



Rolls-Royce Corporation

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Date: 12 February 2021

To: Jon Michael

Subject: Findings of the Series II Fourth Stage Compressor Wheel from Dynamic Aviation

Introduction

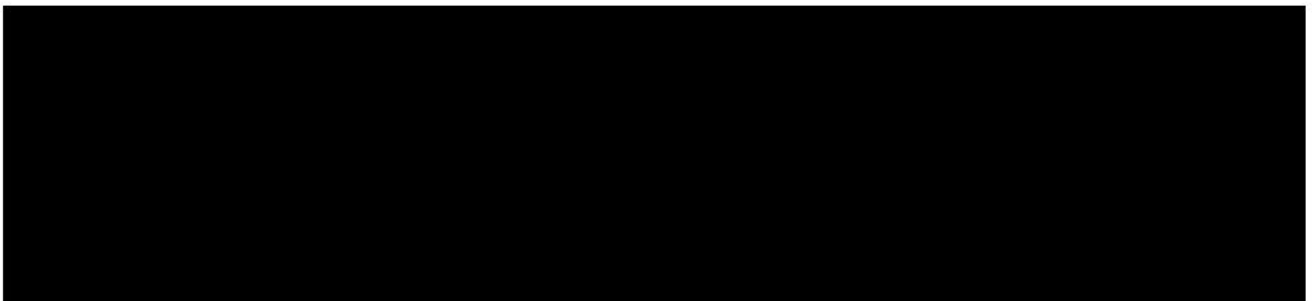
The purpose of this letter is to provide a summary of the findings from evaluations on the fourth stage compressor wheel S/N ER59690 installed in an M250-C20B, S/N CAE-823398, operated by Dynamic Helicopters. Due to the condition of the fourth stage compressor wheel, the actual part number was not legible.

Investigation

Following the wreckage inspection at the Vernal, UT airport under the guidance of the SLC FAA FSDO inspector, the compressor module was shipped to the Rolls-Royce Regional Customer Training Center and was disassembled by Rolls-Royce employees with an NTSB representative virtually connected. The as-received module is shown in Figure 1.



Figure 1: As-received compressor module





When the teardown was complete, selected hardware was submitted to the Rolls-Royce Failure Analysis Lab. The summary of findings from the Rolls-Royce laboratory is as follows:

- At least three stage 4 compressor blades exhibited fracture features consistent with fatigue. Two of the blades exhibited fracture features consistent with fatigue progression from the suction side crown and one blade exhibited fracture features near the suction side crown location that were consistent with fatigue progression aft from the leading edge area.
- The stage 4 compressor rotor exhibited corrosion damage on the airfoil and rim surfaces. Both of the blades that fractured in fatigue from the suction side crown had corrosion damage near the middle of the fatigue fractures.
- The stage 4 and 5 compressor blades did not have a diffused aluminide coating on the gas path surfaces.
- The remaining stage 4 compressor blades exhibited a combination of overload fracture features and smearing damage.
- One of the stage 5 compressor blades exhibited partially smeared fracture features that were consistent with fatigue progression from the suction side crown location.
- Several stage 5 blades exhibited shiny thumbnail-shaped areas within fields of overload fracture and smearing damage.
- There was no evidence of any foreign object impact damage upstream of the stage liberated stage 4 compressor blades.

The as-received condition of the compressor rotor following teardown is shown in Figure 2. All the stage 4 and 5 blades were fractured and liberated near the root, and all the fracture surfaces exhibited some amount of smearing damage. The stage 3 blades exhibited impact damage on the trailing edges. The stage 6 compressor blades exhibited tip deflection against the direction of engine rotation. The damage to the stage 3 and 6 compressor blades was consistent with impact damage from the liberated stage 4 and 5 compressor blades.

Figures 2-14 are a summary of the photos from the metallurgical report:

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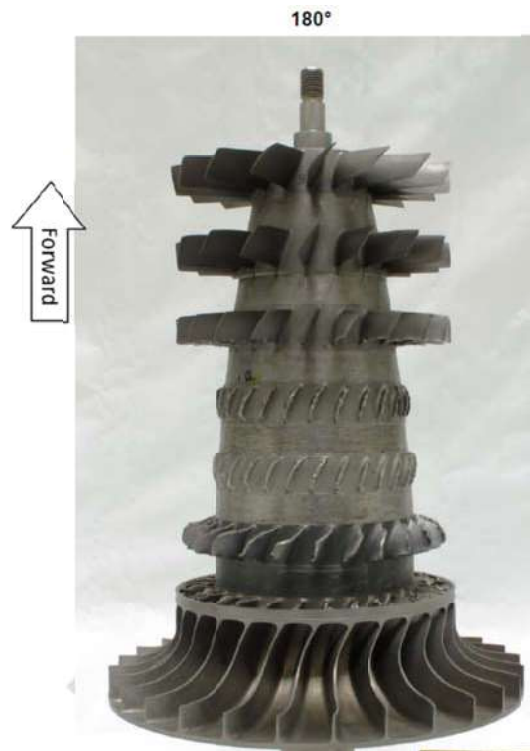


Figure 2: As-received compressor rotor



Figure 3: Representative leading edge tip erosion found on the stage 1 compressor blades. The red dashed line shows the approximate original profile of the leading edge tip.

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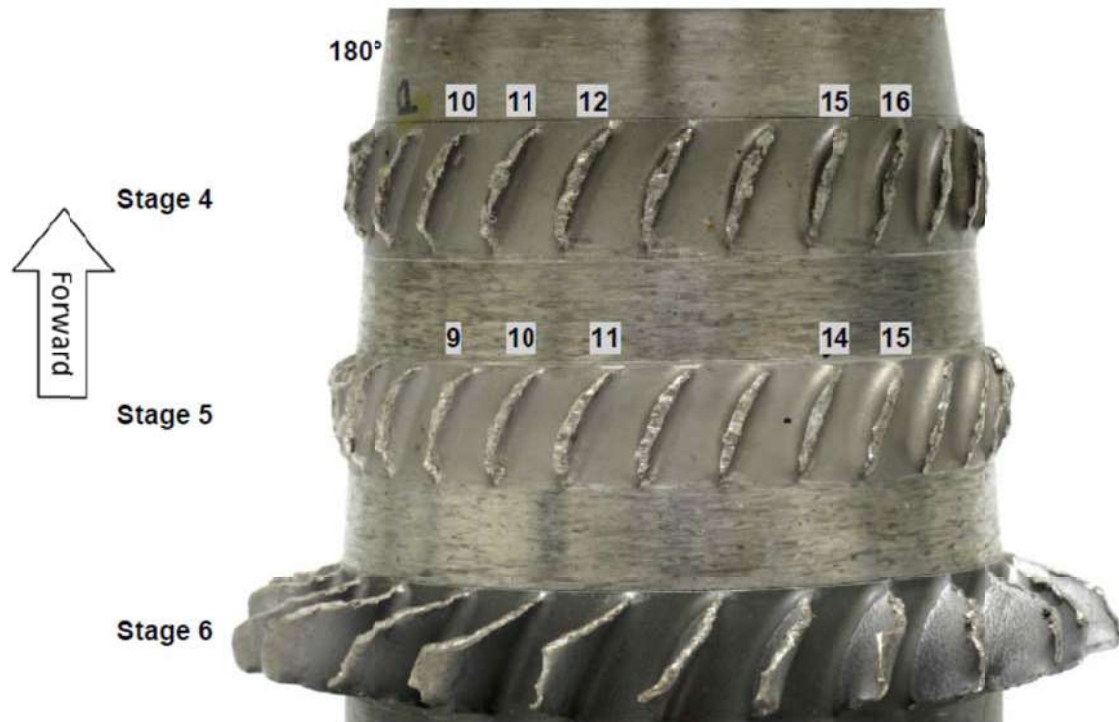


Figure 4: Close up view of the stage 4, 5 and 6 compressor wheels

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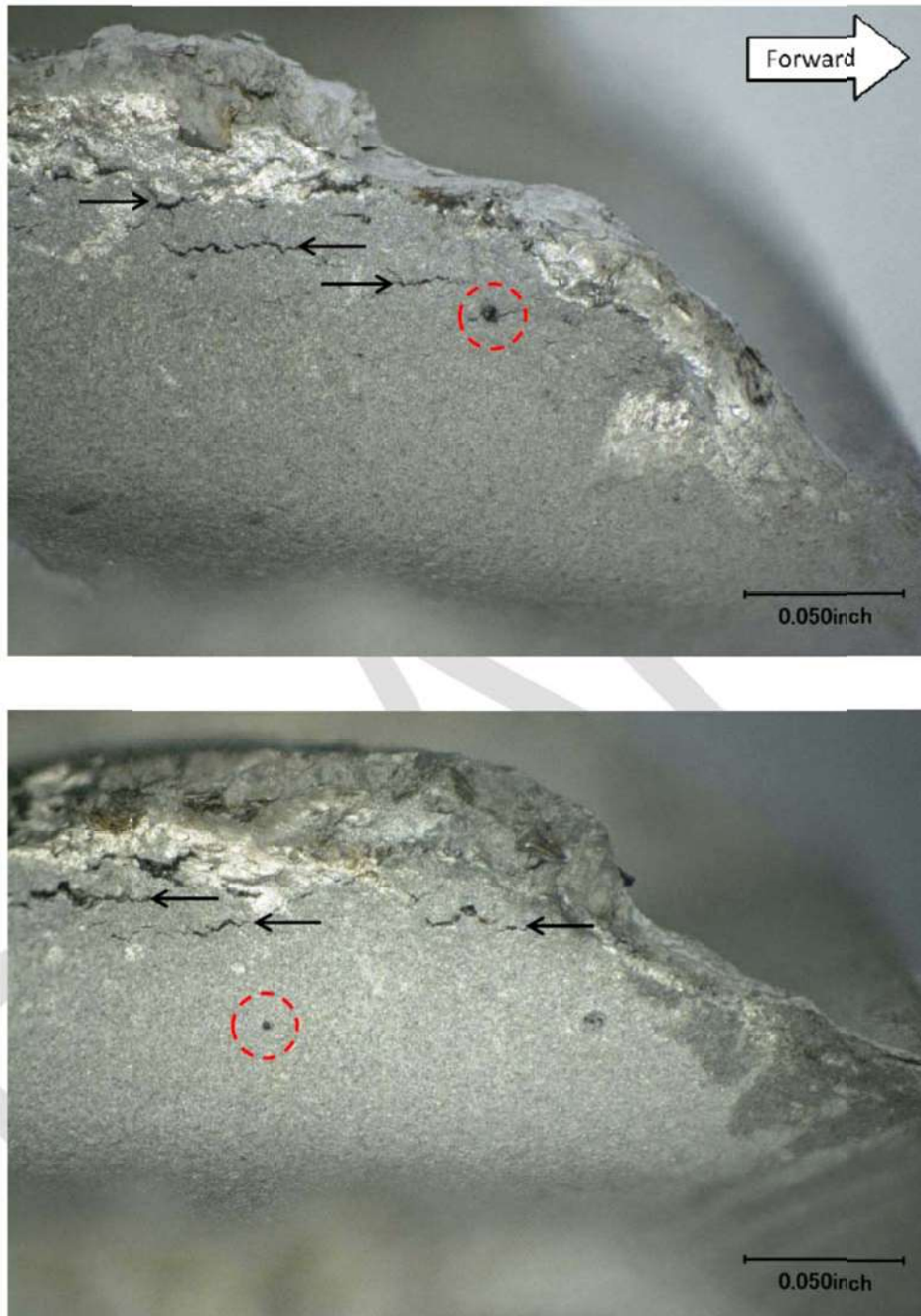


Figure 5: Detailed pressure side views of stage 4 blade #5 (top) and #23 (bottom) (randomly numbered) showing representative corrosion damage (red dashed circles) and pressure side cracking (arrows) found on the stage 4 blades. Not all instances of damage are annotated.

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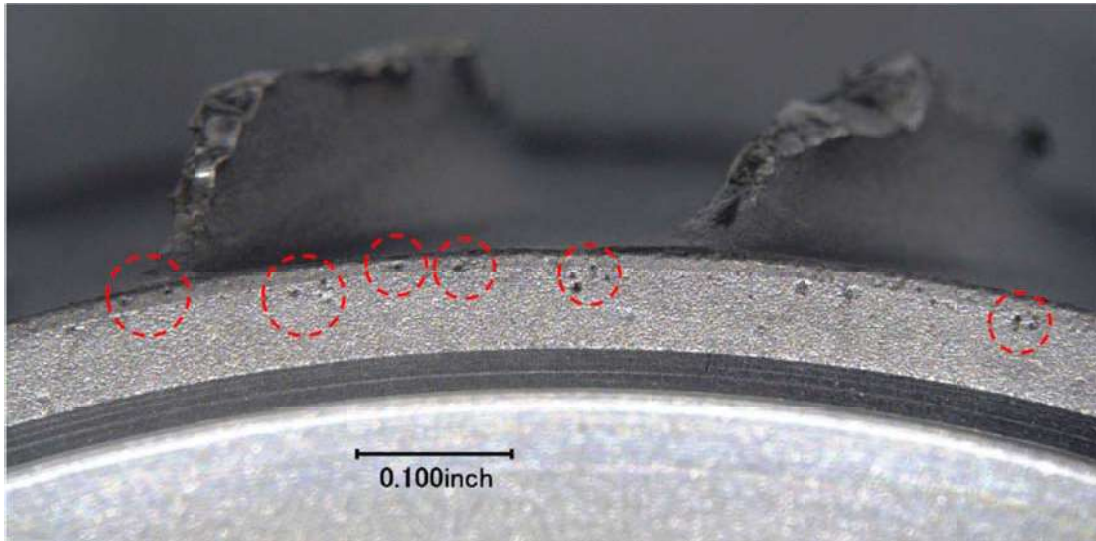


Figure 6: Representative corrosion pitting (red dashed circles) found on the forward rim face of the stage 4 compressor wheel.

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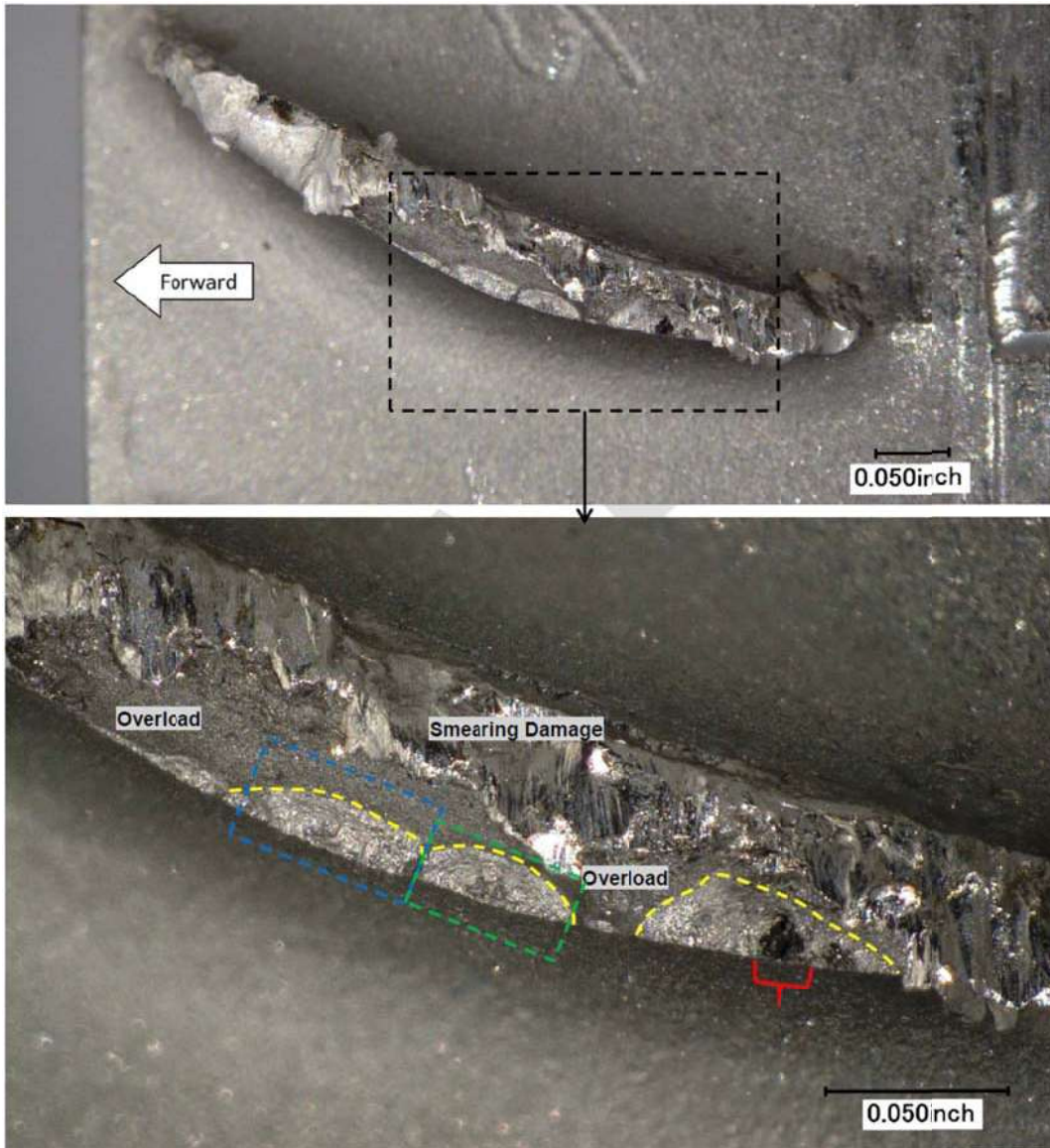


Figure 7: Detailed views showing the fracture surface on a representative stage 4 compressor blade (#5). Multiple fatigue fractures propagated across the airfoil from the suction side surface near the crown. The yellow dashed lines show the ends of the fatigue fractures. There was a corrosion pit (red brace) near the center of one of the fatigue fractures.

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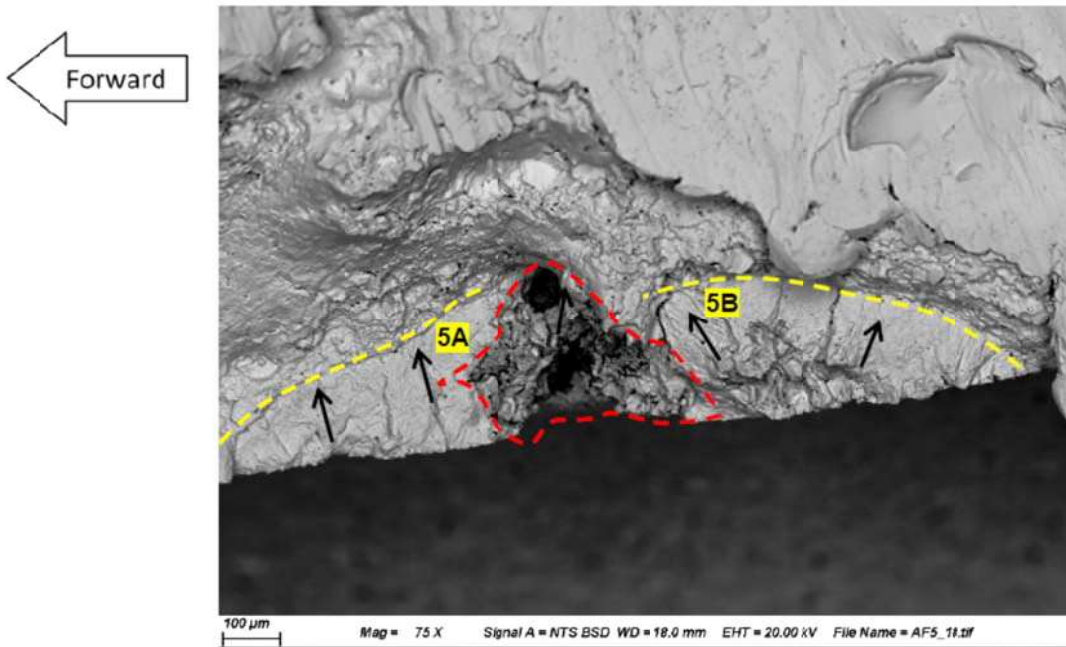


Figure 8: Backscattered electron SEM image of the corrosion pit area shown in Figure 7. The yellow dashed line shows the end of the fatigue fracture. Arrows show the local direction of fatigue progression.

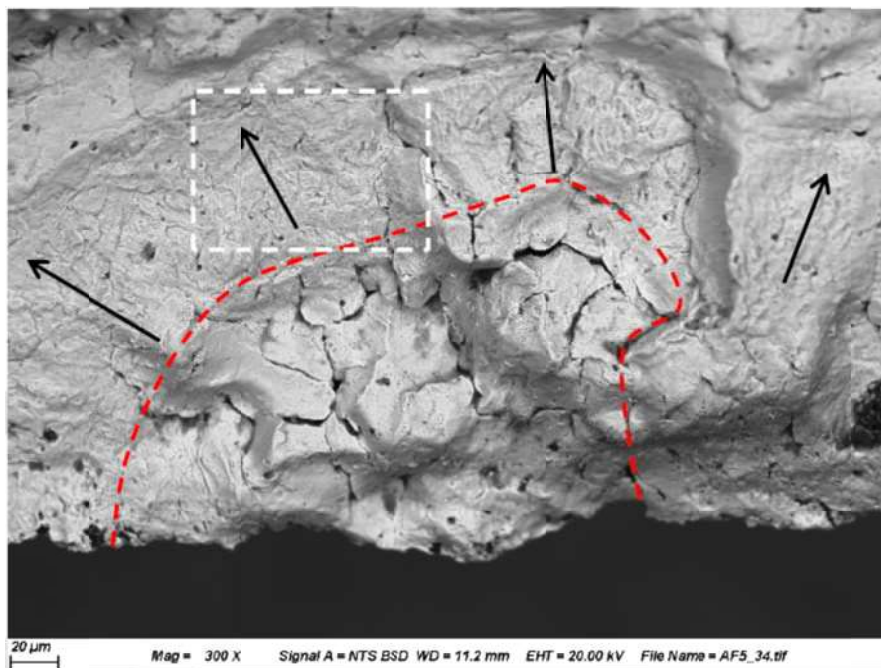


Figure 9: Backscattered electron SEM images showing the forward-most fatigue fracture thumbnail on stage 1 blade #5 (area noted as 5A in Figure 3). The fracture features emanated away (black arrows) from an area of intergranular damage and a relatively smooth intergranular surface morphology (red dashed outlined area) consistent with corrosion damage.

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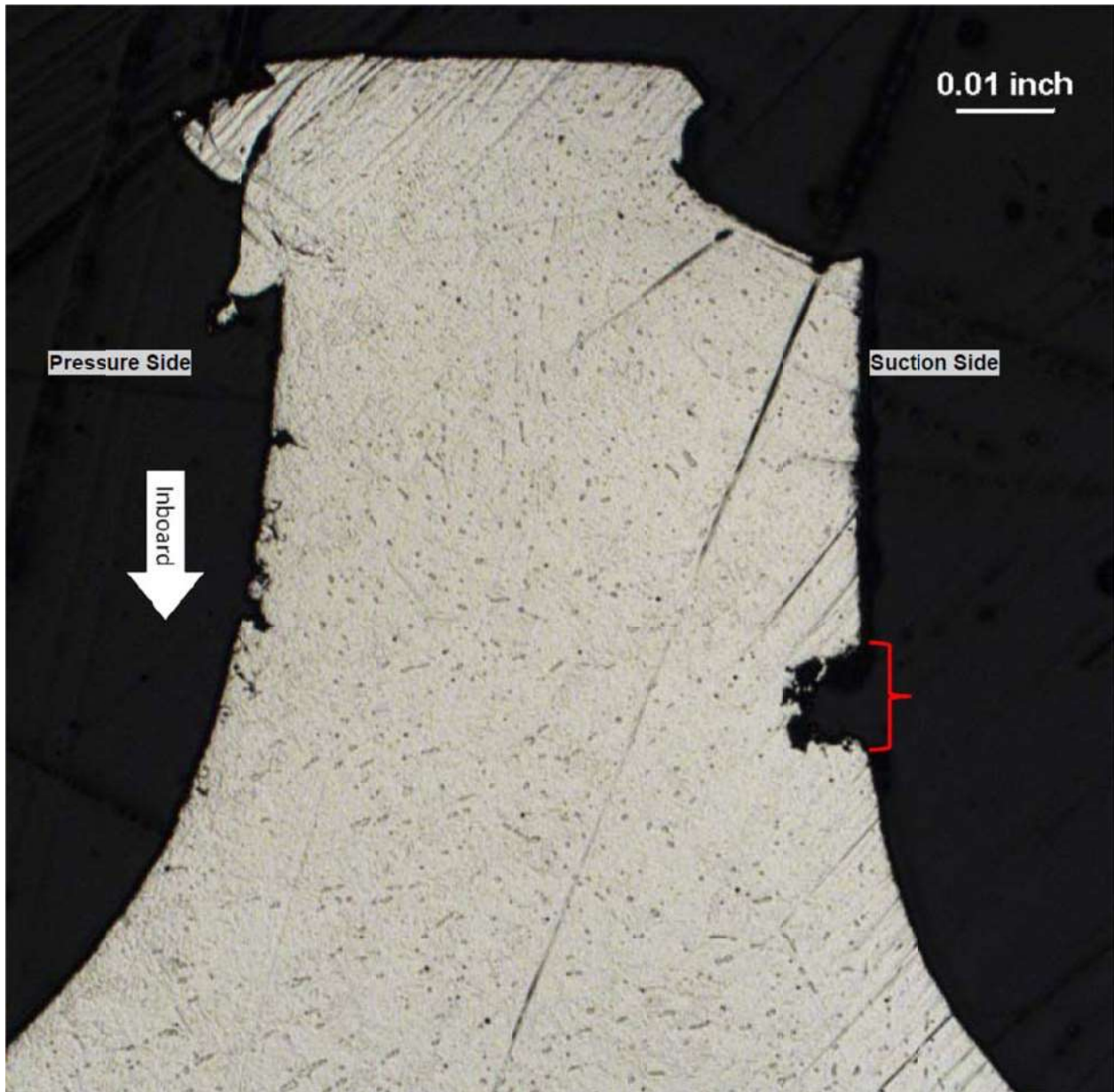


Figure 10: Overall view of the cross-section through the suction side corrosion pit on stage 4 compressor blade #9. The linear features on the surface of the mount were scratches from specimen preparation. There was no coating apparent on the cross-section.

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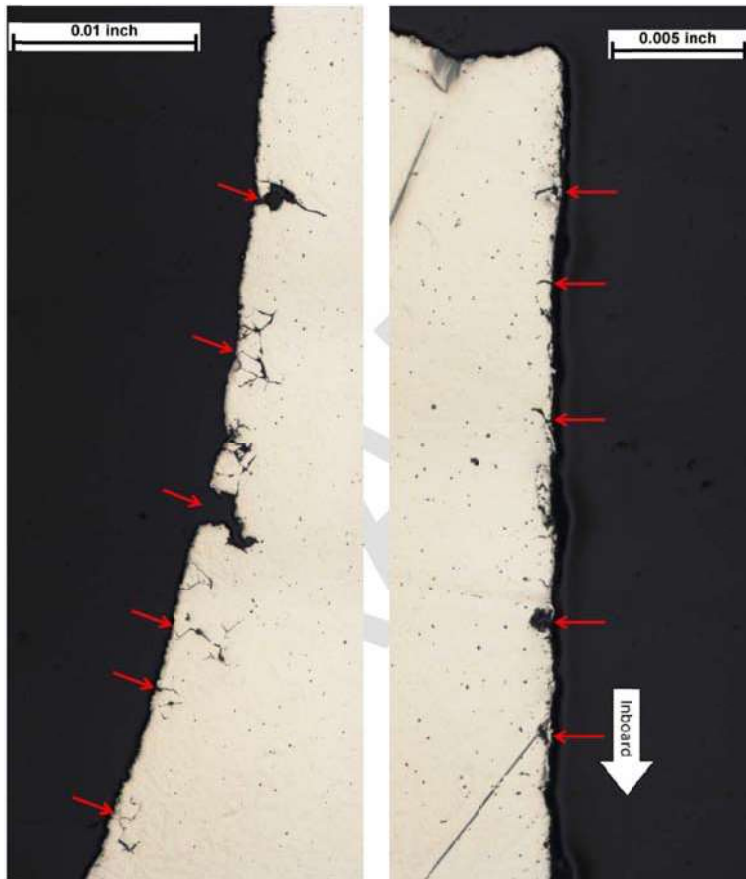


Figure 11: Pressure (left) and suction (right) side detailed views showing corrosion damage and surface damage (red arrows, not all instances are annotated) on Stage 4 blade #9, inboard of the fracture surface.

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The following Figures are from photographs taken by the Rolls-Royce Air Safety Investigator during the wreckage inspection in May of 2020.

FORM 2782 A (BACK)

TRANSFER RECORD

Part II
Page No. 1

SHIPPED				Engine Time		RECEIVED	
Date	From	To	Since OH	Total	Date	By	
2-11-77	DDA - GMC	BELL	New	0.0	2-18-77	Bell Helicopter	
	Cooper		New	1183.8	24 Jul 79	Cooper Airmotive	
22 Aug 79	Airmotive	South Air Aviation	New	1183.8			
12-21-95	HELITRANS	DALLAS AIRMOTIVE	NEW	9048.1	01/03/96	DALLAS AIRMOTIVE, INC.	
02/27/96	DALLAS AIRMOTIVE	HELITRANS, INC.	NEW	9048.1	3-1-96	HELITRANS, INC.	
12-9-05	PRECISION AIR POWER	DYNAMIC AVI		10,538.1	12/11/06	PRECISION AIR POWER	
10/27/06	PRECISION AIR POWER	DYNAMIC AVI		10,538.6	9-10-08	PRECISION AIR POWER	
9-11-08	PRECISION AIR POWER	DYNAMIC AVI	NEW	11406.4			

Figure 12: Photograph taken of the Transfer Record Log book page showing the engine was transferred from Helitrans, Inc. to Dynamic Aviation in December 2005.

ASSEMBLY RECORD

ENGINE ASSEMBLY

Part V
Page No. _____

Engine Serial Number CAE- 823398 Engine Model 250-C 20A

Nomenclature	Part Number	Serial Number	INSTALLED			REMOVED			Reason
			Date	Engine Total Time	TSO This Item	Date	Engine Total Time	TSO This Item	
COMPRESSOR	6890550	37650	9-11-08	11406.4					
COMPRESSOR	6890550	6AC 35038F	25 JAN. 2012	13					

Figure 13: Photograph taken of the Engine Assembly Log book page. NOTE - Neither of these compressor assemblies was installed on the engine at the time of the event.

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The following photograph is the only reference found in the Log book to the compressor assembly serial number found at teardown (see red box). As no compressor log book cards were available, there is no history as to where this module was operated prior to being installed on engine CAE823398.

"COMPONENT RECORD CARD" for ENGINE COMPONENTS

DYNAMIC AVIATION - HELICOPTERS, James Richards, A&P [REDACTED] IA

COMPONENT NAME: COMPRESSOR PART NUMBER: 6890550 SERIAL NUMBER: CAC36300

COMPONENT FINITE LIFE: Impeller, 3,500 HOURS, if applicable. TBO (TIME BETWEEN OVERHAULS): HOURS, if applicable.

ACRONYMS: TT (Total Time) TSO (Time Since Overhaul) TBO (Time Between Overhauls OR Time in Hours REMAINING before Overhaul is due. O/H (Overhaul) A/C (Aircraft) N/A (Not applicable. If a Component does NOT have a Finite Life or O/H Life, enter N/A as applicable.

INSTRUCTIONS: Attach YELLOW TAGS, FAA Form 8130-3 AIRWORTHINESS APPROVAL TAGS, OVERHAUL RECORDS, and other DOCUMENTATION to this "COMPONENT CARD." Attach to the Reverse Side if necessary. Attach Additional Cards as required.

NOTES and RECORDS: This is the LIFE Record for the IMPELLER installed in Compressor listed above. IMPELLER P/N: 23058147

IMPELLER S/N: KR97847 Note: The IMPELLER has a LIFE of 3,500 Hours. THIS IMPELLER has a Total Time of 1,086.4 Hours Time in Service with a Time Remaining of 2,413.6 Hours. Cycle LIFE is 7,500 Cycles. It has 1,053 TOTAL CYCLES. It has 6,447 Total Cycles REMAINING.

This Compressor and its IMPELLER were installed in Helicopter N7173S on 12 June 2012. See Record below.

DATE COMPONENT INSTALLED	AIRCRAFT N° NUMBER and DATE MONTH YEAR	A/C HOBBS Meter Reading and A/C TT at this Component Installation	Component TOTAL TIME of FINITE LIFE and/or TSO in this Removal (in applicable)	HOURS REMAINING of FINITE LIFE and RETIREMENT DUE at A/C TT (in applicable)	REMOVAL DUE to OVERHAUL at HOBBS Hours of and A/C TT (in applicable)	DATE COMPONENT REMOVED DATE MONTH YEAR	A/C HOBBS meter reading and Aircraft TOTAL TIME at this COMPONENT REMOVAL	Component HOURS in SERVICE since the last Installation, at this Removal	Component TOTAL TIME and FINITE LIFE REMAINING at this Removal (as applicable)	Component TIME SINCE OVERHAUL (TSO) at this Component Removal (as applicable)	Component TBO HOURS REMAINING before O/H is DUE at this Removal (as applicable)
12 June 2012	N 7173S S/N 2381	61.7 Hobbs 13,289.7 Hrs. A/C Total Time	1,086.4 Total Time Hrs. Hrs. Since OH	2,413.6 Hrs. Remaining Retirement 16,703.2 A/C Total Time	Hobbs For Overhaul A/C Total Time		Hobbs A/C Total Time	In Service Total Time	Hrs. Total Time REMAINING	Hrs. Component TSO at this Removal (as applicable)	Hrs. Component TBO Hours REMAINING at this Removal
	N S/N	Hobbs Hrs. A/C Total Time	Total Time Hrs. Hrs. Since OH	Hrs. Remaining Retirement A/C Total Time	Hobbs For Overhaul A/C Total Time		Hobbs A/C Total Time	In Service Total Time	Hrs. Total Time REMAINING	Hrs. Component TSO at this Removal (as applicable)	Hrs. Component TBO Hours REMAINING at this Removal

NOTES:

Component Record Card, ENGINE, IMPELLER

Figure 14: Photograph taken of the Impeller Component Record Card.

Table 602 in the Rolls-Royce Operations and Maintenance Manual defines the required inspections on the engine at different intervals. The 300 hour inspection contains the caution note shown below:

INSPECTION FREQUENCY MUST BE BASED ON THE NATURE OF THE EROSION AND/OR CORROSIVE ENVIRONMENT. THE OPERATING ENVIRONMENT CAN DICTATE A MORE FREQUENT INSPECTION INTERVAL. WHEN OPERATING IN A CORROSIVE AND/OR EROSION ENVIRONMENT FOR NON-COATED COMPRESSOR WHEELS, THE INSPECTION MUST NOT EXCEED 300 HOURS OR 6 MONTHS. FOR COATED COMPRESSOR WHEELS, INSPECTION MUST NOT EXCEED 300 HOURS OR 12 MONTHS. FOR COMPRESSOR BLISKS, INSPECTION MUST NOT EXCEED 300 HOURS OR 12 MONTHS. IF ANY WHEEL EXHIBITS CORROSION AND/OR EROSION, THE INSPECTION REQUIREMENT MUST REVERT BACK TO 300 HOURS OR 6 MONTHS.

The engine log cards show that since 2014 the 100 hour inspection was being done annually, but there are no records of the 300 hour/6 month inspection having been completed. It has been approximately 8 years since the compressor assembly was installed which should have resulted in 16 compressor inspections.

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Per Rolls-Royce records, the 4th stage compressor wheel found at teardown, serial number ER59690, was originally sold as an uncoated part number, 6876654, as a spare part on 5/29/1987. The 5th stage compressor wheel found at teardown, serial number KR38340, was originally sold as an uncoated part number, 6876655, as a spare part on 8/11/1987. The part numbers of the 4th and 5th stage wheels were illegible following the event. Based on this information and the metallurgical confirmation, neither wheel was the coated configuration. Therefore, the inspection requirements for a non-coated wheel should have been followed.

Furthermore, RR specifies daily compressor rinses and full compressor washes at 300 hrs per the OMM for engines subjected to salt water or other chemically laden atmosphere (including pesticides, herbicides, industrial pollutants, sulfur laden atmosphere, etc.).

Conclusion

The investigation concluded that the direct cause of this event was the liberation of the 4th stage compressor blades due to corrosion pitting from being operated for some time in a corrosive environment.

Since the 4th stage wheel was sold in 1987, Rolls-Royce has made several changes, including adding a protective coating, to enhance the robustness of the design. Another design change was released in 2007 that is made from a different material with improved corrosion resistance (referred to as a compressor blisk). When inspections are conducted and the engine maintained per the prescribed OMM, the design has proven reliable.

It is understood that these requirements put more responsibility on maintenance personnel to maintain the engine records so that the configurations are more easily understood, thus not having to revert to the more stringent inspection requirements. Rolls-Royce believes this can be done with the recommended engine and module log cards available.

If there are any questions, please contact Helicopters Customer Support by telephone at 317-230-2720 or by email at helicoptercustsupp@rolls-royce.com

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Chief Engineer - US Helicopters Engines
Rolls-Royce Corporation

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