REPORT A-039/2010

DATA SUMMARY

LOCATION

Date and time	**Wednesday, 27 October 2010; 16:35 local time[1]**
Site	**Seville Airport (Spain)**

AIRCRAFT

Registration	**EI-EBR**
Type and model	**BOEING 737-800**
Operator	**Ryanair**

Engines

Type and model	**CFM 56-7**
Number	**2**

CREW

	Captain	First Officer
Age	**43 years old**	**29 years old**
Licence	**ATPL(A)**	**CPL(A)**
Total flight hours	**8,232 h**	**561 h**
Flight hours on the type	**4,919 h**	**410 h**

INJURIES

INJURIES	Fatal	Serious	Minor/None
Crew			**6**
Passengers			**150**
Third persons		**1**	**2**

DAMAGE

Aircraft	**None**
Third parties	**None**

FLIGHT DATA

Operation	**Commercial Air Transport – Passenger**
Phase of flight	**Taxi**

REPORT

Date of approval	**19 December 2012**

[1] All times in this report are local. To obtain UTC subtract two hours to local time.

1. FACTUAL INFORMATION

1.1. History of the flight

The aircraft was parked at stand 10 of the Seville Airport (see Figure 1). It had started up its engines and the crew had requested taxi clearance. A flight dispatcher was coordinating the operation from the apron.

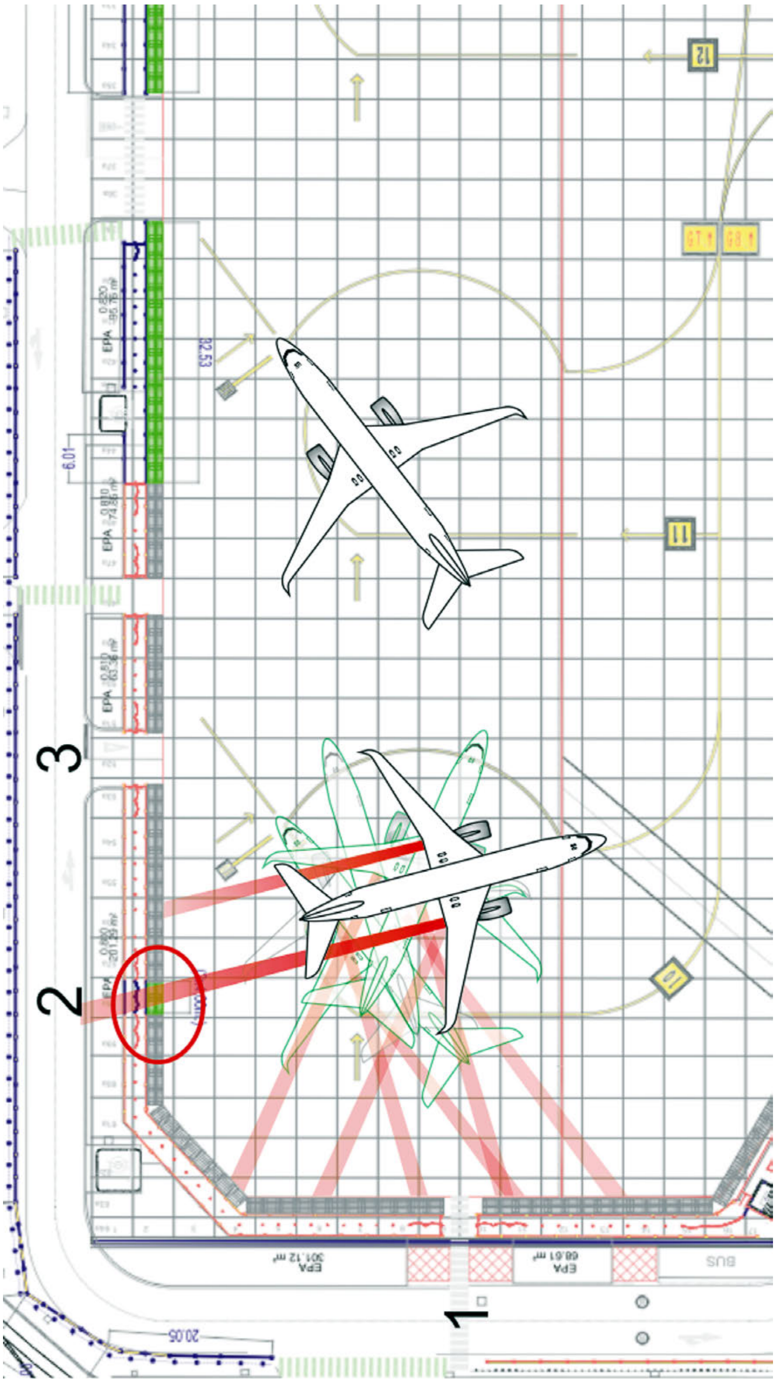

Figure 1. Position of aircraft and area affected by the jet blast

Meanwhile, a group of passengers was being led by two operators to board another aircraft of the same airline located at stand 11. The access to the aircraft was through a walkway on the apron protected by jet blast barriers. This walkway had areas that lacked barriers so as to allow the passengers to access the parked aircraft (points 1 and 2 in Figure 1).

When the aircraft started its engines and taxied, the boarding to the second aircraft was interrupted. The passengers remained behind the jet blast barriers at point 2, but the jet blast from the aircraft impacted some passengers, throwing them to the ground, as a result of which one passenger fractured an arm.

1.2. Personnel information

1.2.1. *Captain*

The captain had an airline pilot transport license and 8,232 total flight hours, 4,919 on the type.

On the day of the accident he was on duty for six and a quarter hours and made a total of four flights. He had had 22 h of rest prior to the flight.

1.2.2. *First officer*

The first officer had a commercial pilot license and 561 total flight hours, 410 on the type.

On the day of the accident he was on duty for six and a quarter hours and made a total of four flights. He had had 14 and a quarter hours of rest prior to the flight.

1.2.3. *Marshaller 1*

Marshaller 1 had been working at the airline since May 2007. He had received training on the dangers posed by running engines on the apron as part of the APRON SAFETY AND PROCEDURES course he had taken on 22 December 2009.

1.2.4. *Marshaller 2*

Marshaller 2 had been working at the airline since 2006. His training records showed he had taken the APRON SAFETY AND PROCEDURES course, which included a part on the risks entailed by running aircraft engines, on 5 January 2010.

1.2.5. *Flight dispatcher*

He had started working at the airline in 2007. His training consisted of a theory course and two weeks of on-the-job training.

1.3. Aircraft information

The aircraft, a Boeing 737-8AS, serial number 37530, is a twin-engine jet aircraft used to transport passsengers. It is outfitted with two CFM56-7 engines.

As in most twin-engine jets, the engines exhaust a jet while in operation, even in flight idle, that can cause serious damage if suitable precautions are not taken. That is why taxiing should be initiated using low power settings.

According to the information contained in the operator's Ground Operations Manual, the jet blast hazard areas for this aircraft extend 100 ft from the aft end of the aircraft at idle power and 510 ft at breakaway power.

1.4. Meteorological information

At the approximate time of the event, the wind was variable at 2 kt. Visibility was in excess of 10 km with no clouds. No significant changes were expected.

1.5. Communications

The aircraft was in contact with the Seville tower. At 16:29:00, the crew requested start-up and at 16:35:38 they requested taxi. No communications involving the event were recorded.

1.6. Aerodrome information

The Seville Airport has one concrete runway in a 09/27 orientation.

In the north of the airport there is an area called ramp 4 (R-4) that houses the remote parking stands 10 and 11. Both are sized for B737-800 aircraft, and aircraft can carry out autonomous exit maneuvers.

Section 20 of the Seville AIP, LOCAL REGULATIONS, 2.1 Push-back and Taxi Procedures, states that:

Figure 2. Path used by passengers to access stands 10, 11 and 12

> "In all stand positions, the autonomous exit maneuver will be carried out at the minimum regime required to initiate taxiing."

In order for passengers to go from the terminal to parking stands 10, 11 and 12, they must access the apron on foot and walk along a designated path flanked by fences on either side. This path has jet blast barriers in place which are designed to protect passengers from the jet blast of stationary and maneuvering aircraft on adjacent stands. There are gaps in the barriers to allow access to the aircraft.

1.7. Flight recorders

The event was reported to the CIAIAC two months after its occurrence, meaning none of the information contained in the flight recorders was preserved.

The information contained in the quick access recorder was obtained, which yielded data on the power settings selected by the crew at the start of the taxi phase.

Based on the information obtained from this recorder, the values for N1 at the start of the taxi phase were 39% in the left engine and 38.3% in the right. At that moment the aircraft was starting to taxi unassisted and turning right so as to enter the taxiway.

1.8. Tests and research

1.8.1. *Eyewitness statements*

1.8.1.1. Captain's statement

The captain of the aircraft was unaware of what had happened and continued taxiing normally.

1.8.1.2. Injured passengers' statements

Injured passenger 1

This passenger reported that they were going to board the second airplane and two people stopped them. A very strong blast from the departing airplane located alongside him caused a family member to be blown away who had to hold on to a chain alongside the walkway.

Injured passenger 2

They were on a path with fences and chains, walking toward their airplane. Two employees who were leading them to the airplane stopped them because another airplane was starting to taxi. The ensuing strong gust threw her to the grounds. He boarded the flight to Barcelona with neck and back pain. Two days later he went to the hospital due to the pain.

Injured passenger 3

Two people stopped them on the access walkway. Suddenly a very strong gust of air from another airplane blew her off her feet and tore away the chain that she was holding on to, throwing her to the ground. Since her airplane was about to depart, she boarded and continued on the flight to Barcelona despite the pain in her neck and elbow and a cut on her finger. In Barcelona she was treated by the airport doctor, who recommended that she go to a hospital for a more thorough examination of her injuries. Once at the hospital she was informed that she had a broken elbow and a pulled neck muscle.

1.8.1.3. Marshallers' statements

Marshaller 1

He was on duty guiding passengers to stands 10 and 11. While taking passengers to the aircraft parked at stand 11, the aircraft parked at stand 10 was cleared to taxi. He and his coworker instructed the passengers to stop for their safety so as not to be exposed to the jet blast. Some passengers were talking and did not hear their instructions. They repeated them but their warnings went unheeded.

Marshaller 2

He was acting as safety marshaller at stand 10. When the aircraft was ready taxi, he stopped the passengers who were on the walkway, warning them to go back to avoid the jet blast from the departing airplane. Those passengers who followed his instructions, which he repeated several times, did not have any problems, but some who did not were exposed to the blast of air issued by the engines. One woman fell to the ground, though she continued walking and boarded the aircraft located at stand 11.

1.9. Organizational and management information

1.9.1. *Operations Manual*

The airline's Operations Manual includes information on taxi procedures. This manual states that breakaway thrust should keep to a minimum. Normally, 30 to 35% of N1 is all that is necessary to commence taxi. The document states that the captain is in charge during the taxi phase.

1.9.2. *Ground self-handling contract at the Seville Airport granted to RYANAIR LIMITED*

RYANAIR has a contract with the Seville Airport to conduct its own handling operations. Among other things, these operations include escorting the passengers on foot to and from the aircraft and the terminal building. It also includes assistance for aircraft start-up and providing the means necessary to do so.

1.10. Additional information

1.10.1. *Boarding/Disembarking procedure used by RYANAIR prior to the event*

Section 10.11.4.1 of the Ground Operations Manual stated that during boarding and disembarking, passengers must be supervised to ensure they do not deviate from the prescribed route. It also added that procedures would be implemented for each of the airports at which Ryanair operates so as to comply with this requirement. There were no specific procedures in effect at the Seville Airport when this event took place.

Boarding passengers at Seville were led to the airplane on foot.

According to information provided by the handling personnel, a person was posted at every location where there was no jet blast to ensure that no one strayed from the designated walkway used for boarding.

When the anti-collision lights were turned on, or when instructed by the dispatcher through signs or verbally, marshallers interrupted the boarding process until the aircraft left the parking stand and entered the taxiway, at which point the boarding process would resume.

The flight dispatcher and the crew communicated using standard signals or verbally. Headsets are used now.

1.10.2. *Boarding/disembarking process at the Seville Airport after the event*

The operator issued a Safety Notice dated 6 December 2010 with the passenger boarding and disembarking procedure for the Seville Airport. It was directed at all of the personnel at the Seville Airport, informing them that, in keeping with the Ground Operations Manual (Section 10.11.4.1), boarding and disembarking passengers had to be supervised at all times at the Seville Airport.

The notice then detailed the boarding and disembarking procedure. Specifically, for the boarding procedure it stated that a marshaller had to be stationed at those points along the aircraft access walkways that did not have jet blast barriers so as to ensure that passengers did not deviate from the designated path.

Additional information was provided to remind that aircraft access points had to be properly monitored to ensure passengers did not deviate from the designated path and remained behind the jet blast barriers.

In January 2011 the boarding procedure was revised and a memo issued to all personnel at the Seville Airport on 5 January 2011. This memo noted that when passengers are boarding or disembarking from aircraft located at stands 11 or 12 and an aircraft on stand 10 requests clearance to taxi, all of the passengers must stop behind the jet blast barriers. It stated that they had to stop at least 3 m behind the aircraft access point.

1.10.3. *Actions taken by the airport and actions planned*

After the event, the Seville Airport closed the access to the affected apron by using jet blast barriers (point 2, Figure 1). This was not done initially because it was expected that passengers would access stand 10 through point 2, but since it was noted that the preferred access point was 1 (see Figure 1), it was decided to close off point 2.

Also, for each parking stand where boarding is conducted on foot, the airport is defining the requirements for the number of marshallers who must take part in the boarding process so as to ensure the safety of the operation.

Before these requirements were put in place, the self-handling contract included the obligation to have the provider of this service accompany the passengers from the terminal building to the aircraft, though the number of marshallers to be used during boarding and disembarking operations was not specified.

1.10.4. *Instructions and guidelines regarding passenger access to aprons*

ICAO Airport Services Manual

The ICAO Airport Services Manual includes information regarding jet blast protection.

ICAO Airport Services Manual. Part 8. Airport Operational Services.

10.6 APRON SAFETY

10.6.1 Blast precautions

10.6.1.1 All apron users should be made aware of the hazards arising from jet effluxes and propeller slipstreams. Where necessary apron design will have incorporated blast fences and the best use must be made of these to protect equipment. All vehicles and wheel equipment must be left properly braked and, where appropriate, on jack to minimize the risk of movement when subjected to jet blast or propeller slipstream.

Particular care must be exercised with apron equipment having a large flat side surface area. Litter or rubbish can constitute a risk when acted on by blast and it is thus necessary to ensure that aprons are kept clean.

Responsibility for the marshalling of passengers across aprons rests with the airline or its agent. However, airport staff should be aware of the risk to passengers on aprons from jet blast and should be prepared to give warning where this seems necessary.

CAP (Civil Aviation Publication) 642 of the United Kingdom's Civil Aviation Authority (CAA). Airside Safety Management

CAP 642, Airside Safety Management, was originally produced to provide guidance to aircraft and airport operators, and third party organizations as necessary, on safe operating practices for airside activities. The document was written by a working group that included representatives from the CAA, the Health and Safety Executive and the airport and airline industries.

Section 4 in Chapter 2 of this document details the hazards present to passengers on the apron, in particular when passengers have to walk from the terminal building to the aircraft. Specifically, it states that the use of air bridges for accessing and exiting aircraft avoids exposing passengers to the risks associated with walking on the apron to board.

If the use of air bridges is not possible, the safety of the passengers must be ensured by providing a route that is clearly marked and demarcated. Some of the recommendations listed include having the passengers be led at all times, avoiding routes that cross vehicular traffic, marking the routes with barriers or chains so that there can be no doubts regarding which path to take, establishing access restrictions when engines are running, positioning handling personnel along the apron to supervise the boarding and informing passengers of the route to take before leaving the terminal or the aircraft.

All of the above would be of little use if enough staff is not made available to ensure that no passengers are allowed to roam the apron freely outside the specified routes.

Section 6 of this same chapter contains the safety instructions to be observed when an aircraft is conducting autonomous operations at a parking stand. It states that areas through which passengers may pass or where personnel may be working must be protected with jet blast barriers. Flight crews must also be notified to use the minimum thrust necessary to complete the maneuver and to check that the area forward and aft of the engines is clear of equipment and people before starting the engines.

2. ANALYSIS

2.1. Aircraft boarding process

All of the documentation involving the safety of persons on airport aprons recommends the use of air bridges for boarding and disembarking passengers. This measure avoids exposing passengers to risks they may be unaware of or even having passengers inadvertently, or deliberately, damage an aircraft.

The Seville Airport has stands with air bridges to keep passengers from walking on the apron. However, the airline, as the end user, can decide whether to use air bridges or foot paths to board passengers.

The aircraft operator decided to board the passengers on foot since it was possible for the stand where aircraft was parked.

In any event, this method cannot undermine security, meaning that if passengers are boarded or disembarked on foot, sufficient staff must be used and the risks must be identified so that the measures and procedures needed to mitigate them can be established.

During the boarding in Seville, once the aircraft departing from stand 10 turned on its anti-collision lights, the boarding of the aircraft at stand 11 was interrupted. The passengers were behind the jet blast barriers but not sufficiently far away from the end to keep the jet blast from affecting them once the aircraft turned.

In its boarding procedure, the airline did not consider the fact that the angle of incidence of the jet blast from a turning aircraft could affect passengers or persons who, though behind the barrier, might be too close to the end of the barrier. The changes made as part of the last revision to the procedure does take into account this situation.

For its part, the airport closed the gap that existed in the barrier involved in the event and is drafting a procedure that specifically defines the staff that must be on hand at each parking stand during boarding and disembarking.

The airline's new procedure specific to stands 11 and 12 ensures that jet blast will not affect people even if an aircraft is turning. Also, by stationing marshallers at those points where passengers might deviate from the path, it ensures that passengers walk only along the designated boarding routes.

In addition, both the measures present at the airport facilities and the procedures used by the airline comply with the safety standards recommended in international publications in terms of passenger traffic on the apron and jet blast protection.

2.2. Maneuver performed by the aircraft

Parking stand 10 allows aircraft to park and taxi again without assistance. In these cases, both the aircraft operations manual and the airport AIP state that movements be made at the lowest thrust necessary. Specifically, the operations manual limits N1 values to between 30 and 35%.

International guidelines on autonomous aircraft operations state that the crew must ensure the area around the engines is clear of people and equipment before engine start-up. In this case, the jet blast barriers in place ensured that people and equipment would be protected against jet blast when the engines were started.

Even though during the maneuver the aircraft slightly exceeded the values provided in the operations manual, reaching an N1 of 39%, what really affected the passengers was the angle at which the jet blast crossed the gap in the barrier and which allowed the blast to reach the passengers who, though behind the barrier, were too close to the gap.

3. CONCLUSION

3.1. Findings

- The crew had all the required licenses and certificates valid and in force.
- The aircraft was parked at stand 10 at the Seville Airport.
- Passengers were being boarded onto another aircraft parked at stand 11.
- Stands 10 and 11 allow aircraft to park and depart without any assistance from ground personnel or equipment.
- There is a marked route protected by blast barriers for passengers to use when accessing stands 10 and 11.
- The aircraft parked at stand 10 started its engines and then taxied.
- When the aircraft started its engines, the boarding process for the aircraft parked at stand 11 was interrupted and its passengers remained behind the jet blast barrier.
- The aircraft at stand 10 turned to leave the parking stand.
- During the turn the jet blast reached an apron access point (2) at an angle such that it affected people standing behind the jet blast barrier.

3.2. Causes

The accident took place when the jet blast from the aircraft reached a passenger, throwing her to the ground. This was because the angle of incidence of the jet blast changed as the aircraft turned to leave the parking stand, allowing the jet blast to strike the passenger even though she was standing behind the jet blast barrier.

DATA SUMMARY

LOCATION

Date and time	**Monday, 11 April 2011; 14:00 local time**
Site	**Mijares (Ávila, Spain)**

AIRCRAFT

Registration	**SP-SUH**
Type and model	**PZL W-3A, PZL W-3AS**
Operator	**LPU Heliseco Ltd.**

Engines

Type and model	**PZL-10W**
Number	**2**

CREW

	Pilot	Flight Engineer
Age	**52 years old**	**59 years old**
Licence	**ATPL(H)**	**FEL (Flight Engineer License)**
Total flight hours	**7,564 h**	**1,200 h**
Flight hours on the type	**2,955 h**	**1,200 h**

INJURIES

INJURIES	Fatal	Serious	Minor/None
Crew			**2**
Passengers			
Third persons			

DAMAGE

Aircraft	**Minor**
Third parties	**None**

FLIGHT DATA

Operation	**General aviation – Other – Test**
Phase of flight	**En route – Cruise**

REPORT

Date of approval	**28 November 2012**

1. FACTUAL INFORMATION

1.1. History of the flight

On 11 April 2011, a PZL W-3AS aircraft, registration SP-SUH, took off from the aerodrome in La Iglesuela (Toledo) on a post-maintenance test flight. Over the course of the flight, the two crewmembers heard a strange noise coming from the area of the engine and then saw smoke filling the cockpit. The crew decided to make an emergency landing on a road, which was the most suitable place they could find. They were able to land without further incident and without any personal injuries.

When they exited the helicopter they saw smoke and fire issuing from the air intake system on the engines, which they proceeded to extinguish with the onboard extinguishers.

A subsequent inspection of the aircraft revealed that several components on the engine's air intake cooling system were broken, causing a misalignment with respect to the axis of rotation. This resulted in friction inside the intake, which caused the smoke and fire.

1.2. Personnel information

1.2.1. *Pilot*

Age:	52 years old
Nationality:	Polish
Flight license:	ATPL(H) • Initial issue date: 05/04/2006 • Expiration date: 01/05/2011
Medical certificate renewed on:	21/12/2010
Medical certificate valid until:	16/12/2011
Valid ratings and date issued:	• TR Mi2, 11/01/2012 • TR W-3 Sokol, 01/05/2011 • FI, 01/10/2012 • TRI Mi2, 01/10/2012 • TRI W-3 Sokol, 01/06/2013 • AGRO (agricultural spraying), 11/01/2013 • FFF (firefighting), 11/01/2012

1.2.2. *Flight mechanic (Non JAR-FCL)*

Age:	59 years old
Nationality:	Polish

Flight license: FEL (Flight engineer license)

- Expiration date: 19/05/2014

Valid ratings and date issued: W-3 Sokol, 15/10/2011

1.3. Aircraft information

Manufacturer: WSK PZL Swidnik
Model: PZL W3AS
Serial number: 310205
Year of manufacture: 1988
Airworthiness certificate number: DLR/10/083, valid until 19 May 2011
Left engine: PZL-10W, S/N: 119904031AS
Right engine: PZL-10W, S/N: 119894020AS
Dry weight: 3,850 kg
Maximum takeoff weight: 6,400 kg
Airframe hours: 3,107 h

1.3.1. *Maintenance records*

According to the maintenance program, the aircraft's maintenance intervals are every 25, 50, 100, 300 and 600 h and every 12 and 24 months.

The last tasks performed were part of the 25-, 50-, 100- and 300-hour inspections. This work took place between 21/02/2011 and 11/04/2011. Once completed, a test flight was required in order to issue the return to service certificate.

Periodic inspection	Date	Airframe hours
25 h	11/04/2011	3,107 h
50 h	11/04/2011	3,107 h
100 h	11/04/2011	3,107 h
300 h	11/04/2011	3,107 h
600 h	20/05/2010	2,931 h
1,500 h	20/05/2010	2,931 h

Among the maintenance tasks performed, the 300-hour inspection included a check of the alignment of the fan drive shaft on the system, a check of the fan blades and of the coupling nuts. The 100-hr and/or annual inspection also includes lubricating parts of the air intake cooling system.

1.3.2. *Accessory cooling system*

The purpose of the accessory cooling system is to direct atmospheric air to those helicopter accessories that require forced cooling, to the heating system and to the ventilation or air conditioning system (Figure 1).

1.3.2.1. General description of the system

The accessory cooling system consists of a cooling fan with a diffuser and a system for distributing cooling air. Figure 2 shows the cooling assembly with the diffuser.

The function of the fan is to force outside air to flow through the oil coolers toward the accessory cooling system. The fan is turned by a drive shaft (A) that is connected to the rotor shaft on the fan itself (B).

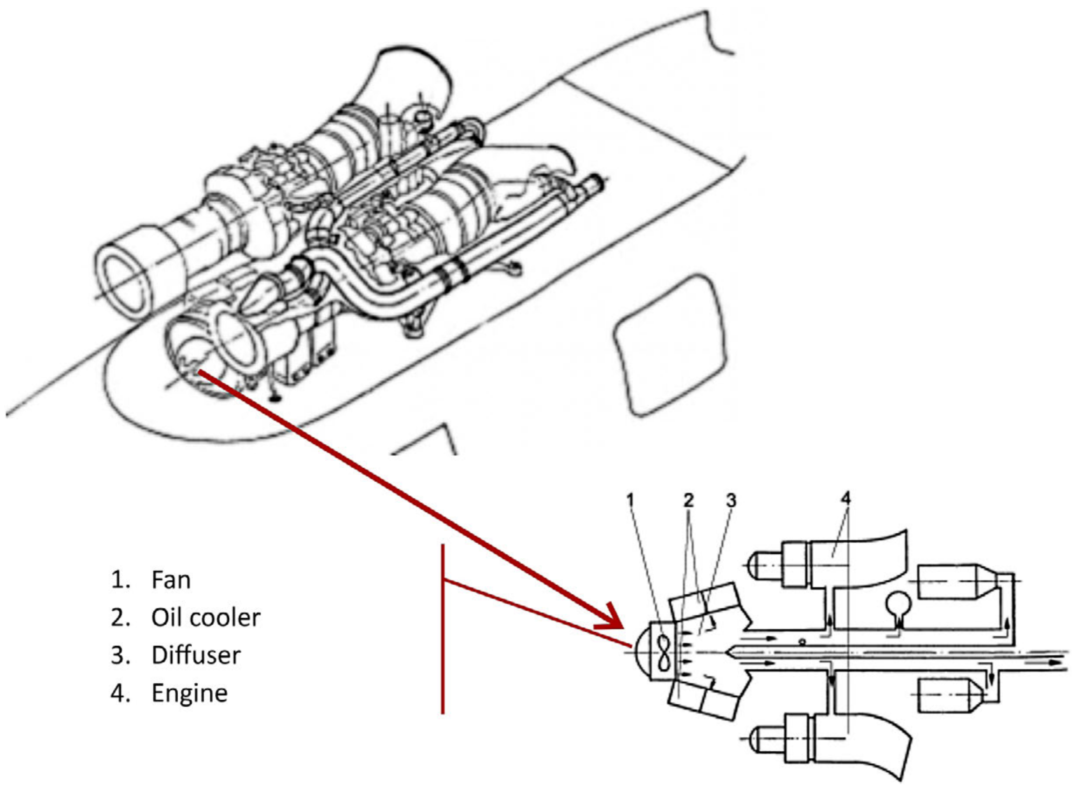

Figure 1. Accessory cooling system

The fan has two assemblies, one for the air inlet (assembly 1) (C) and one for the air outlet (assembly 2) (D). These two assemblies are connected to each other. Assembly 1 features discs with guide blades for channeling the air, while assembly 2 comprises the structural part of the fan and is attached to the fuselage by way of a strut. A diffuser (E) is attached to assembly 2 to force the cooled air through the distribution system.

The axis (B) of the fan rotor (F) turns on two bearings in the air outlet assembly. The front bearing is of the roller type (G), while the aft one is a bearing sleeve (H). The rotor shaft and the bearings are sealed using felt gaskets and labyrinth seals inside a sealed conduit which allows for lubrication.

The aft end of the rotor shaft (B) is joined to a coupling (I) that doubles as a clutch and allows it to be connected to the drive shaft (A) that turns it. The coupling between the two shafts is designed to withstand a certain amount of longitudinal and transverse motion.

The lubrication system consists of a grease nipple (J) and a conduit that is used to direct the lubricant to the fan rotor shaft. Excess grease exits through two orifices[1] that serve to check that the filling is completed with new grease.

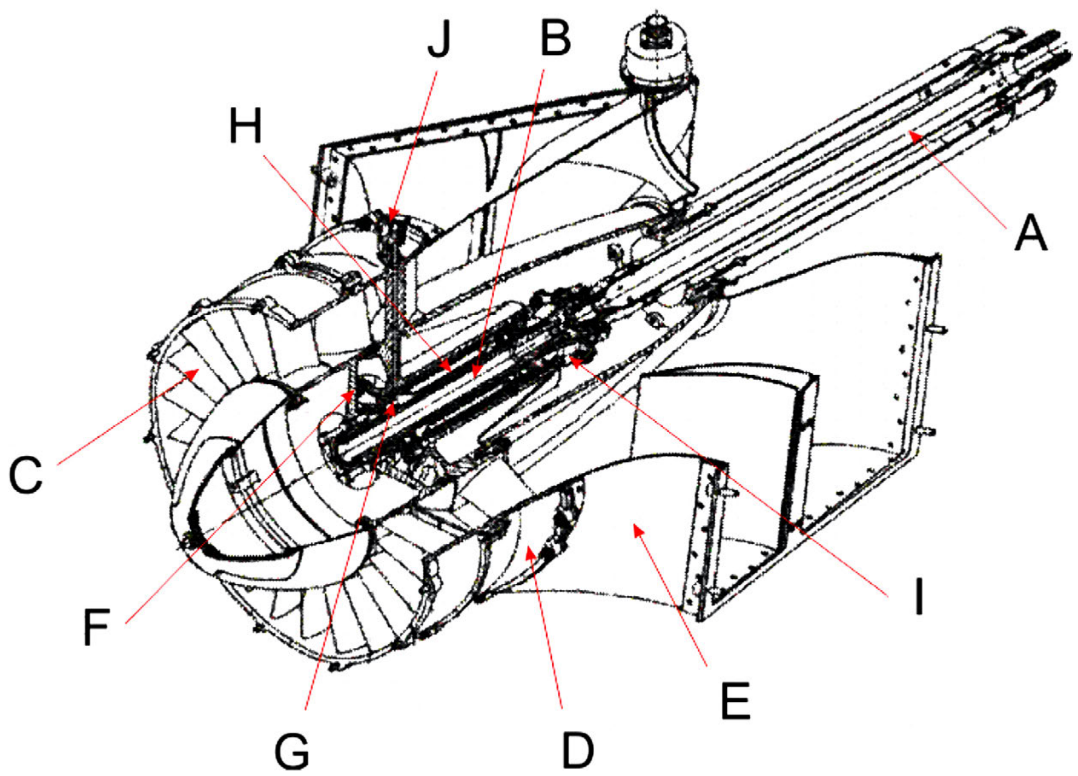

Figure 2. Fan and diffuser

[1] The two checking orifices on the fan rotor shaft are located at the front and rear of the shaft. The one in the rear is not visible during lubrication operations.

1.3.2.2. Lubrication of fan bearings

The procedure for lubricating the fan bearings is described in work sheet 37.10-1 of the Maintenance Manual. The instructions state to apply grease to the grease nipple (J) using a grease gun and then to check that the new grease issues from the inspection hole located at the front of the rotor shaft.

Section 12.20.00 of the same manual lists the type of grease that can be used and the lubricating frequency. The maintenance center used Grease 15 with a lubricating interval of 100 h or 12 months, as specified in the Maintenance Manual.

1.4. Tests and research

Under the supervision of Poland's State Commission on Aircraft Accident Investigation (SCAAI), the components of the affected fan, P/N: 2-6351-00 s. III, S/N 88048, were sent to the aircraft manufacturer (PZL Swidnik, S.A.) in coordination with the fan manufacturer (WSK Kraków Sp. Z o.o.) to determine the cause of the fracture of the fan's drive shaft.

The findings of the investigation and its conclusions are summarized in the paragraphs below.

1.4.1. *Visual inspection*

The fan drive shaft was fractured with its casing. Both had been affected by the temperature and by the torsional stress produced by the rotation of the shaft (Figure 3, A). The appearance of the aft bearing area on the rotor shaft that attaches to the clutch coupling (I) showed this to be the source of the highest temperatures (Figure 3, C).

The remains of burned grease were found inside the fan (Figure 3, B), and there were dents on the outer case that contains the lubricating grease for the bearings, see Figure 4. The lubricating grease in the clutch was also burned.

The rotor blade tips were found to have contacted the perimeter of the air conduit (Figure 3, D). They also rubbed against the outside of the stator stage aft of the rotor.

When the bearings were disassembled, damage was found to the roller cage components, the balls and the bearing seals.

Figure 3. Close-up of the fan components

Figure 4. Dents in the outer case

1.4.2. *Test conducted on the fan components*

The conditions of the clutch (component I in Figure 2) and the drive shaft (component A in Figure 2) were evaluated. The extent to which some of the clutch components (cadmium) had melted and the color of the drive shaft material (aluminum alloy) indicated that they had been subjected to temperatures ranging from 320 °C to 766 °C.

Surface hardness tests were also conducted on various steel components from the clutch and the bearing race and balls, as well as on the aluminum material (PA7) on the drive shaft. Comparing these results to the nominal values showed that, on average, they were subjected to temperatures of around 600 °C for some 10 minutes. Likewise, the variation in the surface hardness of the drive shaft material showed that the highest temperature reached was about 490 °C, with a transition area of some 200 °C. The heat source was determined to have originated from the direction of the aft bearing on the rotor shaft.

Once the shaft was reconstructed and verified to meet the manufacturer's standards for this component, the values for the drive shaft were confirmed with a functional test that simulated the conditions to which the shaft was subjected.

Other tests were conducted to determine the effect that the grease pressure used during lubrication, the type of lubricant used, the condition of the grease and the grease gun had on the dents found on the outer case of the rotor shaft. These tests were carried out in accordance with the fan manufacturer's standards on the original fan components, except for the damaged parts.

The pressure at which the lubricant was applied was monitored during one of the tests, which revealed that at a pressure of 20 bars, the new grease issued from both check lubricating orifices. Subsequently, when the assembly was subjected to dynamic lubrication, internal pressures of approximately 50 bars were reached that caused denting of the outer case of the rotor shaft, and degraded the joints and rings that comprise the bearing seals. It even caused detached material to clog the check orifices.

1.4.3. *Causes of the failure*

The findings from the tests concluded that the failure resulted from the high grease pressure used during the lubrication of the aft bearing on the fan rotor shaft, causing it to malfunction. The internal damage caused to the bearing led to high friction inside said bearing, resulting in temperatures that, with prolonged operation, reached a value of around 600 °C. This caused the lubricating grease under the fan cover to combust and the clutch grease to ignite.

The temperature reached in the ensuing fire caused the aluminum alloy in the drive shaft to reach its melting point (between 490 and 500 °C) such that the strength of the shaft decreased by up to six times in the fracture area. This effect was exacerbated by the torsional stress to which the drive shaft was subjected.

1.4.4. *Findings and proposed measures*

The inspection conducted by the working group led to the following conclusions and actions.

1.4.4.1. Test findings

- The fan is constructed in such a way that the front bearing can easily be checked for lubrication, since the forward telltale orifice can be accessed by removing the front cover on the air intake assembly. The check orifice for the aft bearing, however, is inaccessible during greasing operations. This lack of accessibility means that if the aft orifice is clogged, an excessive amount of grease may be forced into the bearing.
  In addition, the graphite seals on the fan rotor do not allow for a full adjustment of the area between the rotor shaft and the bearings, meaning any excess grease flows toward the outside of the rotor housing.
- Grease 15 is the lubricant recommended by the fan and helicopter manufacturer, and was the type used by the operator. This grease breaks down into two components: oil and a high-density base component[2]. Based on the tests conducted, given the high density of the grease, the components that comprise the seal between the rotor and the bearings can warp if it is applied at pressures of around 50 bars.
- The references made to lubricating the fan in the manufacturer's documentation and in the helicopter Maintenance Manual revealed that:

  – There is no consensus regarding the type of lubricant (grease) used, since the Maintenance Manual allows the use of several types.
  – The action of injecting grease until it issues from the chek orifices cannot be performed by the maintenance technician since one of the orifices is not accessible, except by the manufacturer.
  – Work sheet 37.10-1 in the Maintenance Manual does not specify what action to take if the helicopter is out of service for an extended period and only offers brief lubricating instructions.
  – The same work sheet also does not specify the amount of grease to inject.
  – There is no exact equivalence between the greases listed in the helicopter Maintenance Manual (Chapter 12.20.00) for use in the fan rotor bearings and those referenced by the fan manufacturer.

1.4.4.2. Proposed measures

The working group consisting of Poland's State Commission on Aircraft Accident Investigation (SCAAI), the aircraft manufacturer, PZL Swidnik, S.A., the fan

[2] This dissociation was observed in the grease gun used by the maintenance center and in the container with new grease supplied by the fan manufacturer.

manufacturer, WSK Kraków Sp. Z o.o and the operator proposed the following measures:

- As regards the construction of the fan:
  - Consider the possibility of modifying its construction to allow checking the aft check orifice when lubricating the fan.
  - Consider the possibility of changing the graphite-felt seals to another type that provides greater damage resistance.
- As regards the lubricant used to lubricate the fan:
  - That Grease 6 be the base lubricant recommended for civil use helicopters. The recommendation is to be implemented in the fan and helicopter manufacturers' documentation.
- As regards the fan lubrication records contained in the fan's documentation and in the helicopter's documentation, the work sheet is to include aspects such as:
  - Determine the lubrication pressure,
  - Implement the lubrication pressure control,
  - The specific amount of grease needed to ensure lubrication,
  - A process for lubricating the fan after the helicopter is out of service and after the fan is placed in storage for an extended period of time,
  - Expand the period for lubricating the fan installed on helicopters that are flown regularly (currently done every 100 h).

2. ANALYSIS AND CONCLUSIONS

2.1. General

Once the work associated with the 25-, 50-, 100- and 300-hour inspections was completed, the aircraft was taken on the test flight that is procedurally required before its return to service.

Over the course of the flight, the crewmembers heard a strange noise coming from the engine area and saw smoke filling the cockpit. The crew decided to perform an emergency landing, which was completed without further incident.

An initial inspection of the aircraft revealed that the accessory cooling system (Figure 1), specifically the fan, was damaged and exhibited the effects of the fire. A more detailed inspection was conducted later by a working group consisting of, among others, technicians for the aircraft and fan manufacturers, the findings of which are summarized in Section 1.4 of this report.

2.2. Findings and cause of the failure of the cooling system fan

In order to determine the cause of the malfunction in the accessory cooling system, the components of said system that were damaged in the event were tested and a series of functional and material tests scheduled in an effort to find the origin of the failure and the process that led to the fracture of the fan drive shaft.

As noted in Section 1.4, the analysis of the results concluded that the failure occurred due to the malfunction of the aft bearing on the fan rotor shaft, resulting from the high grease pressure to which it had been subjected during the lubricating operation. The internal damage to the bearing caused friction in the bearing and, as a consequence, a gradual increase in temperature over the course of operations that ended with the fracture of the drive shaft.

The experiments carried out, however, also underscored the important aspects discovered as a result of these tests, as detailed in Section 1.4.1.1, most notably:

- That the construction of the fan impedes proper access to verify the lubrication of the aft bearing on the rotor shaft or any other problems that may be present during or after the greasing.
- That the characteristics of the recommended lubricant (Grease 15), which was used in the tests, can cause degradation of the sealing elements and of the parts to be lubricated.
- That certain aspects of the documentation detailing the task of lubricating the fan can be improved, such as the type of lubricant used, how to monitor the amount of lubricant to be applied, addressing the impossibility of having the maintenance technician verify the lubrication of the aft bearing and improving work sheet 37.10-1 in the aircraft Maintenance Manual.

2.3. Measures proposed

The technicians representing the aircraft manufacturer, PZL Swidnik, S.A., and the cooling system manufacturer, WSL Kraków Sp. Z o.o, who took part in the investigation proposed the corrective actions mentioned in Section 1.4.4.2.

In light of the documentation supplied to investigators, this Commission is of the opinion that the corrective actions proposed for PZL W-3AS are adequate, and thus includes three Safety Recommendations directed at the following parties: the Civil Aviation Authority of Poland, as the country of manufacture and registration of the aircraft; the aircraft manufacturer, PZL Swidnik, S.A., and the manufacturer of the fan, WSK Kraków Sp. o.o. To the former, that it ensures the implementation of the corrective actions proposed as a result of the investigation into the incident involving the PZL W-3AS aircraft, registration SP-SUH, in Spain, and to both manufacturers, that they develop and implement said proposed corrective measures.

3. SAFETY RECOMMENDATIONS

REC 97/12. It is recommended that the aircraft manufacturer, PZL Swidnik, S.A., carry out the actions detailed below involving the PZL W-3AS aircraft and proposed in the wake of the investigation into the cooling system fan on said aircraft:

- As regards the construction of the fan:
  - Consider the possibility of modifying its construction to allow checking the aft telltale orifice when lubricating the fan.
  - Consider the possibility of changing the graphite-felt seals to another type that provides greater damage resistance.
- As regards the lubricant used to lubricate the fan:
  - That Grease 6 be the base lubricant recommended for civil use helicopters. The recommendation is to be implemented in the fan and helicopter manufacturers' documentation.
- As regards the fan lubrication records contained in the fan's documentation and in the helicopter's documentation, the work sheet is to include aspects such as:
  - Determine the lubrication pressure,
  - Implement the lubrication pressure control,
  - The specific amount of grease needed to ensure lubrication,
  - A process for lubricating the fan after the helicopter is out of service and after the fan is placed in storage for an extended period of time,
  - Expand the period for lubricating the fan installed on helicopters that are flown regularly (currently done every 100 h).

REC 98/12. It is recommended that the fan manufacturer, WSK Kraków Sp. Z. o.o, carry out the actions detailed below involving the fan on the cooling system on PZL W-3AS aircraft and proposed in the wake of the investigation into the cooling system fan on said aircraft:

- As regards the construction of the fan:
  - Consider the possibility of modifying its construction to allow checking the aft telltale orifice when lubricating the fan.
  - Consider the possibility of changing the graphite-felt seals to another type that provides greater damage resistance.

- As regards the lubricant used to lubricate the fan:
  - That Grease 6 be the base lubricant recommended for civil use helicopters. The recommendation is to be implemented in the fan and helicopter manufacturers' documentation.
- As regards the fan lubrication records contained in the fan's documentation and in the helicopter's documentation, the work sheet is to include aspects such as:
  - Determine the lubrication pressure,
  - Implement the lubrication pressure control,
  - The specific amount of grease needed to ensure lubrication,
  - A process for lubricating the fan after the helicopter is out of service and after the fan is placed in storage for an extended period of time,
  - Expand the period for lubricating the fan installed on helicopters that are flown regularly (currently done every 100 h).

REC 99/12. It is recommended that Poland's Civil Aviation Authority ensure that both the manufacturer of the aircraft, PZL Swidnik, S.A., and the manufacturer of the fan, WSK Kraków Sp. Z o.o, implement the corrective actions proposed as a result of the investigation into the incident involving the WSK PZL Swidnik W-3AS aircraft, registration SP-SUH, in Spain.