REPUBLIC OF RWANDA

Ministry of Infrastructure

Aviation Accident and Incident Investigation Division

Report on the serious incident to Bombardier CRJ900 with registration 9XR-WH, operated by RwandAir, involving engine damage caused by foreign object debris, February 4th 2018

Ref AAID 2018-01

The sole objective of investigations carried out by the Rwanda Aviation Accident & Incident Investigation Division (AAID) is the prevention of accidents and incidents. It shall not be the purpose of such an investigation to apportion blame or liability.

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List of Abbreviations used in this report

AAID	Aviation Accident & Incident Investigation Division
ACI	Airport Council International
AMT	Aircraft Maintenance Technician
EASA	European Aviation Safety Agency
FOD	Foreign Object Debris
FWD	Forward
GE	General Electric Company
ICAO	International Civil Aviation Organisation
LT	Local Time
NTSB	National Transport Safety Board (USA)

Synopsis

After arrival in Kigali of flight WB 465, conducted by a Bombardier CRJ900 aircraft, on February 4th 2018 considerable damage was found to all 28 fan blades of the left-hand engine. This damage was caused by a metal bolt that was found stuck in the acoustic lining of the fan intake. It was established that this bolt did not originate from the aircraft itself.

The most likely incident scenario is that the bolt initially was picked up by the left outboard main gear tire during taxi-out after the transit stop in Entebbe and subsequently came loose during the take-off roll, whereby it was ingested by the left-hand engine running at a high power setting.

At the time of the incident extensive works at Entebbe airport were in progress. These works form part of a large scale airport expansion project, that will continue for the years to come.

The investigation by the Rwanda Aviation Accident & Incident Investigation Division (AAID) revealed significant shortcomings in the programmes that aim to prevent damage by foreign objects, both at Kigali and Entebbe airport.

1. FACTUAL INFORMATION

1.1 History of Flight

Flight WB 465 on February 4th 2018 was a scheduled passenger flight from Jomo Kenyatta International Airport in Nairobi (NBO) via Entebbe International Airport (EBB) to Kigali International Airport (KGL). The flight was executed with a Bombardier CRJ900, registered 9XR-WH.

The crew consisted of the Captain, the First Officer, the purser and a cabin attendant.
Apart from the flight crew, also an Aircraft Maintenance Technician (AMT) travelled with the flight.
On the stretch from EBB to KGL flight WB 465 carried a total of 43 passengers.

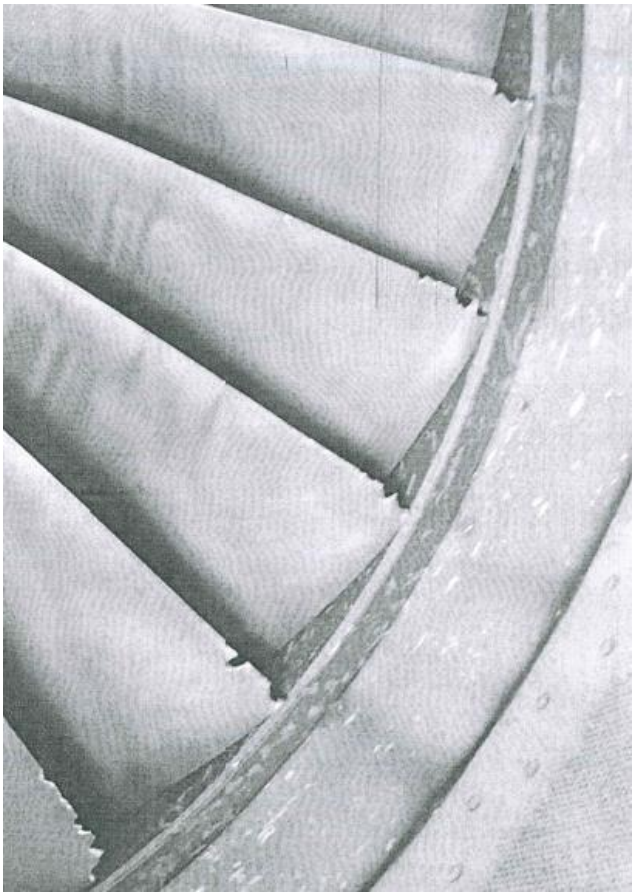
The same crew, including the AMT, had operated the incoming flight WB 464 from KGL to NBO with a transit stop at EBB.

Both after arrival of flight WB 464 at NBO, and after arrival of flight WB 465 at EBB, thus on the homebound flight with destination KGL, the AMT performed a walk around check as per company procedure. The inspection at NBO took place during night-time hours; the inspection at EBB was done in the early morning shortly after sunrise between 05:45 and 06:20 local time (LT). On both occasions the walk around check revealed no abnormalities.

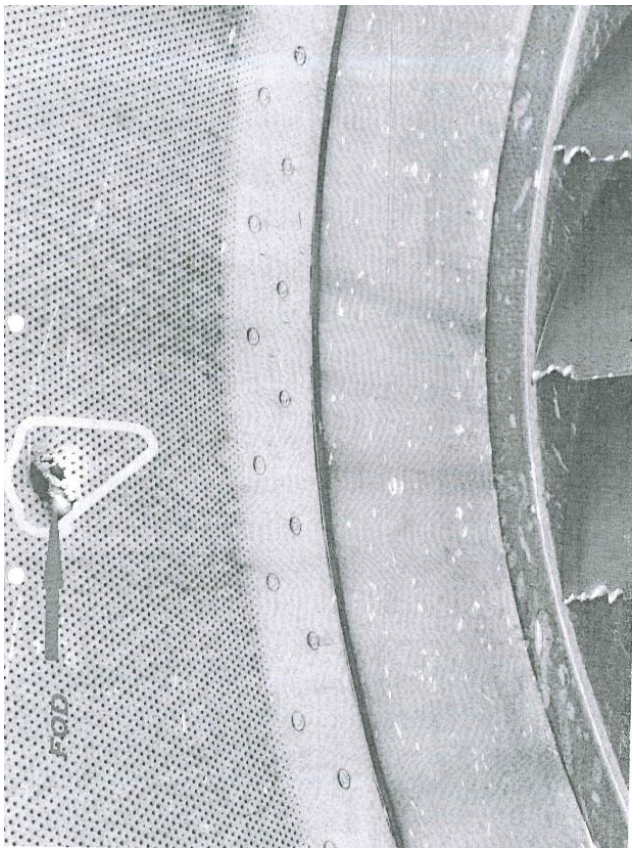
The subsequent flight from EBB to KGL proceeded normally with, as stated by the Captain in his report, 'nothing unusual'. Flight WB464 landed at 06:09 LT on runway 28 of Kigali airport, during the landing most probably idle reverse thrust[1] was used.

[1] Reverse thrust is the temporary diversion of an aircraft engine's thrust so that it is directed forward, rather than backward. Reverse thrust thus provides additional deceleration after landing. Operational procedures from the operator recommend the use of idle reverse when the available landing distance allows to do so. The available landing distance for runway 28 at KGL was 3279 m.

After arrival at KGL at 06:15 LT again a walk-around check was performed by the crew. On that occasion it was found that all fan blades from the left-hand engine were damaged, see the picture 1 below. Further investigation revealed that a metal bolt was stuck in the acoustic lining in the upper part of the fan intake, see picture 2.



Picture 1:
Damage to fan blades of left-hand engine



Picture 2:
Bolt, found stuck in acoustic lining in the upperpart of left-hand fan intake

1.3 Damage to aircraft[2]

Post flight inspection of the left-engine[3] revealed impact of foreign object debris (FOD[4]) to all 28 fan blades and the nacelle intake. As a result of the FOD damage the engine as well as the nacelle intake were replaced. An initial borescope inspection suggested additional FOD damage to compressor section of the engine, findings from the engine overhaul facility however indicated clearly that the FOD damage was confined to the fan section only.

[2] This report follows the paragraph numbering according to Appendix 1 of ICAO Annex 13. Paragraph numbers that are not listed, are not applicable to this investigation.
[3] Engine type: General Electric CF34-8C5, Serial Number 195229
[4] Foreign object debris (FOD): An inanimate object within the movement area which has no operational or aeronautical function and which has the potential to be a hazard to aircraft operations (ICAO definition).

During inspection of the aircraft after landing in KGL also minor damage to the tread of the outboard tire from the left main tire was found, see Appendix 1.

1.7 Meteorological information

During flight WB 465 no precipitation occurred. Meteorological aspects had no bearing on this incident.

1.10 Aerodrome information

At the time of the incident large scale airside works on at EBB were in progress as part of a multi-year airport expansion programme.
This upgrade and expansion project forms part of a 20-year National Aviation Master Plan (2014-2033) unveiled by the Civil Aviation Authority of Uganda in January 2015.
The project includes expanding and strengthening of the main runway (RWY 17-35), the secondary runway (RWY 12-30) and the associated taxiways F, G and H.

1.16 Tests and research

1.16.1 Support from the USA National Transport Safety Board

After the incident the operator sent pictures of the bolt that was found stuck in the fan intake of the left-hand engine to the Boeing Commercial Aeroplanes company with the request to determine the origin of the bolt. Boeing in turn forwarded the pictures to the National Transport Safety Board (NTSB) in the USA. The NTSB concluded unambiguously that the bolt did not originate from the engine itself. Their findings, as well as a picture of the bolt concerned, are incorporated in Appendix 2.

1.16.2 Runway inspection guidelines and requirements

The most relevant information on FOD prevention programmes, comes from the Airports Council International (ACI), the International Civil Aviation

Organisation (ICAO) and the European Aviation safety Agency (EASA). This information is listed below:

Airports Council International (ACI)

With regard to protection against Foreign Object Damage (FOD) the Airside Safety "Handbook[5] from the Airports Council International (ACI) states amongst others the following:

- *Organizing regular joint airport, airline, handler apron FOD walks to check for FOD and to identify its source*
- *Organizing campaigns and publicity to remind staff of the dangers presented by creating FOD*
- *Ensuring that contractors involved in construction projects are aware of the need to contain all their materials on-site and not allow spillages to enter the aircraft areas*
- *Setting up a runway / taxiway / stand inspection or sweeping schedule of suitable frequency. Analysing items of FOD to identify the likely contributors*
- *Reviewing items of FOD at Airside Safety Committee meetings involving airlines, handling agents, support companies and aircraft maintenance organizations.*

As well as:

> *In order to protect aircraft against Foreign Object Damage (FOD), and in particular the risk of ingestion of debris by aircraft engines, aerodrome operators should ensure that active measures are taken to keep airside areas clear of loose objects and debris. A written programme should be established, setting out the practices and procedures as required. Regular consultation should take place with the Airside Safety Committee, to obtain widespread support for FOD prevention measures. It is recommended to collect and measure the amount of FOD found on the airside at regular intervals.*

International Civil Aviation Organisation (ICAO)

With regard to protection against Foreign Object Damage (FOD), ICAO Doc 9137[6] states amongst others that inspections of the movement area[7] should be regular and as frequent as possible. The Document further states that as a minimum

[5] ACI Airside Safety Handbook, 4th Edition 2010, Sections 1.14 & 5.18

[6] ICAO Doc 9137 – Part 8, 1st Edition 1983, paragraphs 3.1, 3.3.7 & 3.7.3

[7] ICAO definition of 'movement area': That part of an aerodrome to be used for the take-off, landing and taxiing of aircraft and the apron(s)

four daily inspections of all runways should take place: the dawn, morning, afternoon and dusk inspection.

The times of commencement and completion of all inspections must be noted and included in the Record of Inspection Log.

Should aircraft parts or tire pieces be found during a runway inspection, then airport operations and air traffic control must be informed immediately so that tracing and notification action can be taken.

European Aviation Safety Agency (EASA)

The European Aviation Safety Agency is currently preparing new guidelines[8] on proactive FOD prevention policies that are scheduled to be incorporated in ICAO documentation by the end of 2020. Some relevant parts of the proposed new FOD prevention policies are described below.

Aerodrome FOD training programme

Apart from practising the general cleanliness and inspection standards of work areas, personnel on the movement area should employ a 'clean-as-you-go' technique, by looking for FOD during the course of their regular duties.

Aerodrome FOD control programme

The aerodrome FOD control programme should cover hazards involved with construction activities.

During construction activities many material (rocks, tools, vehicle parts, etc.) have the potential to become FOD if transferred by vehicles, weather phenomena, etc. on the movement area or other operational areas. For this reason, specific FOD prevention procedures should be established and employed for each construction project.

Aerodrome pre-construction planning should therefore include means for controlling and containing FOD generated by the construction.

[8] EASA, Notice of Proposed Amendment 2018-14

1.17 Organizational and management information

1.17.1 FOD prevention & runway inspection regime in force at Entebbe International Airport

Despite several requests, no information from the Entebbe Airport Authorities on their FOD prevention programme and runway inspection regime was received.

1.17.2 FOD prevention & runway inspection regime in force at Kigali International Airport

After requesting information from the Kigali Airport Authorities on their FOD prevention programme and runway inspection regime, two handwritten runway inspection sheets were received, see Appendix 3.

The airport authorities did not provide information on the FOD prevention programme for Kigali Airport. The supplied runway inspections sheets indicate that some 20 runway inspections per day are carried out in an irregular pattern.

On Febr. 4th 2018 the last runway inspection prior to the landing of flight WB465 has taken place between 04:56 and 05:04 LT. This inspection revealed no abnormalities. Between the inspection and the landing of flight WB465 at 06:09 LT two take-off's and one landing were reported. The next runway inspection, conducted between 07:30 and 07:48 LT, again revealed no particulars.

2. ANALYSIS

2.1 Most likely incident scenario

The fan blade damage, that was found after arrival of flight WB465 at KGL, was consistent with impact forces from the bolt that was found lodged in the acoustic liner of the fan intake. Since it was unambiguously demonstrated that this bolt did not originate from the engine or the aircraft itself, the bolt must have been ingested by the engine. However, even at high power settings such as during take-off, ingestion of a small object with a mass like that of the bolt concerned is not very likely for a Bombardier CRJ900 aircraft because of its relatively high positioned rear-mounted engines. It is therefore significant that, apart from the fan blade damage, also small punch-type damage to the tread of the left-hand outboard main gear tire was found that had not been detected before, see Appendix 1. This leads up to the most likely scenario whereby during taxi-out or on the runway the bolt was picked up by the left-hand outboard tire at low speed, subsequently came loose from the tire by centrifugal forces during the high speed part of the take-off run and then was ingested by the left-hand engine, running at take-off power.

The fan blade damage was found after arrival at KGL, whereas during the pre-flight inspections at the en route stations of flight WB465 no abnormalities were found. Besides the last runway inspection at KGL prior to the landing of flight WB 465 had shown no abnormalities.
The available landing distance for runway 28 at KGL is 3279 m, which is more than adequate for CRJ900 operations. This aspect, in combination with the prevailing company procedure to use idle reverse whenever possible, make it credible that no high reverse power settings during the landing roll of flight WB465 have been applied.

These circumstances indicate that ingestion of the bolt most probably has occurred during the take-off run at the last transit stop before reaching destination KGL, being Entebbe International Airport.

The reported extensive airside works in progress at EBB, that in itself create an additional FOD hazard, during the time of the incident add to the credibility of the scenario depicted above.
Nonetheless it must be stated clearly that, however likely, this scenario could not be demonstrated unambiguously due to lack of available data.

2.2 FOD prevention programme and runway inspection regime at Kigali and Entebbe

Both the Kigali and Entebbe Airport Authorities have been asked for their FOD prevention programme and runway inspection regime.

Kigali International Airport
From the KGL Airport Authorities two hand written runway inspections sheets were received, see Appendix 3. Since no specific runway inspections forms for KGL Airport are available, regular plain paper sheets from a notepad are used.
From the two sheets it can be concluded that frequent runway inspections at irregular intervals are being conducted. However, it could not be demonstrated that these inspections are based on a sound policy, laid down in the KGL Airport Operations Manual, nor that a FOD prevention programme is documented.

Entebbe International Airport
Despite several requests no information from the EBB Airport Authorities on their FOD prevention programme or runway inspection regime was received.

In conclusion
Based on the above it must be concluded that both KGL and EBB Airport Authorities should make an effort to develop and implement both a comprehensive FOD prevention programme and criteria for their runway inspection regime.
Such programme and criteria should be clearly documented in their respective Airport Operations Manuals and follow the directives and guidelines from ACI, ICAO and EASA as discussed in paragraph 1.16.2.

Especially the EASA documentation is of importance since it contains the latest standards and the most up to date information on this subject, that will be incorporated in the ICAO documentation framework by the end of 2020.

To this respect it is worthwhile to mention that EASA calls amongst others for:

- A continuous aerodrome FOD training programme, whereby employees from all stakeholders who perform activities on airside are made aware of FOD risks and adopt a 'clean as you go' technique during their work.
- Specific FOD prevention procedures to be established and employed for each construction project. Thereby aerodrome pre-construction planning should include means for controlling and containing FOD generated by the construction in a pro-active way.

As stated in paragraph 1.10, extensive works on the manoeuvring area of EBB airport will be going on for the next years to come, imposing an increased risk for FOD related incidents. Pending implementation of a comprehensive FOD prevention programme as described above, the EBB Airport Authorities should therefore evaluate their current efforts to control FOD, both proactively and reactively, without delay. Based on this evaluation immediate action should be taken where needed.

3. CONCLUSIONS

3.1 Findings

3.1.1 After arrival of flight WB 465 at KGL on Febr. 4th 2018, impact damage to all fan blades of the left-hand engine was found, as well as minor punch-type damage to the left-hand outboard main gear tire.

3.1.2 The fan blade damage was caused by a bolt, that was found lodged in the acoustic liner of the fan intake.

3.1.3 The bolt causing the fan blade damage did not originate from the engine and thus has been ingested by it.

3.1.4 Most probably the bolt was picked up by the outboard wheel from the left-hand main gear during taxi-out at EBB and subsequently ingested by the left-hand engine during the take-off roll. This scenario however could not be demonstrated unambiguously.

3.1.5 The Airport Council International (ACI), the International Civil Aviation Organisation (ICAO) and the European Aviation Safety Agency (EASA) have issued comprehensive guidelines on Foreign Object Debris (FOD) prevention programmes.

3.1.6 The EASA guidelines on FOD prevention programmes will be incorporated in ICAO documentation by the end of 2020.

3.1.7 The newly developed EASA guidelines emphasise that the aerodrome FOD control programme should cover hazards involved with construction activities.

3.1.8 At the time of the incident extensive works on airside of EBB airport were in progress.

3.1.9 The Airport Authorities from KGL and EBB have not demonstrated their FOD control programmes nor documented rules on runway inspection requirements.

4. SAFETY RECOMMENDATIONS

4.1 The Kigali International Airport and Entebbe International Airport Authorities are recommended to develop, document and implement policies and procedures for Foreign Object Debris (FOD) prevention.

4.2 The Kigali International Airport and Entebbe International Airport Authorities are recommended to develop, document and implement policies and procedures for runway inspections.

4.3 The Kigali International Airport and Entebbe International Airport Authorities are recommended, when establishing their FOD prevention programme, to take into account the proactive FOD prevention guidelines as proposed in EASA amendment 2018-14 that will be adopted by ICAO by the end of 2020.

4.4 In view of the continuing extensive works on the manoeuvring area, the Entebbe Airport Authorities are recommended to evaluate and intensify where needed their efforts to control FOD, both proactively and reactively, without delay.

5. APPENDICES

Appendix 1: Damage to outboard tire of left-hand main gear

Appendix 2: Analysis of foreign object damage by National Transport Safety Board, USA

I received some photos of the CRJ900 Foreign Object damage event you are investigating through the GE customer support office and wanted to reach out and provide you some information. All the fan blades look like they experienced hard impact damage, consistent with impact from the bolt that was found lodged in the inlet. Upon closer examination of the bolt (See the first picture), the bolt does not seem to match anything in the inlet of the engine. The event bolts looks like a 6-point bolt whereas the engine and inlet has mainly 12-point bolts with none of the 6-point bolts located ahead of the fan. The only 6- point bolts are airframe bolts that attached the inlet to the engine but they are external to the airflow and well behind the inlet. Additionally these bolts are covered by the thrust reverser so not in a location that could have gotten into the fan inlet. This seems to indicate that the engine pick up this bolt may be from the last airport (if they do a walk around after every flight). Attached are pictures that GE was kind enough to take of the CF34-8C with the inlet cowl installation from their training center. Based on this information, it would be very hard to determine where the bolt originated, it could have come from a number of non-aviation sources, fuel trucks, baggage carts, air stairs, etc. but it looks like it is certainly did not come from this airplane.

Please let me know if you need any further assistance.

Best Regards,

Bolt that was found lodged in acoustic lining of fan intake.

Appendix 3: Runway inspection sheets from Kigali Airport Authorities

Sheet 1

Sheet 2

19h08	I have [illegible] the activities of shift Nr 2 by [illegible]
19h17	I have entered in the run way for inspection
19h40	I have come out of the run way & it's clear
19h49	I have entered in the run way for inspection
21h05	I have come out of the run way & it's clear
21h16	I have entered in the run way for inspection
22h02	I have come out of the run way & it's clea
22h10	I have entered in the run way for inspection
23h26	I have come out of the run way & it's clear
23h30	I have entered in the run way for inspection
23h50	I have come out of the run way & it's clear
23h58	I have entered in the runway for inspection
00h45	I have come out of the run way & it's ok
00h49	I have entered in the run way for inspection
01h25	I have come out of the run way & it's clear
01h30	I have entered in the run way
01h45	I have come out of the run way & it's clea
01h50	I have entered in the run way for inspection
03h52	I have come out of the run way & it's clear
04h02	I have entered in the run way for inspection
04h56	I have come out of the run way & it's clea
04h56	run way inspection
05h04	Run way is cleared
05h16	Turkish plane take off safely
05h34	9XR-W has landed safely
05h56	5H-OJC has taken off safely
06h09	9XR-WH has landed safely
06h14	9XR-WO has landed safely no bird strike
06h19	9XR-WG has landed safely no bird strike
06h24	9XR-WF has landed safely
07h07	9XR-WL has landed safely no bird strike
07h25	SHIFT NUMBER II 04/02/2018
07h30	Runway inspection BC 28 FM 27
07h48	Runway clear
07h52	5Y-FFC has landed safety no bird strike
08h08	Runway inspection BC 10 FM 28
08h25	Runway clear out of the runway
08h29	9XR-WL has landed safety no bird strike
08h32	9XR-WL has taken off safety no bird strike
08h40	AG-EFH has taken off safety no bird strike
08h46	9XR-WP has taken off safety no bird strike
08h54	5Y-FFC has taken off safety no bird strike
09h01	9XR-WG has taken off safety
09h02	Runway inspection BC 28 FM 10
09h07	9XR-WF has taken off safety & clear
09h13	Runway inspection BC 28 FM 10
09h26	Runway clear
09h29	9XR-WG has taken off safety no bird strike
09h34	Runway inspection BC 10 FM 10
09h46	Runway clear
09h54	9XR-WJ has taken off safety no bird strike
14h42	Niyonzima runway inspection BC 10-28
14h58	[illegible] runway inspection 28 BC
15h00	ET-ADA [illegible]