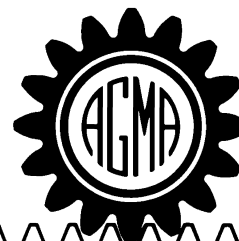


CH47D Engine Transmission Input Pinion Seeded Fault Test

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Company and T.E. Neupert, U.S. Army

American Gear Manufacturers Association



TECHNICAL PAPER

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[The statements and opinions contained herein are those of the author and should not be construed as an official action or opinion of the American Gear Manufacturers Association.]

Abstract

This paper summarizes an Engine Transmission Input Pinion Seeded Fault Test that was accomplished as a portion of the validation process for the Boeing Rotorcraft Transmission Vibration Diagnostic System (TVDS) Analyzer. The test specimen was a high speed CH47D (Chinook) engine transmission input pinion with a known defect (i.e., seeded fault) machined into a high stress area of a gear tooth root. The specimen was operated at "overload" conditions in order to initiate and propagate a fatigue crack from the seeded fault. During the testing, the TVDS analyzer monitored the test pinion real time and successfully provided a sufficient warning time of the impending failure. (Note: No metallic chips were generated during the test). Following testing, the TVDS data (acquired real time) was evaluated along with a post-test fractographic evaluation of the fatigue crack. During the post-test fractographic evaluation, arrest lines and fatigue striations were analyzed to develop crack propagation data as a function of the number of applied load cycles. This data was then correlated with the collected TVDS data to better understand the potential warning signals the TVDS system could provide about the impending failure of a helicopter's primary drive system components. In this test, the TVDS analyzer provided a minimum of eleven minutes warning time (at higher than normal operation loads) of the impending failure, which would allow the pilot enough time to unload the suspect engine transmission and continue to fly on the remaining engine.

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INTRODUCTION

Boeing Rotorcraft of Philadelphia (BRP) has been involved in the development of an airborne failure detection system designed to monitor major load carrying helicopter transmission gears and shafts. In 1991, BRP created a specification to develop and build a Transmission Vibration Diagnostic System (TVDS) Analyzer based on Stewart Hughes Limited Mechanical System Diagnostic Analyzer (MSDA). That same year, Stewart Hughes Limited was contracted by BRP to build and qualify a TVDS analyzer under BRP Independent Research & Development (IR&D) funding.

In order to obtain an understanding of the analysis techniques and warning times associated with different types of fatigue failures, a bench test program, performed on the CH47D drive system using various sizes of seeded faults, was developed by BRP and the U.S. Army (ATCOM). The understanding of these analysis techniques through bench testing, followed by a flight test program, would determine the correct implementation path of a real time, flight worthy airborne system into the fleet. In 1992, BRP was awarded U.S. Army contract DAAJ09-G-90-A014 to perform seeded fault bench testing. It was determined that prior to initiation of the contract, BRP would conduct the first test under IR&D funding. Following completion of the initial test, the remaining eight tests would be performed per the U.S. Army contract.

TVDS ANALYZER

The TVDS analyzer was developed as an enhanced derivative of the Stewart Hughes S-61 system utilized during the UK Civil Aviation Authority Health and Usage Monitoring System Trial. It offered a Stewart Hughes Signal Averaging (SGAV) analysis suite up to FM4A/B and key SOA / IDENT/ COMP analysis techniques of the Stewart Hughes MSDA Base Band Power Spectrum (BBPS) Package. It was designed to process transmission vibration signals from every major shaft and gear on the CH-47D drive system at least every 150,000 fatigue cycles. The analyzer was designed and built with default alarm levels for each analysis technique. At the discretion of the analyzer operator, the alarm levels could be re-established at the mean of the average value of the first N samples plus 5 standard deviations or to a specific level. It was designed with a luminescent display / keypad that is used to operate and monitor the analyzer during configuration downloading and data transfer. The analyzer also has a unique set of four warning lights that would notify the operator when any single analysis technique on an individual component exceeded its threshold. Each light represented an analysis technique; therefore, if four or more techniques were exceeded at one time, all four of the warning light indicators would be illuminated. The analyzer utilized an IBM compatible PC, operating under the XENIX and MS DOS operating systems, as a ground station. The ground station was used to configure the analyzer for testing, long term storage

of the data transferred from the analyzer, a platform to review analyzed data utilizing a set of graphic displays and a medium to transfer test data. Figure 1 is a picture of the BRP's TVDS Analyzer and its support PC ground station.



Figure 1 - TVDS Analyzer and its support PC ground station

CH-47D ENGINE TRANSMISSION DESCRIPTION

The CH-47D aircraft contains two engine transmissions mounted on the front of the left hand and right hand engines, see Figure 2. The engine transmission consists of a single spiral bevel mesh with an overall gear reduction of 1.23:1. The transmission transfers the power received from the engine through a quill shaft and redirects the power 90° to the combiner transmission via shafting. Each engine transmission has a continuous twin engine design power rating of 3,750 hp and a single engine design power rating of 4,600 hp with both ratings at an input speed of 15,066 rpm and an output speed of 12,263 rpm. The transmission also incorporates a one-way clutch, which allows the drive system to overrun the engines during autorotation or a sudden reduction in engine rpm. Each of the two engine transmissions are the same except for the location of some external lubrication system components. Either transmission can be converted to one for the opposite side by exchanging the location of these components. Figure 2 also shows a sectioned view of the engine transmission.

DESCRIPTION OF TEST SPECIMEN

The test specimen was a CH-47D engine transmission spiral bevel input pinion. The specimen was visually and magnetic particle inspected prior to inducing the stress riser (seeded fault). Following these inspections, Electric Discharge Machining (EDM) was used to produce a notch in the drive side root fillet of one tooth, as illustrated in Figure 3. The actual notch size, which was developed from BRP's

stress data on the pinion, was 0.100 inch long by 0.010 inch deep by 0.006 inch wide.

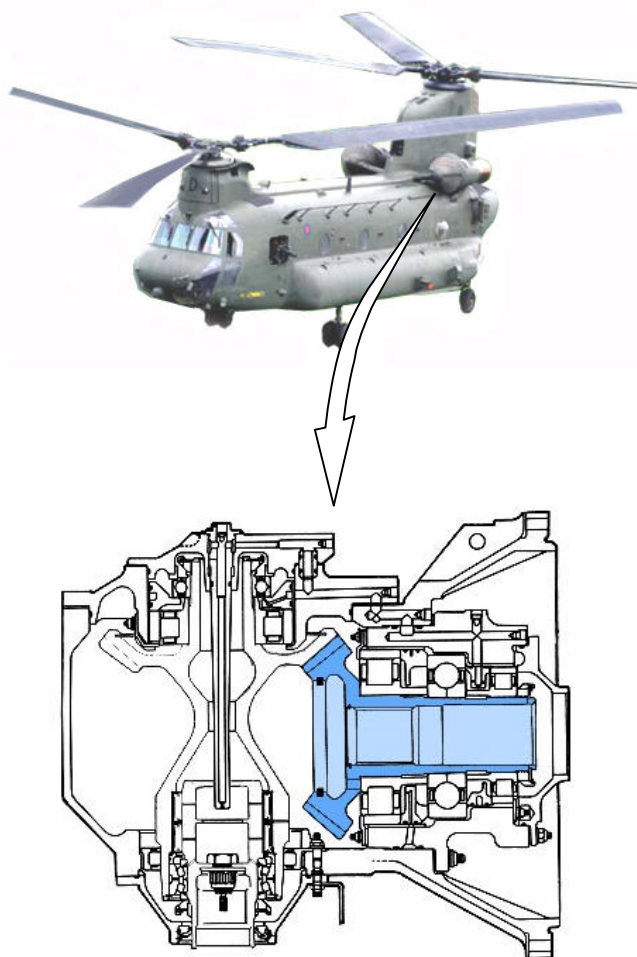


Figure 2 – Schematic of Test Pinion (Blue) installed in an Engine Transmission

TEST STAND DESCRIPTION

The CH-47D Engine / Combiner Transmission Test Stand, located at BRP's transmission facility, was used to conduct this testing. The bench test stand is a closed loop torque system, which has the exact gear ratio as the CH-47D engine / combiner transmission set. The test stand has the capability to change torque and speed while the transmission is operating. Shown in Figure 4 is the test Right Hand (R/H) Engine Transmission, Left Hand (L/H) Engine Transmission and Combiner Transmission installed into the Engine / Combiner Transmission Test Stand.