Replacing Obsolete Equipment For Drivetrain Health Monitoring On RAN Sea King Helicopters

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Abstract

Following an in-flight failure of an input drive-shaft assembly on an RAN Sea King in April 2003, a method of providing early warning of this failure mode was sought. Vibration analysis of the input coupling has been shown to be a reliable method for providing warning of incipient failure, mitigating the need for periodic visual inspections of the coupling. A DSTO developed system based on a Fieldworks ruggedised laptop computer is currently used to perform this vibration analysis function. The DSTO system, now more than 15 years old, is obsolete. Spare parts are unobtainable rendering it unsupportable. The MSPU 1209 has been identified as a replacement. This is the story behind the introduction of new equipment for drivetrain health monitoring on Sea King helicopters.

Keywords: Sea King, vibration monitoring, helicopter, drivetrain

Introduction

In April of 2003, while conducting low level reconnaissance over Iraq, an RAN Sea King suffered an uncommanded shutdown of the port engine [1]. A spline in the input coupling that connects the input pinion to the driveshaft had failed. The engine was protected by a mechanism that automatically shuts it down in the event of an overspeed condition.

DSTO investigations identified a number of independent factors contributing to the failures including a modification to the input assembly that replaced plain bearings with roller bearings making alignment of the assembly more critical, and the blockage of oil jets which likely resulted in the excessive wear of roller bearing tracks. A vibration based method of identifying couplings in-service that were wearing abnormally was developed and a program of periodic monitoring using the DSTO developed measurement and analysis system was implemented. The monitoring program enabled inspections of the input assemblies to be carried out on-condition, instead of with fixed periodicity.

The DSTO system was developed in the mid 1990s as a concept demonstrator. It is now reaching a point where components that have become difficult, if not impossible to source replacements for are beginning to fail. Without a viable, commercially supported replacement, the program of periodic monitoring would no longer be able to be relied upon to identify couplings for inspection on-condition. All input couplings would therefore be required to undergo the intrusive and time consuming process of a visual inspection every 100 flight hours.

Input Spline Condition Monitoring

Prior to the April 2003 failure there had been two incidents of spline failure in UK Sea Kings. A Westland Helicopters service bulletin was issued following these failures requiring build changes to the input assembly and periodic inspections. The RAN issused a special technical instruction (STI) incorporating these requirements. The failure of the spline in the RAN Sea King was of particular concern as it had already passed the STI.

To perform the periodic visual inspection of a spline, the engine must first be removed to gain access to the input assembly. To alleviate the maintenance burden of periodic engine removals, and more reliably identify couplings that were wearing abnormally, a non invasive method of detection was sought.

The RAN Sea Kings had already been fitted with permenantly mounted, hardwired, high frequency accelerometers for drivetrain condition monitoring. One of these sensors was mounted on the input housing, allowing for high quality measurements of the input coupling vibration. Analysis of data recorded in a fleetwide survey of input coupling vibration revealed a feature of the vibration that could be used to identify input couplings that had abnormal wear. A process of time domain synchronous averaging was used to isolate the vibration signature of the input shaft. A Fourier transform of the synchronous average then gives a frequency domain representation of the signal. Two of the couplings in this survey showed a significant vibration at the 7^{th} order. Subsequent inspections of those two couplings showed that they had worn outside of allowable limits.

The amplitude of the 7^{th} order vibration of the input shaft, as measured by the accelerometer mounted on the input housing, was found to be a suitable index for gauging the health of the input shaft assembly. A limit was set based on the fleetwide survey, and the NASPO Condition Monitoring Cell implemented a procedure to perform periodic vibration monitoring of all input shaft assemblies. Benefits of this approach have been increased aircraft availability and the avoidance of around 3000 hours of unplanned maintenance over the remaining life of the fleet [2].

DSTO Vibration Analysis System

The DSTO vibration analysis system was developed in the 1990s and was first trialled on a Black Hawk helicopter in October 1995 [3]. The system was intended to be a concept demonstrator for carry-on equipment that could be fitted in only a few minutes, requiring only three connections to the aircraft; power, tachometer and accelerometer signals. It was intended to be used to supplement warnings from magnetic chip detectors on the Black Hawk transmission. The system has the capability to record time domain data for tachometer channels and vibration channels simultaneously and can perform various analysis tasks using the collected data. Analysis of the raw data is typically done post-flight as it is a time consuming task.

The ability of the DSTO system to perform time domain synchronous averaging, and interface with the hardwired sensors on Sea King made it suitable for vibration monitoring of the input coupling. Built around a Fieldworks ruggedised laptop

computer, the system was portable enough to be deployed with the Sea King. A single large Pelican case housed everything required.



Fig. 1: DSTO vibration analysis system

A total of four systems were deployed in support of Sea King, enabling a minimum capability to be maintained when units were being repaired or calibrated. As the units aged, and failures became more common, the ability to maintain this capability was eroded. With no commercial support for the product, spares for the signal conditioning and data acquisition cards became more difficult to source. It was necessary to cannibalise components from non-essential channels to maintain those required for the input spline check.

Prior to their replacement in 2010 two of the systems suffered failures to components that could not be replaced from spares, or cannibalised from other systems. One of the failures was in the computer motherboard, fortunately another Fieldworks computer was able to be sourced from within DSTO. The second of the two failures was in the analog to digital converter card, for which replacements have proven impossible to source due to their age. This reduced the number of serviceable units available to the RAN to three. At this level it could not be certain that a system would always be available.

Replacing Obsolete Equipment

The Honeywell (IAC) MSPU 1209 was identified as a system capable of performing the required data acquisition and signal processing functions. DSTO was tasked with setting up the units to replicate the input spline monitoring functions being performed by the DSTO vibration analysis system.

The 1209 has signal inputs for 36 accelerometers, and can sample up to 6 simultaneously, along with up to 2 of 8 tachometer inputs. It also has inputs for 2 blade trackers and a number of general purpose analog inputs. Input spline monitoring

on Sea King can be acomplished using 1 tachometer channel and 2 accelerometer channels so there is scope for the role of the system to be expanded or when the Sea King is paid off, retasked to another platform.



Fig. 2: The MSPU 1209

The system acquired by the RAN has three distinct components. The 1209 is designed as an on-board system to be permenantly fitted to an aircraft and is used to measure and process vibration and other signals in flight. The 1209 interfaces with ground based software (GBS) which is located on Panasonic CF-19 Toughbook computers, one of which is kept with each unit. The third component of the system is another ground based computer system that will be used to collate the data from all of the onboard systems for archiving and managing the configuration of the software setup.

The 1209 units are programmed to perform various acquisition and analysis tasks by uploading a setup configuration file, that is in turn produced by configuring a database with the desired functions. The database is configured via software that runs on the ground based computer system. When the 1209 is connected to the Toughbook computer (via an ethernet connection) it checks to see if there is a more recent setup file to upload.

As the 1209 is designed to be a permenantly fitted onboard system a number of changes have been necessary to convert it to a carry on-carry off system. The first and most obvious is the carry case. Each DSTO system was stored in a large Pelican case complete with its connecting cables. Similarly, the 1209s were mounted in (smaller) Pelican cases. Where the DSTO system had a cable connector box mounted to the side of the computer chassis, the new system has cable connections built directly into the side of the case.



Fig. 3: MSPU 1209 mounted in a Pelican case.

The cable connections to the Pelican case were kept identical to those for the DSTO system. This ensured that the new equipment could be used from the same location in the aircraft, and made use of the existing cable design. An input signal adapter was constructed to adapt the 1209 unit to the connections on the outside of the case. The 1209 has a single connector that carries power and all of the signal inputs. In a change from the DSTO system, the adapter assembly uses an isolation transformer instead of a voltage divider to step down the 115VAC tachometer to a signal in the range ±5V.

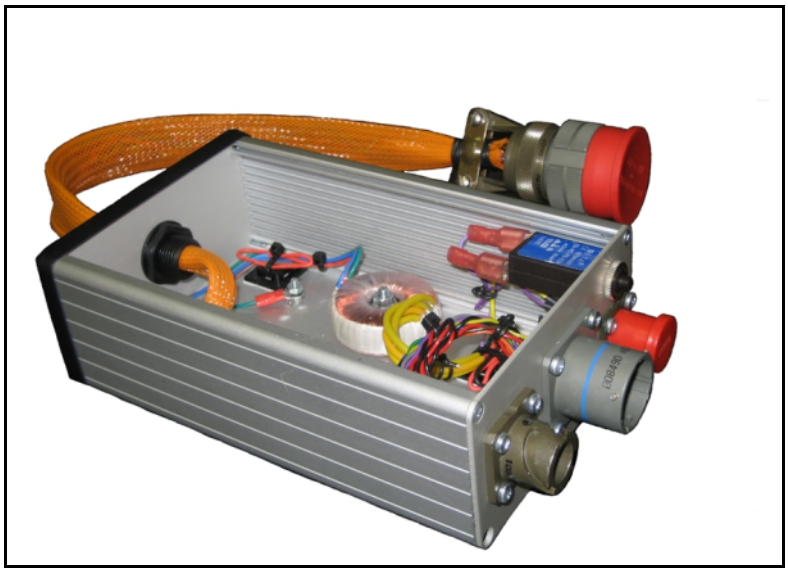


Fig. 4: Input signal adapter.

In a permanent installation, the various functions of the 1209 are accessed by flight crew via a cockpit header box, while the 1209 unit itself may be mounted elsewhere in the airframe. In the carry-on mode, as used on Sea King, the 1209 will be controlled directly by the Toughbook computer that will be connected via ethernet. The Toughbook computer and all of the required cabling to connect to the aircraft are stored in the case with the 1209, making the job of installing and de-installing the system easier for maintenamce personnel.

With the carry on-carry off configuration, another issue arises with the software setup. An installed unit is set up with the data acquisition and analysis parameters, including the aircraft ID (tail number) and this would rarely need to be changed. As the carry-on equipment may be used on a different aircraft each time, the setup file must be updated every time it is used. The acquisition and analysis parameters will be the same, but if the tail number does not match the data will be archived incorrectly. This issue has been handled procedurally, with a requirement to update the tail number in the setup written into the users guide that was developed for the equipment.

One advantage of the 1209 over the DSTO system is it's much faster processing speed. The DSTO system would typically be used to acquire data from the aircraft that would then be processed off-line. The 1209 is able to perform a synchronous average quickly enough to be able to give an immediate go/no go indication on the input spline check condition index. The ability to process data on board also speeds the process of downloading information to the ground based system, only the much smaller set of contition indices need be downloaded. Raw data may still be kept if required, but this greatly increases download times.

Conclusion

While the DSTO vibration monitoring system was never intended to be used in an ongoing operational role, it has performed well for many years. Age and obsolescence has reduced the system's ability to function reliably. As the Sea King nears its planned withdrawal date it remains essential for the input spline monitoring program to continue, periodic engine removals to enable a visual inspection would still otherwise be necessary.

Consideration has been given to the design of the new system, to enable it to fulfill the role with no modification to the aircraft or connections, and minimal training burden. The equipment procured for the task and the expertise in its operation has the potential to be transferred to other platforms and different monitoring tasks when the Sea King is decommissioned.

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