the original recorded data pertaining to that incident, as retained by the recorder for a period of 60 days unless otherwise directed by the investigating authority.'

In June 2010, AAIB Safety Recommendation 2010-012, concerning the unintentional overwriting of CVR records, was made to the UK CAA. On

24 August 2010, the UK CAA issued Airworthiness Communication (AIRCOM) 2010/10. In addition to identifying operator requirements for the preservation of recordings, as laid down in ICAO Annex 6, Part I, 11.6 and EU-OPS 1.160, AIRCOM 2010/10 also made the following recommendations to operators.

- '4.1 Operators and continuing airworthiness management organisations should ensure that robust procedures are in place and prescribed in the relevant Operations Manuals and Expositions to ensure that CVR/FDR recordings that may assist in the investigation of an accident or incident are appropriately preserved. This should include raising awareness of Flight Crew and Maintenance staff to minimise the possibility of loss of any recorded data on both the CVR and FDR.
- 4.2 When appropriate, the relevant circuit breakers should be pulled and collared/tagged and an entry made in the aircraft technical log to make clear to any airline personnel that an investigation is progressing. Furthermore, confirmation from the investigating authority/operator is required to be obtained before systems are reactivated and power is restored.
- 4.3 Operators who contract their maintenance or ground handling to a third party should ensure that the contracted organisation is made aware of all their relevant procedures.'

Aircraft and engine information

The EAI system is operated by individual switches for each engine. When selected ON, the leading edge of the engine cowl is anti-iced by engine bleed air and the engine ignition is activated. The spinner utilises

a flexible rubber tip which, in conjunction with the rotational forces imparted on the spinner during engine operation, limits the build-up of ice on the spinner to acceptable levels.

The aircraft has two central EICAS screens. Primary engine indications are shown on the upper EICAS screen, which is always displayed, and secondary engine indications are shown on the lower screen, which is selectable or will display automatically if an amber band or red line limit is reached.

The aircraft has an airborne vibration monitoring system that monitors engine vibration levels. The sensors measure vibration in a radial direction on each engine (ie out of balance forces) and the vibration indications are displayed on the secondary engine display on the lower left side of the lower EICAS screen (see Figure 7). The amber alert level is at 2.5 units. The maximum continuous EGT is 795°C, at the start of amber caution area, and the maximum takeoff limit is 850°C, at the red line.

The Quick Reference Handbook (QRH) contains non-normal checklists for *'Engine Vibration'* and *'Engine Limit or Surge or Stall'*.

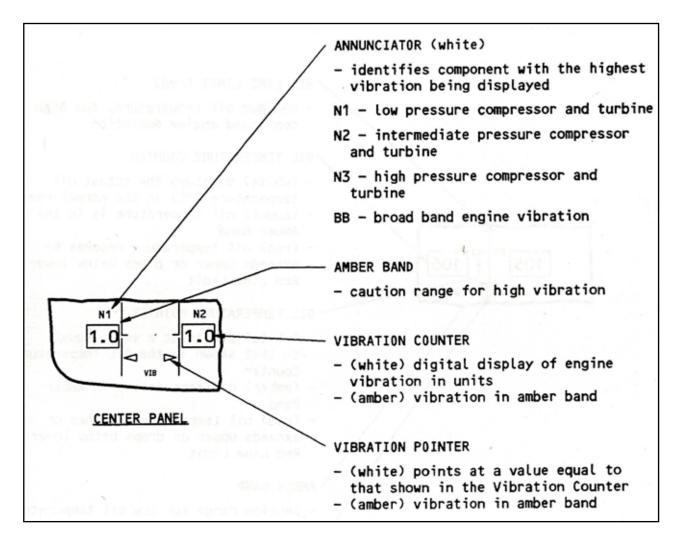


Figure 7EICAS Engine vibration display

The issue of moisture ingress into the cavity between the spinner and the spinner fairing, resulting in asymmetric ice build-up and subsequent engine vibration, has been recognised by the engine manufacturer. The manufacturer originally introduced SB72-AD132 in September 2001 to address this issue. The key element of the Service Bulletin (SB) is an 'Omega' seal that is bonded to the spinner and provides a seal between the spinner and the spinner fairing, preventing the ingress of moisture into the cavity. This modification is now instructed by SB72-AF034 revision 1, released in August 2006 and all parts of the SB are to be accomplished by March 2015.

The spinners on the incident aircraft were checked and neither featured modified spinners to SB72-AD132 or SB72-AF034 standard

Engine manufacturer's assessment

The presence of visible icing on the wiper indicated the aircraft was operating in icing conditions, whilst the recorded vibration monitoring parameters indicated that the low pressure shaft was the source of the vibration.

The engine manufacturer was aware of several low pressure shaft vibration events on this engine type which have been attributed to ice. All these events have occurred on aircraft which have either not had SB72-AD132 or SB72-AF034 embodied or have exhibited damage to the spinner/spinner fairing or Omega seal.

The possibility of core engine icing was considered an unlikely factor by the engine manufacturer. This was based on the higher temperatures in the front stages for this 3-spool engine and the lack of previous events in such conditions for this engine type. The engine manufacturer noted that, in cold high altitude conditions, the clouds consist of dry ice crystals that do not stick

to the fan blades or the spinner. Thus, they considered the most likely source of the vibration was ice collecting under the spinner fairing.

The Fan Ice Removal procedure is to reduce the thrust to idle rapidly (which untwists the blades and sheds ice), followed by a short delay of around 5 seconds to allow the engine to stabilise thermally, and then to restore the required thrust. If ice in the spinner and spinner fairing region was the source of the vibration, then this procedure was not likely to be successful in removing the source of the vibration. Furthermore, on this occasion the thrust was reduced to a setting higher than idle, the thrust reduction was over a nine second period and the engine did not stabilise prior to the thrust being increased.

In summary, the engine manufacturer believes that the most likely source of vibration was an accumulation of ice crystals behind the spinner fairing and that a surge or stall condition occurred as a result of the rapid increase in thrust demanded by the thrust lever movement, without a short period at idle to allow the engine to stabilise. The accumulation of ice behind the spinner fairing is believed to be addressed by the SBs.

Airframe manufacturer's assessment

The aircraft manufacturer stated that the fan ice shedding procedure found in the Flight Crew Operating Manual and the Engine Operating Instructions was intended to shed ice from the fan. The prevailing conditions were not likely to form ice on the fan so this procedure was unlikely to be successful. However, the flight crew having no way of knowing this information continued with the procedure.

The procedure, as carried out by the crew, produced the unexpected result of increasing the vibration. It is the airframe manufacturer's opinion that the resulting

surge or stall behaviour could have been a result of the procedure not being carried out correctly, or the presence of ice in the engine, decreasing margins.

Analysis

The aircraft climbed through an area of convective cloud, where conditions favourable for the formation of ice were likely to exist, to its cruising level of FL370. It subsequently passed through extensive areas, as much as 500 nm along track, where high altitude ice crystal concentrations could be expected. While ice crystals would not normally be expected to adhere to engine or airframe components, it is possible that they could stick to any pre-existing ice. Physical evidence of icing is often difficult to establish and this incident was no exception. Furthermore, the modest range of recorded parameters and low sampling rates made it difficult to reach robust conclusions. Subsequent examination of both engines on the ground, both externally and internally, did not reveal any damage that could be attributed to the root cause of either the vibration or the surge or stall condition. Therefore, the most likely cause of the vibration is considered to be a build-up of ice, although the exact mechanism of ice accumulation is not certain.

The engine manufacturer's opinion that the source of the vibration was probably icing under the spinner fairing seems plausible, given the N_1 as the source of the vibration, the presence of visible icing and that the conditions at the time were not favourable for icing on the fan blades. Whether the ice accumulated there during the climb through convective cloud, or subsequently, as a result of prolonged exposure to ice crystals, could not be determined.

The weather information available to the flight crew at the planning stage did not indicate that any large areas of convective activity were to be expected along the route. An analysis of the satellite image covering the time of the flight shows that two Mesoscale Convective Systems (MCS) had formed across the track of the aircraft. When en route, the crew observed some significant areas of thunderstorms and altered course to the east, upwind, to avoid the most intense areas.

The crew noticed that the engine vibration had increased to a sustained level of approximately 2.3 units and there was a small amount of ice on the wiper arm. This led them to select the EAI ON, which was in accordance with the QRH checklist. However, the engine manufacturer advised that EAI would be ineffective in these circumstances because only the engine cowl is anti-iced.

The increased vibration led the crew to refer to the ORH checklist. The checklist suggested that no further action was required if icing conditions were present, which the crew decided was the case because of the visible ice on the wiper arm. As the vibration increased above the alert level of 2.5 units, the crew tried to find a solution to prevent a further increase. There was a fan ice removal procedure published in their OM which they decided to carry out. However, on retarding the left thrust lever, the immediate effect was to increase the vibration significantly and the procedure was not completed.3 The thrust did not reach idle and, without the required five second delay, it was rapidly increased towards the previous level. As the thrust increased, a surge or stall condition developed and the engine did not respond to the thrust lever movement. The crew noticed the EGT rising towards the limit and observed a peak of 803°C.

Footnote

³ Vibration may increase as a result of out of balance forces during ice shedding.

However, this was not recorded on the QAR because of the 64 second sampling rate for this parameter.

The crew operated the engine at a reduced power setting of around 1.2 EPR and respected the maximum EGT limit. A diversion was initiated. Several attempts were made to increase the power again on the left engine but, at first, these were unsuccessful. The crew decided not to shut down the left engine in case the other engine should become similarly affected; during the descent, the right engine was operated at an intermediate setting. At some point during the descent the surge/stall condition on the left engine was resolved, probably as a consequence of the warmer external air temperature.

The root cause of the left engine surge or stall condition was considered by the engine manufacturer to have been the result of the deceleration and sudden re-acceleration of the engine.

The crew had attempted to carry out the ice shedding procedure but omitted what the engine manufacturer considered were critical elements. These were, a rapid reduction of thrust to idle, stabilisation at idle for five seconds and a steady reapplication of thrust. The reason the procedure was interrupted was probably that the crew did not expect the sudden increase in vibration that occurred when left engine thrust was reduced. In view of this, the engine manufacturer carried out a review of their published Engine Operating Instructions (EOI) and concluded that they should be improved to give better clarity to flight crews in the recognition of ice crystals and reaction to vibration in icing conditions. They also proposed that the ice shedding procedure should not be used when at climb or cruise thrust in high altitude ice crystal clouds above FL250 and the most appropriate action was to descend into warmer conditions.

Safety action

In November 2010 the engine manufacturer sent the aircraft manufacturer's Flight Operations Department a proposed revision to the engine operating instructions for the RB 211-535-E4-B, with respect to the Fan Ice Removal Procedure. The proposed revision has been reviewed by the aircraft manufacturer and the following response has been received by the AAIB:

The proposed changes have been agreed to by the airframe manufacturer. Procedures addressing ice crystal icing in addition to changes to the Fan Ice Removal procedure will be embodied in the QRH and FCOM in the 2011 revision.

Therefore, on the basis of this assurance, the AAIB does not intend to make a Safety Recommendation on this aspect of the incident.

CVR and FDR recordings

During the investigation, it was found that the operator had no formal procedures for the preservation of either the CVR or FDR. This had not been identified during previous audits of the operator by the UK CAA. Further, on 3 October 2010 a different UK operator failed to preserve the CVR following a landing accident involving another aircraft, registration G-OOBK. That operator's procedures did include the preservation requirements detailed in EU-OPS 1.160 and EU-OPS 1.085 (commander's responsibilities) but its procedures proved ineffective in stopping the CVR from being overwritten. Two further operators' procedures were reviewed and found to contain similar content to that of G-OOBK's operator. Therefore, the following Safety Recommendation is made:

Safety Recommendation 2011-020

It is recommended that the Civil Aviation Authority ensures that United Kingdom operators have procedures for preventing the loss of Cockpit Voice Recorder and Flight Data Recorder recordings, following an occurrence subject to mandatory reporting, in accordance with the legislative requirements of EU-OPS 1.160 and EU-OPS 1.085.

FDR documentation requirements

Information for the conversion of the FDR digital record to engineering units was provided in the aircraft manufacturer's document D226A101-3 Revision J issued 1 April 2003. The document was confirmed as being the latest revision. During the course of the investigation, it was found that the 757-2 data frame, which was applicable to G-STRY, incorrectly defined the conversion of the left and right engine vibration parameters. The output resolution of the parameters was confirmed as being 0.02 units, and not 0.01 as stated in D226A101-3, with the input bits being 21 to 28 and not 20 to 28. Applying the incorrect conversion resulted in both parameters being converted to half the actual vibration units displayed on EICAS. Although it cannot be established, the error may have led to the incorrect analysis of previous engine vibration events, for aircraft utilising the 757-2 data frame. The accuracy of FDR conversion documentation is fundamental.

Therefore, the following Safety Recommendations are made:

Safety Recommendation 2011-021

It is recommended that Boeing advises all operators utilising the Flight Data Recording 757-2 Data Frame of the need to correct the conversion of the left and right engine vibration parameters.

And

Safety Recommendation 2011-022

It is recommended that Boeing provides updated documentation that corrects the Flight Data Recording 757-2 Data Frame conversion information for the left and right engine vibration parameters.

Comment

The aircraft experienced a prolonged exposure to an area where ice crystal concentrations may have been present. Although ice crystals may not have been the cause of this event it is an atmospheric condition that is not yet well understood. This has been recognised and a data collection programme is presently underway in the USA to increase the understanding of high water content ice crystal conditions. These are conditions where strong convective weather activity lifts high concentrations of ice crystals to high altitude. The crystals can partly melt and stick to internal engine surfaces causing power loss and/or surge/stall to occur. Data indicates that there have been at least 100 events of jet engine power loss due to core-icing during the last 30 years. The data gathered should enable certification authorities to define new parameters for developing and certifying engines. It may also lead to better forecasting of the presence of such areas, which are not detectable by existing aircraft weather radars. The knowledge of these conditions, and their effect upon various aircraft systems, is at present limited. Proposed guidance to flight crew is restricted to avoiding such weather or flying clear if encountered.

In March 2011 the EASA published two Notices of Proposed Amendment (NPAs), 2011-03 and 2011-04, entitled 'Large Aeroplane Certification Specifications in Supercooled Large Drop, Mixed phase, and Ice Crystal Icing Conditions' and 'Turbine Engine Certification

Specifications in Icing Conditions' respectively. The background to these NPAs is described:

'It has been evidenced that the icing environment used for certification of large aeroplanes and turbine engines needs to be expanded in order to improve the level of safety when operating in icing conditions.

Several accidents and incidents occurred in severe icing conditions including supercooled large drop (SLD) icing conditions. Please refer to NPA 2011-03 for details on the history of these events.

Other incidents involved turbine engine power losses or flameouts in ice crystal and mixed

phase icing conditions. From 1988–2003, there were over 100 documented cases of ice crystal and mixed phase engine power loss events. Some of these events (11) resulted in total power loss from engine flameouts. During the same period there were 54 aircraft level events of SLD icing engine damage where 56% occurred on multiple engines on an aircraft and two events resulted in air-turnback.

These particular severe icing conditions are not included in the current certification icing environment for aircraft and engines.'