of the Czech Republic

Ref. No 329/06/ZZ

FINAL REPORT

Investigation of Serious Incident A/C Airbus A 321, Registration Mark OK-CEC, during the take off on 18 th July 2006

Prague
July 2007

A) Introduction

Operator:	CSA a.s., Czech Republic
Aircraft manufacturer and model:	Airbus Industries, A321 - 221
Registration Mark:	OK - CEC
Planning destination:	Prague (LKPR), Czech Republic
Place of incident:	Rijeka (LDRI), Croatia
Alternate destination:	Pula (LDPL), Croatia
Date and time:	18/07/2006, 20:28 (all times are UTC)

B) Synopsis

On 19^{-th} July 2006 at 01:51 AAII Czech Republic, was notified by the operator of a serious incident involving the OK-CEC airplane during its take off from Rijeka aerodrome (LDRI). When the plane was taking off, the left engine experienced an uncommanded shut down (IFSD), ejecting hot metal parts. As the speed was higher than V_1 the captain decided to complete the takeoff with one engine only. The separated hot metal parts of the engine set the grass surfaces of LDRI aerodrome on fire, putting it out of service for 50 minutes. Since the captain could not land safely at LDRI, he accepted the offer by ATCO LDRI to make a safety landing on the nearest alternate aerodrome Pula (LDPL). The flight ended up safely on the alternate aerodrome. There was no other damage to the aircraft and no passengers were injured during the incident.

The final report on the incident issued AAII based :
Beranových 130, 199 01 Prague 99, Czech Republic
fax: +420 266 199 234
web site: www.uzpln.cz

The cause of the incident was investigated by an Air Accident Investigation Institute commission comprising:

Commission chairman:	Mr. Ing Lubomír Střihavka, AAII
Commission member:	Mr. Ing. Josef Procházka, AAII
	Mr. Ladislav Musil, deputy of operator
	Mr. Ing. Zdeněk Schmid, deputy of operator
	Mr. Jan Kubač, deputy of operator

C) The report includes the following main parts:

1) Factual information
2) Analysis
3) Conclusions
4) Safety recommendation
5) Annexes : A/ Shop findings CFM56-5B ESN 779275
   B/ Quick event reports and data analysis DFDR
6) Other Annexes (to copy No.1 stored in AAII archive)

Used abreviations:

AAII	-	*Air Accidents Investigation Institute of the Czech Republic*
ATCO	-	*Air Trafic Controller*
ATO	-	*Aborted Take-Off*
CC	-	*cabin crew*
CFM56	-	*type of engine*
CFM International	-	*engine manufacturer*
CSLSV	-	*cycles since last shop visit*
CSN	-	*cycles since new*
ECU	-	*Engine Control Unit*
ECAM	-	*Electronic Centralized Aircraft Monitoring*
FC	-	*flight crew*
FCy	-	*flight cycles*
FCOM	-	*Flight Crew Operating Manual*
FH	-	*flight hours*
ESN	-	*Engine Serial Number*
FPI	-	*Fluorescent Penetrant Inspection*
FOD	-	*Foreign Object Damage*
GATX	-	*owners of A/C*
GE	-	*General Electric - engine manufacturer*
HPC	-	*High Pressure Compressor*
HPT	-	*High Pressure Turbine*
HPTACC	-	*High Pressure Turbine Active Clearance Control*
IFSD	-	*In Flight Shut Down*
LLP	-	*Life Limit Part*
LPC	-	*Low Pressure Compressor*
LPT	-	*Low Pressure Turbine*
LRU	-	*Line Replaceable Unit*
MRO	-	*Maintenance, Repair & Overhaul*
QEC	-	*Quick Engine Change*
TSLSV	-	*time since last shop visit*
TSN	-	*time since new (hours)*
TWR/APP	-	*approach TWR*
Snecma Services	-	*engine manufacturer's Product Support organization for CSA investigation and selected MRO Shop for CFM56-5B ESN 779275 and repair activities*
SEM	-	*Scanning Electron Microscope*
V_R	-	*rotation speed*
V_1	-	*critical engine failure speed*

1 Factual information

1.1 History of the flight

The flight history description is focused on how the aircrew reacted to the situation to land safely at the alternate aerodrome.

1.1.1 OK-CEC Airplane Operation

The airplane arrived at LDRI on 18-th July 2006 to land there at 19:13. The plane was to continue as a charter flight CSA 8309 back to LKPR where it was scheduled to land at 21:10. When flying from LKPR to LDRI the crew did not notice any anomaly in the engine operation or aircraft systems. According to the crew neither a bird strike nor a foreign object (FOD) intake was recorded during the flight from LKPR to LDRI.

1.1.2 Flight CSA 8309 from Rijeka to Prague

The flight started at 20:28. When taking off, the left engine experienced an uncommanded shut down, which was accompanied by a strong noise. The pilots reported the engine's instruments indicated some "severe damage". The left engine speed equalled to zero. When troubleshooting the problem the aircrew followed the operator's procedures in a standard way, according to ECAM.

Based on subsequent radio communications with ATCO, the aircrew made sure the plane was showing no signs of fire. The crew was also informed that LDRI aerodrome was not serviceable providing no possibility of landing due to the fire along the runway. ATCO offered the crew an alternate aerodrome, LDPL for landing, which the crew accepted. The plane continued to LDPL aerodrome where it landed safely at 20:55.

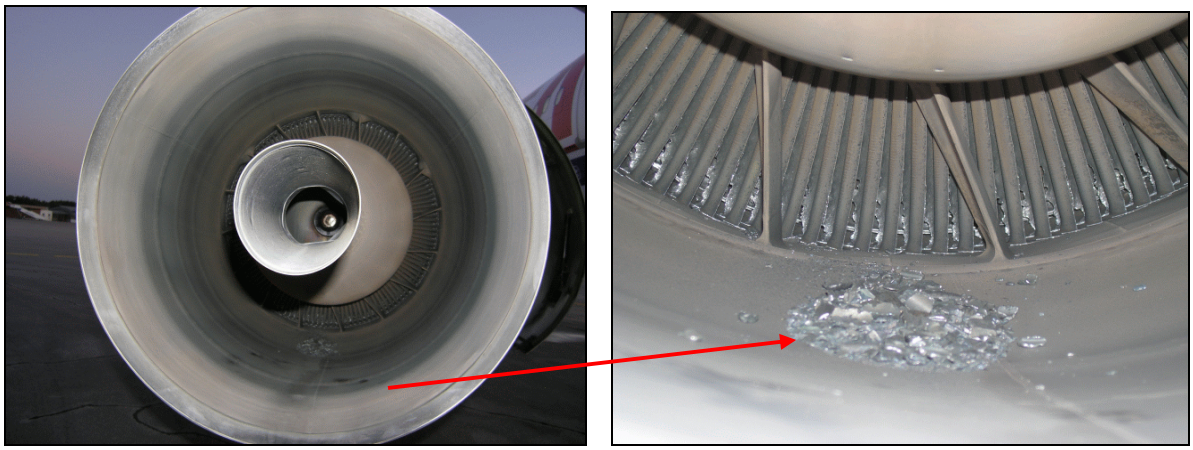
When dealing with the situation and getting ready to land at the alternate aerodrome, stewards prepared the passenger cabin for possible emergency landing or evacuation. The passengers remained calm during the whole flight. After landing and a short wait on the runway for the plane check up, the aircrew continued taxiing with only one engine on to the aircraft stand where the passengers got off.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others (inhabitants, etc)
Fatal	0	0	0
Serious	0	0	0
Light/no injury	0/7	0/159	0

1.3. Damage to Aircraft

The internal parts of the left engine suffered damage causing the engine shut down. The engine cowling and other aircraft parts were not damaged.



The Snecma Services shop in St. Quentin, France, have specified the engine damage in more details, which may be found in a report "Shop findings ESN 779275" of 16-th August 2006 in Annex A.

1.4 Other damage

After the plane took off from RWY 32 LDRI, the grassy left side of RWY 32 about 1,000 m long caught fire. The fire was caused by the engine´s hot metallic parts ejected on and beside the runway. The aerodrome operator reported no other damage.

1.5 Personnel information

1.5.1 Captain (CPT)

Male, aged 43 years, ATPL(A) licence valid till 20-th February 2007, rating CP A320/321, medical valid till 22-nd August 2006

Flying experience	Flight time in last 24 hrs	Flight time in last 90 day	Total
Total	**9:32**	**160:49**	**8,172**
as PIC	**9:32**	**-**	**3,865**
as PIC on A321	**9:32**	**160:49**	**760**

Time off duty prior to the flight: 19-th Jun – 23-th Jun 2006

CPT passed the latest exam "Line Check" on 11-st Mar 2006

1.5.2 First officer (FO)
Male, aged 31 years, CPL(A) licence valid till 28-th Feb 2007, rating FO A320/321, medical valid till 8-th Nov 2006.

Flying experience	Flight time in last 24 hrs	Flight time in last 90 day	Total
Total	**1:11**	**221:35**	**2,735**
as FO	**1:11**	**-**	**2,115**
as FO A321	**1:11**	**221:35**	**767**

FO passed the latest exam "Operator Proficiency Check "on 2-nd July 2006.

1.6 Aircraft information

1.6.1 General Information on Aircraft
Airbus Industries, type A321, variant 211, serial number 674, year of manufacture 1997, registration mark OK-CEC.
At time of incident the airplane had accumulated a total of 19,044 / 12,145 (FH/FCy).
Latest maintenance followed the AMM A320/321 programme.
The number and frequency of the inspections is shown in the following Table. The inspection results showed no systems failure to influence the left engine shut down. Since 15-th July 2007 the onboard system ECAM did not indicate any malfunction of the aircraft or deviations from the engine's normal operation parameters. The final working hours and cycles of the two engines are different due to their different idling times and repairs in the years 2000 and 2002.

Check results:

check	date	FH(hrs)	FCy(cyc)
DY	**18/07/2006**	**19,032**	**12,139**
WY	**16/07/2006**	**19,002**	**12,129**
A	**20/06/2006**	**18,699**	**12,007**
2A	**29/06/2006**	**18,787**	**12,044**
4A	**17/06/2006**	**18,653**	**11,895**
C (2C,3C)	**18/05/2005**	**15,921**	**10,945**

Note:

- the following Table shows the operational history of the OK-CEC airplane with its particular operators.

operator	registration mark	time of operator
Air France	**F-GTAA**	**from 1997 to 2002**
Air Canada	**C-GKOH**	**from 2002 to 2005**
Czech Airlines	**OK-CEC**	**from 2005**

1.6.2 Left engine (Position 1)

Manufacturer/type:	CFM56-5B3/P;
Serial number:	S/N 779275;
Date of manufact.:	16/05/1997
Flight hours/cycles:	18,158/ 11,447 (FH/FCy)
	11,788/ 6,454 (TSLSV/CSLSV)

On 1-st March 2002, the past aircraft operator (Air France) finished an extensive repair of the engine. On 24-th January 2000 this company worked out a Shop Findings Report No. 2000/WJ022 for the engine CFM56-5B3/P, S/N 779275. At that time the engine had accumulated 6,370/4,993 TSN/CSN. The engine had to undergo a repair following a check on the high pressure turbine blade shrouding "C" clip campaign and performance restoration, and findings in engine modules No. 05 to 15 (S/N 31X, 32 X, 33X, 41X, 42X, 51X, 52X, 53X, 54X, 55X, and 56X). The most significant findings were on module 05 (31X-HPC – replacement of 9 blades, on module 09 (42X Combustion Chamber) – some cracks in radial and axial directions, on module 10 (51X HPT Nozzles) trailing edge cracks in four blades and burns-through >9 mm beyond limit, on module 11 (52X HPT rotor) trailing edge cracks > 3 mm exceeding limit in three blades. On this module a set of new blades HPT P/N 2002M52P11 had been mounted, according to the bulletin SB 72-271. On module 12 (53X HPT stator) cracks were found on 17 sections "C", the module was repaired according to SB72-217 and SB 72-196.
On 25-th May 2005 the Technical Service Air Canada made a BSI of the engine showing no damage to the HPT blades. The inspection results are shown in the following Table.

SECTION 72-51:
- NO DAMAGE FOUND ON HPT NGV'S LEADING OR TRAILING EDGES AREA. VIEW FROM CONVEX AND CONCAVE SIDES, SHOWS COOLING HOLES IN GOOD CONDITION.

SECTION 72-52:
- HIGH PRESSURE TURBINE BLADES FOUND IN GOOD CONDITION.
- THREE WEAR NOTCHES WITHNESS MARK CAN BE SEEN ON THE FOUR SPECIFIC BLADES.

SECTION 72-53:
- NO DAMAGE FOUND ON HPT SHROUDS.
- SHROUDS IN GOOD CONDITIONS.

SECTION 72-54:
- NO DAMAGE FOUND ON LOW PRESSURE TURBINE BLADES FROM STAGE 1 TO 4.

The table of BSI

1.6.3 Right engine (Position 2)

Manufacturer/type:	CFM56-5B3/P;
Serial number:	S/N 779325;
Date of manufact.:	16/05/1997
Flight hours/cycles:	18,008/10,715 (FH/FCy)
	8,780/ 4,041 (TSLSV/CSLSV)

On 27-th February 2002 the previous aircraft operator Air France finished an extensive repair of the engine. On 30-th October 2001 the Air France operator had elaborated a report Shop Findings Report No.2000/WJ038 on the engine CFM56-5B3/P, S/N 779325. At that time the engine had accumulated 9,228/6,674 (TSN/CSN). The repair aimed at checking "C" clip campaign and performance restoration, and findings at engine modules Nos. 09 to 16 (42X, 51X, 52X, 53X, 54X, 55X, 56X, 62X). The most significant findings were on module 10 (51X HPT Nozzles) cracks in trailing edges of 11 blades and burns-through > 9 mm beyond limit, on module 11 (52X HPT rotor) cracks in trailing edges of two blades beyond limit. A new set of blades HPT P/N 2002M52P14 was mounted on this module, according to bulletin SB 72-271, and aptitude order AD001201 was applied.

Note:

- The available documents on engine repairs provide no evidence to show that the repairs influenced the engine operation. In the time span from the repair to the event, the engine S/N 779275 logged 11,788 / 6,454 (TSLSV/CSLSV) hours and the engine S/N 779325 logged 8,780 / 4,041 (TSLSV/CSLSV) hours.
- The last periodic inspections of either engine were carried out on the same dates along with the airplane.
- The following Table shows the engine operation history of the plane OK-CEC.

ESN 779 275 Left (event engine)		**ESN 779 325** right	
TSN / CSN		**TSN / CSN**	
18,158 / 11,447	**time of occurence**	**18,008 / 10,715**	**time of occurence**
TSLSV / CSLSV		**TSLSV / CSLSV**	
11,788 / 6,454	**time of occurence**	**8,780 / 4,041**	**time of occurence**
TSN / CSN	**repair by Air France**	**TSN / CSN**	**repair by Air France**
6,370 / 4,993	**24.1.2000 removal date 25.5.2000 repair date**	**9,228 / 6,674**	**30.10.2001 repair date**

Engines operating CFM56-5B3/P

1.7 Meteorological information

Conditions: CAVOK, wind 280 degrees/4 – 5 m/sec
Light conditions: night

1.8 Aids to navigation

NIL

1.9 Communications

The TWR/APP service was provided from LDRI aerodrome on frequency 119.00 MHz. When the event occurred, the crew issued a "PAN PAN" signal declaring an emergency. The communications with TWR were easy to read and understand.

1.10 Aerodrome information

The incident happened as the plane was taking off from LDRI aerodrome in Croatia. At the take-off time RWY 32 was in use. The aerodrome was temporarily closed down for about 50 minutes due to the grass fire.

1.11 Flight recorders

The aircraft was equipped with a flight data recorder of DFDR type, No. (MSN) 0674V8309. On 4^{-th} September the data were evaluated by ITC Airbus, which issued a Quick Event Report & Analysis MC 2110001/06, see Annex B. The record was legible and showed a sudden drop of the left engine speed without any anomalies being indicated before.
At the moment the engine speed fell, the aircraft´s speed was CAS = 136 kt.

1.12 Description of incident site

NIL

1.13 Medical and pathological information

The passengers transported were mostly children. There were 20 adults on board, 40 children under 12, and 99 teenagers from 13 to 19 years old. Most passengers were asthmatics returning from a health resort. As the passengers had been instructed properly by the cabin staff how to act in emergency, none of them incurred injury.

1.14 Fire

The burning grassy surface was put out by LDRI fire brigade in around 50 minutes.

1.15 Survival aspects

NIL

1.16 Tests and research

The damaged engine was taken from the plane and transported to Snecma Services, France, for repair. There, assisted by AAII professional commission, aircraft operator, company owner, and an insurance company representative, the engine was dismantled for the damage to be found and commented on. The people present agreed to use a destructive method of dismantling some damaged engine pieces that could not be disassembled in the usual way. Further, there was a requirement to conduct a metallurgical analysis of the HPT blades, which was carried out by GE Aviation.

1.16.1 Report on HPT Blade Metallurgical Analysis

MPED-Metallurgical Investigations GE Aviation performed under Log. No. 2006-01563 of 24^{-th} October 2006 a metallurgical analysis of the HPT first stage of the engine CFM56-5B3P ESN 779275. The investigation confirmed the engine manufacturer's hypothesis about a possible root cause. The blade condition is shown in Fig.1. Most of the remaining blade surface was heavily oxidized and deformed, showing marks of fatigue near the trailing edge.

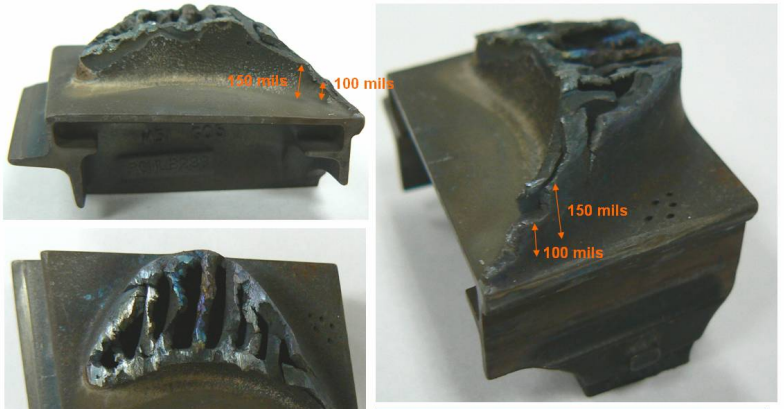


Figure 1. Macro photos of the condition of the primary blade failure. The height of the first confirmed fatigue is ~150 mils above the platform. The next lower ledge at 100 mils, resulted from secondary damage.

The crack origin was not found, due to surface damage. Fig.2 shows SEM photos of the supposed damage origin at the blade trailing edge root.

Figure 2. Scanning electron microscope images of the trailing edge of the blade. This plane is below the main fatigue surface and exhibits secondary damage from the event.

SEM images were showing an extent of fatigue starting near the trailing edge and propagating forward across the seventh blade rib and along the convex wall. The fracture surface condition beyond the surface was too damaged to conduct observations.

Figure 4. The propagation path of the observable fatigue areas from the trailing edge forward along the concave and convex airfoils.

1.16.2 Assessing HPT Stator Segments

Ambiguous observations about the HPT stator shroud segments of ESN 779275 engine prompted the commission to have the segments evaluated. The stator shroud segments have cooling holes. They are contaminated in operation, preventing cooling air from flowing through them. As the holes are plugged, the segment material suffers local overheating and falls off. These conditions of the engines CFM56-5B3/P can be easily monitored using BSI (boroscope inspection). To be sure about the ESN 779275 engine, the operator carried out a BSI on a sister engine ESN 779325. This inspection revealed that the material of HPT stator shroud was really falling off. The engine was dismantled and sent to the repair shop. The ESN 779275 engine´s segments could not be used to analyse cooling hole contamination due to the damage, so segments from the sister engine ESN 779325, removed for HPT stator shroud distress, were used for cooling holes analysis instead.

Fig 7 – Severe burning to a coule of HPT Shrouds (removal cause)

Fig 8 – Burning to more HPT Shrouds. 100% are likely to scrap.

1.17 Organizational and management information

On arriving at LDPL the passengers disembarked from the plane and went to the airport terminal. The operator arranged for alternate transport to the scheduled destination (LKPR) taking place 19^{-th} July at 04:55. The passengers got refreshments from the damaged OK-CEC while waiting.

1.18 Additional information

No dangerous goods were carried on board OK8309.

1.19 Useful or effective investigation techniques

The incident has been investigated according to L 13 National Regulation (Investigation into Air Accidents and Incidents of the Czech Republic as per recommendation of ICAO (Annex 13).

2 Analysis

2.1 Factual Information Analysis

- the aircrew were well qualified, trained and healthy for the flight.
- the aircraft had valid airworthiness certificate
- the engine failed at a CAS speed of 136 kt that was higher than V_1;
- as LDRI aerodrome was temporarily out of service due to the grass fire, the crew accepted ATCO LDRI´s offer to land on an alternate aerodrome LDPL;
- the aircrew noticed no anomalies in work of aircraft systems and/or engines during the previous flight;

2.2 Crew actions when the engine failed

The captain´s decision conformed to “Non-Normal Procedures” in the FCOM. On assessing the situation, the aircrew correctly completed the shut down of the engine. Cabin attendants worked in compliance with the operator´s procedures, fully securing the safety of passengers in emergencies.

2.3 Analysing Manufacturer´s Measures

Having analyzed similar cases concerning operation of CFM56-5B3/P engines of 3D-aero HPT blades configuration from 2000 on, the manufacturer has taken several measures to change the HPT blade production technology, and stipulated operating and maintenance conditions for CFM56-5B3/P users.

Thirteen engines suffered shut down (IFSD) since 2000 for HPT blades distress. Blade crucial spots have been specified by subsequent analyses. HPT blades P/N M52P09/P11 and P/N M52P04/P05 blades sustained damage in most cases. The metallurgical spectral analysis of N5 material, of which the blades had been made, revealed the presence of Yttrium inclusions. In making N5 material, Yttrium is used to precipitate Sulphur in order to improve the resistance of the blades thermal barrier coating. The manufacturer has changed the N5 material manufacturing process to reduce the Sulphur content without using Yttrium. In connection with blade root improved cooling in 3D configuration engine, the manufacturer issued a bulletin SB 72-0422 about installation of additional cooling holes. All the manufacturer’s measures aim at increasing operation reliability and safety of CFM56-5B3/P engines.

HPT 3D Blades Summary

THE POWER OF FLIGHT

Type of Distress	Field Events IFSD/ATO	PN Affected M52P04/P05	M52P09/P11	M52P14	M10P01	M10P03	Summary	Example
Trail Edge Corner Loss	0	X	X				Gaining field experience via CDR to substantiate a serviceable limit for AMM with reduced BSI. Customers report findings to maintain engine on-wing via CDR.	
Root Trailing Edge Cracks	1	X	X 1				Root Cause is known. BoreScope inspection program successful in detecting cracks, preventing IFSD/ATO events. Design improvements implemented and demonstrating good results.	
Airfoil Liberation	7	X 3	X 3	X	X 1		Prime blade known in 4 of 7 events. Yttria inclusion confirmed at origin on 3 of the 4. Blade material change to "N5- low sulfur" eliminates Yttria.	
Transition Zone Cracks	1	X	X 1	X	X		Root Cause is known. Design change implemented on new core dies Field action – shank strip and ECI at repair	
Shank Separation	4	X 4	X				Root cause known. Improved design released to field. P04/P05 CFM recommends remove thick coated at 11-12.5K cycles P09/P11SB 72-389 at repair, strip internal coating, Eddy Current Inspection	

8

SA HPT Blades Sept 2006 CFM International Proprietary Information

3 Conclusions

The main cause of the serious incident was a sudden drop of the left engine revolutions as the airplane was taking off at a speed higher than V_1. The abrupt speed reduction was due to the fact that one of the HPT blades airfoils separated. The blade separation from the HPT rotor at the take-off regime gave in turn rise to further extensive damage to the engine parts past the turbine rotor. Metallurgical analysis of the damaged parts indicated a fatigue crack at the root of a HPT blade trailing edge.

The event has been qualified as a serious incident brought about by an engine malfunction.

4 Safety recommendations

4.1 Safety Recommendations for the Operator

The operator will make FC and CC of A320/A321 aircraft family and technicians familiar with the full wording of this Final report.

4.2 Safety Recommendations for the Engine Manufacturer

The engine manufacturer of CFM56-5B3/P, following on the Final Report, the expert's report and the findings, should inform the engine operator´s about possible causes of damage to the HPT blades (see table chapter 2-3).