ACCIDENT REPORT ADDENDUM

Aircraft Type and Registration:	Hawker Sea Fury T Mk 20, G-RNHF
No and Type of Engines:	1 Bristol Centaurus XVIII piston engine
Year of Manufacture:	1949 (Serial no: ES3615)
Date and Time:	31 July 2014 at 1601 hrs
Location:	RNAS Culdrose, Cornwall

Synopsis

The aircraft was performing in a public air display at Culdrose when the pilot became aware of a significant engine vibration and then a corresponding loss of thrust. Despite the loss of engine power the pilot was able to land the aircraft on the runway but the landing gear collapsed on touchdown, causing it to veer off the runway. The aircraft came to a stop on the grass approximately 1,500 ft from the initial touchdown point. The pilot vacated the aircraft unaided and without injury. The accident was a result of the loss of engine power caused by severe mechanical disruption within the 'front row' crankcase of the engine.

Introduction

The accident report, EW/G2014/07/32, was published in AAIB Bulletin 7/2015 and at the time evidence suggested the breakup was as a result of an overheated articulated connecting rod (con-rod) wrist pin bearing. After this report was published, forensic work continued to try to establish the exact cause of the engine failure and the AAIB undertook to publish the relevant findings when available.

Despite the extensive destruction of most of the components within the front section of the engine, forensic analysis has been able to determine that severe overheating had occurred in the crankpin sleeve bearing in the front bank of cylinders. This led to a chain of events within the engine which became increasingly destructive to the wrist pin bearings, connecting rods, pistons and sleeve valve gear. This destruction was exacerbated by the rear bank of cylinders continuing to run until the accumulated damage within the front bank of the engine stopped the engine producing useable power, although it continued rotating as the aircraft landed until its landing gear collapsed. The extreme damage to the components of the front bank of cylinders left insufficient evidence to determine conclusively the initial cause of the engine failure.

System description

The Bristol Centaurus engine is an eighteen-cylinder double-row sleeve valve supercharged radial, with a 53 litre capacity, capable of producing 2,500 horsepower. Figure 1 and Figure 2 show the arrangement of the master con-rod, articulated rods, crankpin and floating retainer assembly.

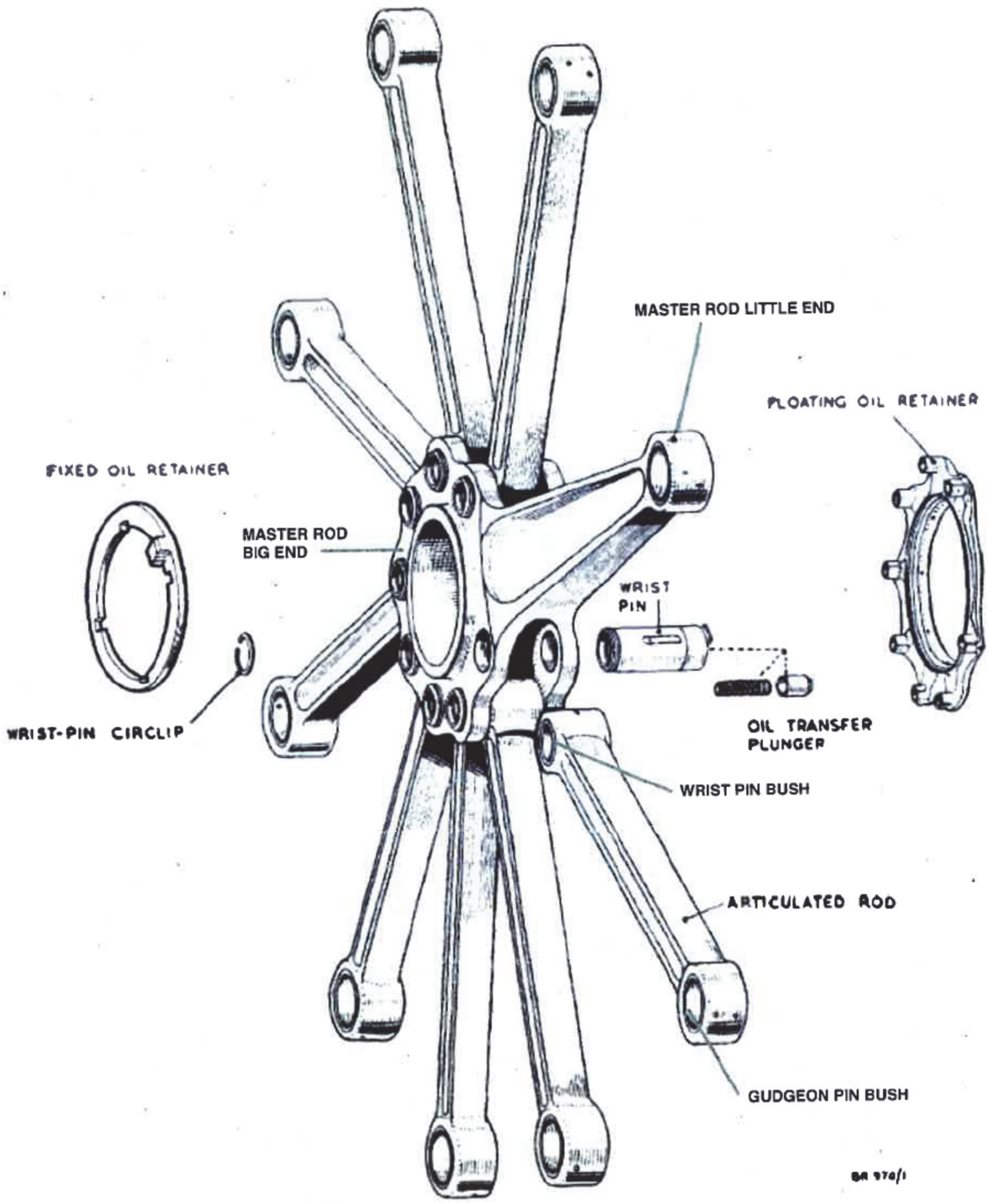

Figure 1

Master and articulated connecting rods with the floating oil retainer

Lubrication system

In this engine, oil pressure is generated by the main oil pump at a nominal 100 psi and distributed into four separate sub-sections around the engine. A main oil feed passes through a tube inside the supercharger into the rear end of the crankshaft. It then travels forward along the crankshaft, finally exiting through feedlines to lubricate the reduction gearbox. Along the way, oil is forced through various ports and jets to lubricate bearings, pistons and cylinders. High-pressure oil also feeds the 'centrifugers', which remove any sludge and aeration before it is used to operate the supercharger control valve and drive system. Another high-pressure feed is supplied to the governor before entering the propeller constant-speed unit. Oil pressure is then reduced by a reduction valve to lubricate the sleeve valve drive system and a small supply of low-pressure oil lubricates the magnetos.

Return oil from the spray jets and oil that has passed through the bearing, collects at the bottom of the engine where it is scavenged by front and rear pumps. Oil is trapped in some locations and used as splash lubrication for start-up.

The oil system in G-RNHF contained a sufficient quantity of lubricating oil and samples taken at the time showed that the oil had suffered some adulteration during the engine failure, but this is not considered causal or contributory to the engine failure.

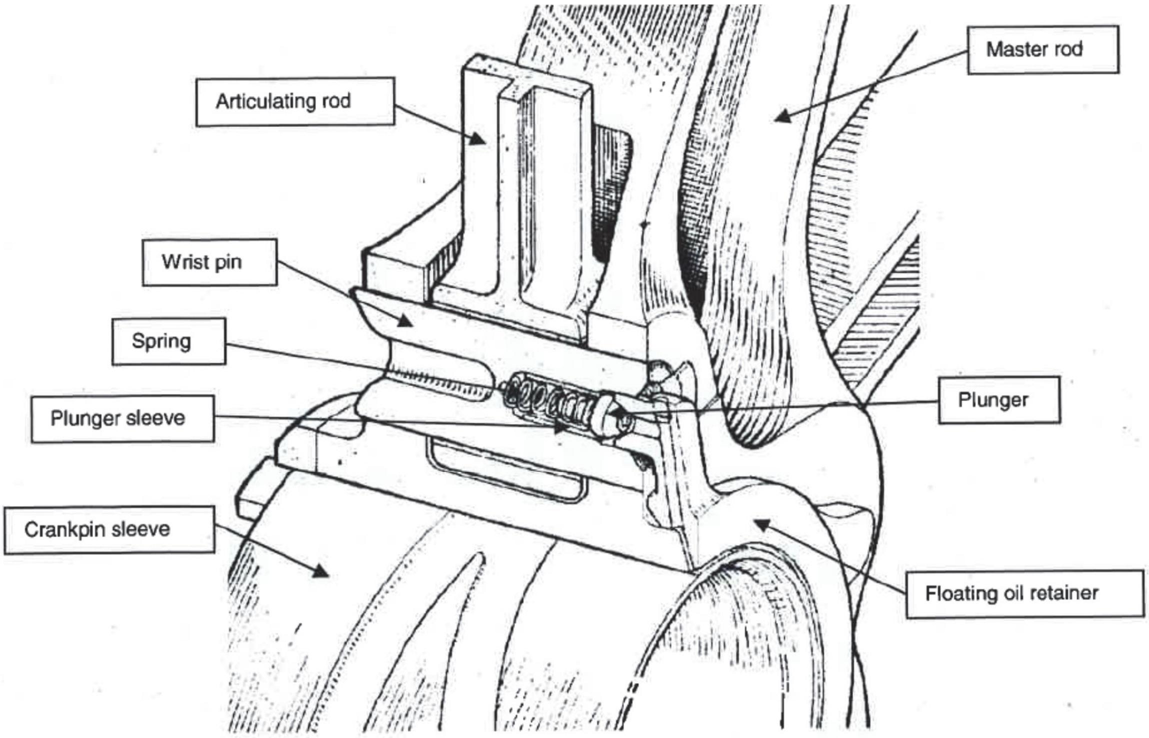

Figure 2

Crankpin sleeve and wrist pin assembly

Crankpin assembly

The crankpin carries all of the loads into the crankshaft from the master and articulated connecting rods via a white metal crankpin sleeve bearing. This bearing is pressure lubricated via ports within the crankshaft. From there oil is collected by an oil retainer, known as the floating oil retainer, which distributes oil to the centre of the wrist pins to lubricate the phosphor bronze wrist pin bearing surfaces. Oil pressure is maintained within the wrist pin by a spring loaded plunger which seals the gap between the wrist pin and floating oil retainer.

Sequence of events

Forensic analysis was carried out in the materials laboratories of 1710 Naval Air Squadron (1710 NAS) within the Royal Navy. The following sequence of events have been identified and are summarised from their report:

> *‘a. For reasons unclear the forward crankpin sleeve bearing overheated, cracked up and liberated flakes of white metal.*
>
> *b. Breakup of the bearing resulted in greater overheating, melting the white metal bearing surface.*
>
> *c. Liquid tin from the bearing penetrated along the grain boundaries of the forward master rod, causing embrittlement at the grain boundaries.*
>
> *d. The embrittled grain boundaries cracked and some fragments of the master rod around the bore become separated. This process continued as the liquid tin penetrated more deeply.*
>
> *e. Loose fragments of master rod material from around the bore gouged the bore surface and the sleeve, overcoming the interference fit and causing it to spin with the master rod, finally cutting off any possible oil flow to the connecting rod assembly.*
>
> *f. Continued embrittlement, high temperature and high stress caused the master rod to burst locally at its thinnest and highest temperature points, behind the wrist pins #16 and #18.*
>
> *g. Erupted material interfered with articulating rods #16 and #18 and frictionally heated them, causing them to overheat, soften and fail.*
>
> *h. The unrestrained piston and articulating rod #16 came out of their cylinder into the engine core and were impacted by the counterweight.*
>
> *i. Continued impacts fractured and propelled the piston, gudgeon pin and articulating rod around the engine core, impacting and damaging other components.*
>
> *j. At some point the gudgeon pin became momentarily trapped and was impacted, shattering it.*
>
> *k. Debris fragments became trapped in the sleeve driving mechanism, jamming them and causing them to fail.*
>
> *l. Throughout the above, the heat generated around the forward crank pin propagated back into the rear bank crankpin, overheating the crank pin sleeve bearing causing it to start breaking up.’*

This sequence was arrested when the landing gear collapsed and the propeller struck the ground and stopped as the aircraft slid along the grass alongside the runway.

Possible contributory factors

Although the exact feature which caused the crankpin sleeve bearing to overheat is unknown, there are a number of areas of interest which may have been contributory factors. These factors have been extracted from the 1710 NAS laboratory report and are set out below:

> *'a. Pieces of a fibrous cellulose material were found within the engine from an unknown source. One was causing a partial blockage of the rear crankweb oil jet, which could not have caused the failure, but in combination with the piece found loose in the crankcase indicates that there was debris in the system. The source could not be confirmed. The material may have come from a degraded fibre gasket somewhere in the system, or possibly from an original gasket that was replaced during earlier maintenance. Alternatively it could have come from a source outside the engine and entered at some point during its life. It is possible that some of this debris may have entered the forward crankpin bearing and disrupted the lubricating oil film, leading to overheating. Cellulose debris may have passed through that bearing and blocked the oil supply to a wrist pin, heating the pin and transmitting heat into the master rod, overheating the crankpin bearing. Whichever specific mechanism, overheating of the crankpin bearing resulting from contamination of the system with fibrous cellulose debris is considered a possibility.*
>
> *b. The crankshaft oil retainer gland was found to be severely embrittled. This may have been due to heat transmitted along the crankshaft or may have been due to its extreme[1] age. If it was embrittled prior to the accident it may have stopped working as an effective seal and caused a pressure loss inside the crankshaft. This pressure loss may have disrupted the oil film in the crankpin bearing and allowed it to overheat. The pressure distribution around the engine is not understood in enough detail to determine if a leak of this type would have been detectable to the pilot. This scenario is considered to be a possibility.*
>
> *c. It is possible that hard debris, from an external source or a part of the engine or oil system not found, was able to enter the forward crankpin bearing and either cause abrasive wear and overheat it or block local oilways, allowing a wrist pin to overheat. If this was the case then the debris was displaced during the failure sequence and not subsequently recovered. This scenario cannot be conclusively ruled out.*
>
> *d. It is possible that an out of balance loading on the forward connecting rod assembly transmitted an excessive loading to the forward crankpin bearing, causing it to overheat. No evidence was observed to indicate that the assembly was intrinsically out of balance.'*

Footnote

[1] It is possible that this seal was originally fitted to the engine when it was built prior to delivery to Iraq in the late 1940s. There is no evidence to suggest this seal was replaced when the engine was brought back into service in 2010.

Discussion

The Centaurus engine is fitted with roller main bearings and conventional close tolerance white metal bearings on the crankpins. White metal, in this case known as Babbitt metal, is an alloy of copper, tin, lead and antinomy alloyed to give a low-friction but hard-wearing surface. The low friction and heat conduction properties of the material is further enhanced by the oil lubrication system whereby a hydrodynamic oil film forms under pressure on the bearing surface. Although the bearing will operate without too much difficulty during momentary reduced lubrication, sustained loss or constant reduced lubrication will result in bearing damage. The damage will initially manifest itself in scuffing and scoring in the bearing surface and is often referred to as 'running' a bearing. Heat is generated in this process and in most circumstances will degrade any oil present, reducing lubrication further. Eventually the heat generated will be so great that bearing damage occurs, as observed in this engine.

Unlike in-line engines, where the big end bearing only carries a single piston load with an impulse once per revolution, a radial engine crankpin bearing carries multiple impulse loads per revolution from the articulated con-rods via wrist pins into the master con-rod. Should a crankpin bearing become distressed, the multiple impulse effect can accelerate the situation and therefore degrade more rapidly than with an in-line engine. If the crankpin bearing is overheated and starts to fail, the wrist pins by their design and location, will also be susceptible to any excess heat from the nearby crankpin bearing.

The evidence, in this case, shows an overheated crankpin bearing and this may be as a result of a seriously degraded or complete loss of lubrication. The condition of the other major engine components, such as the rear bank and supercharger, suggests a localised problem. It is possible that unidentified debris interrupted oil to the bearing. Of interest was the embrittlement of the crankshaft oil retainer gland. Loss of the sealing capabilities of this gland could result in a sustained weakening of the hydrodynamic oil film which may lead to the 'running' of the bearing over a very short period.

In either case the temperature generated would eventually cause any remaining oil present to boil or burn off the vital surfaces in an ever-worsening cycle.

Conclusion

The evidence suggests a localised lubrication problem led to a severe overheating of the crankpin bearing. An extensive forensic examination of the engine has been carried out and it has not been possible to identify the exact initiator that led to this situation. However, it has been possible to identify the precise sequence of metallurgical effects on key components as the bearing overheated and failed, which resulted in the highly destructive chain of events within the front crankcase.

Safety action

Various marks of the Centaurus engine are still in use in a small number of aircraft but findings in this case could equally apply to other radial and in-line aero-engine types. Based on this, the CAA has undertaken to publish a

Safety Notice aimed at the historic aircraft community, to draw attention to the issues and difficulties of maintaining airworthiness of aging aircraft engines and their associated components.