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The HUMS2025 Data Challenge Dataset

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Summary

The Defence Science and Technology Group (DSTG) has prepared a new Data Challenge for the upcoming 14th DSTG International Conference on Health and Usage Monitoring Systems (HUMS2025) conference. This Data Challenge is about the detection and trending of a rare critical failure mode of a fatigue crack in a gearbox casing. The vibration dataset used in this challenge was obtained from a helicopter main rotor gearbox test program based around an artificially induced gear tooth spalling fault. The test was halted temporarily in May 2024 due to the rapid propagation of a non-induced fatigue crack. The Data Challenge prize will be awarded to the team that makes the earliest convincing detection of the gearbox casing crack and accurately tracks the crack progression. Details about the test program and the dataset for the HUMS2025 Data Challenge are presented in this paper.

The Test

In the field of Health and Usage Monitoring Systems/Prognostic Health Management (HUMS/PHM), gear tooth face spalling is a common failure mode in helicopter and general industrial gearboxes. However, there are not many readily available wear debris datasets related to gear tooth spalling faults or tooth degradation by surface contact fatigue. To address this issue, DSTG established a test program to generate a set of Inductive Wear Debris Sensor (MetalSCAN) data, along with accelerometer vibration measurements, from artificially induced gear tooth surface faults (electric discharge machined or EDM notches) under controlled conditions. However, this test was overtaken by the propagation of the gearbox casing fatigue crack, and the test was halted at a very early stage of the gear tooth surface fault progression; i.e. before many wear particles had been detected.

The test was conducted in the Helicopter Transmission Test Facility (HTTF) at DSTG Melbourne, using a retired/non-flightworthy Bell Kiowa 206B-1 (OH-58) main rotor gearbox (the four-planet version). During the test, while the gear tooth fault was being closely monitored, and was still in the early stages of development, an unrelated and non-induced gearbox casing crack was unexpectedly detected in May 2024. HUMS2025 has taken advantage of this opportunity to host a new Data Challenge using a curated vibration dataset derived from this test program. The Data Challenge is for participants to develop effective methods for detecting and tracking the propagation of the casing crack.

The Bell Kiowa 206B-1 (OH-58) main rotor gearbox has two speed reduction stages: a spiral pinion/bevel gear stage, and a planetary stage. The test was run with a nominal input speed of 6000 RPM, giving an output speed of 344 RPM. The gear details and mesh frequencies (rounded to integer numbers) are given in Table 1.

Table 1 Number of gear teeth and mesh frequencies for 6000 RPM input speed

Component	Number of Gear Teeth	Mesh Freq. (Hz)
Input pinion	19	1900
Input bevel gear	71	1900
Sun gear	27	568
Planet gear	35	568
Ring gear	99	568

An exploded-view diagram of the gearbox with sensor locations is shown in Figure 1. A cross-sectional view of the gearbox is shown in Figure 2. In fact, these figures show the three-planet version of the gearbox, but the configuration is essentially the same for the four-planet gearbox apart from detail differences in the planet carrier, planet gears and bearings. Note that the spacing of the planet gears in the four-planet version is not quite equal due to kinematic constraints. The four planet gears are diametrically opposite with 88.6 and 91.4 degrees of angular spacing between the two opposing pairs [1, 2].

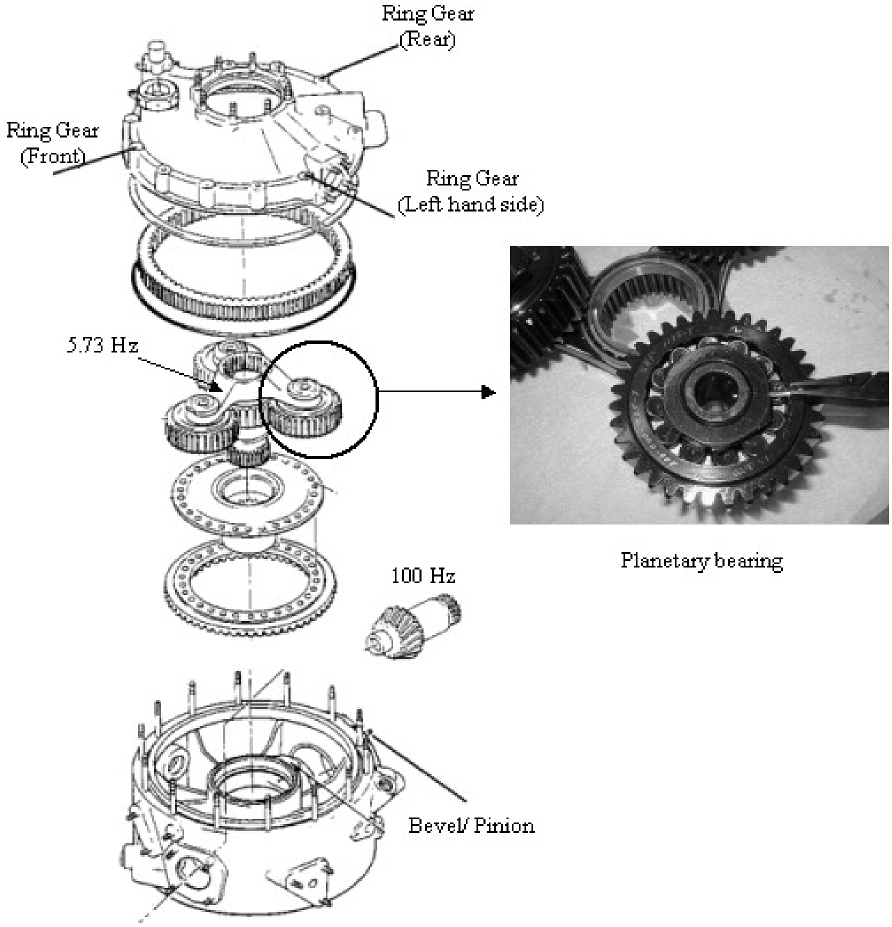

Figure 1 Bell 206B-1 (OH-58) main rotor gearbox (three-planet version). The four-planet version was used in the test. Four sensor locations are indicated in the figure.

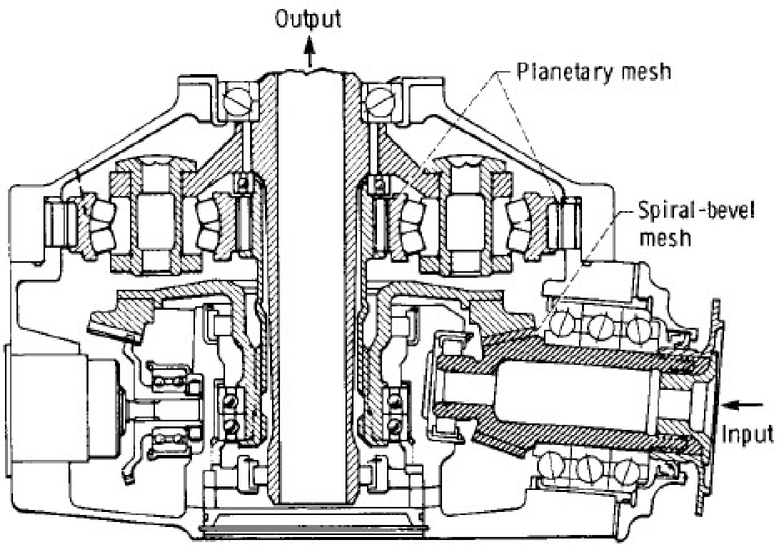

Figure 2 Bell 206B-1 (OH-58) main rotor gearbox (three-planet version) [1].

The test started in October 2023 with three seeded EDM faults on three adjacent tooth faces (sub-pitch line) on the input pinion gear of a retired Bell Kiowa 206B-1 (OH-58) helicopter main rotor gearbox. Note that this was a different gearbox (but of the same type) to the one that we used in the planet gear test to generate the HUMS2023 Data Challenge dataset. The pinion gear was selected as it has the fastest rotational speed and would likely propagate rolling contact fatigue faster than other gears in the gearbox. In order to accelerate the fault progression, severe overloads (125% and 150% of the rated continuous torque) were used for most of the test. The load cycle sequence and timing is described in the key information section at the end of this document. By the end of May 2024, after 89 load cycles at 100%, 125% and 150% rated torque, early stage gear tooth spall damage had begun with a small count of wear debris particles measured by a MetalSCAN sensor. Unexpectedly, however, an upper casing crack was observed as shown in Figure 3. The test was then halted temporarily to replace the cracked upper casing.

The upper casing fatigue crack appears to have initiated in the spline that locates/fixes the ring gear in the upper gearbox casing. The crack then propagated through to one of the studs that secure the upper casing to a gearbox support strut. A secondary crack then grew from the top edge of the spline into the upper casing above the ring gear spline and this ultimately resulted in an overload-induced fracture that caused a section of the casing to break away. Note that the ring gear itself was still intact so that the planetary gear set was still holding together. It is important to point out that this casing crack has no bearing on the quality of the gearbox because the test gearbox was (*a*) retired from service and no longer fit to fly; and (*b*) subjected to severe overload (125% and 150% of the rated continuous torque) for most part of the test in order to accelerate the spall progression.

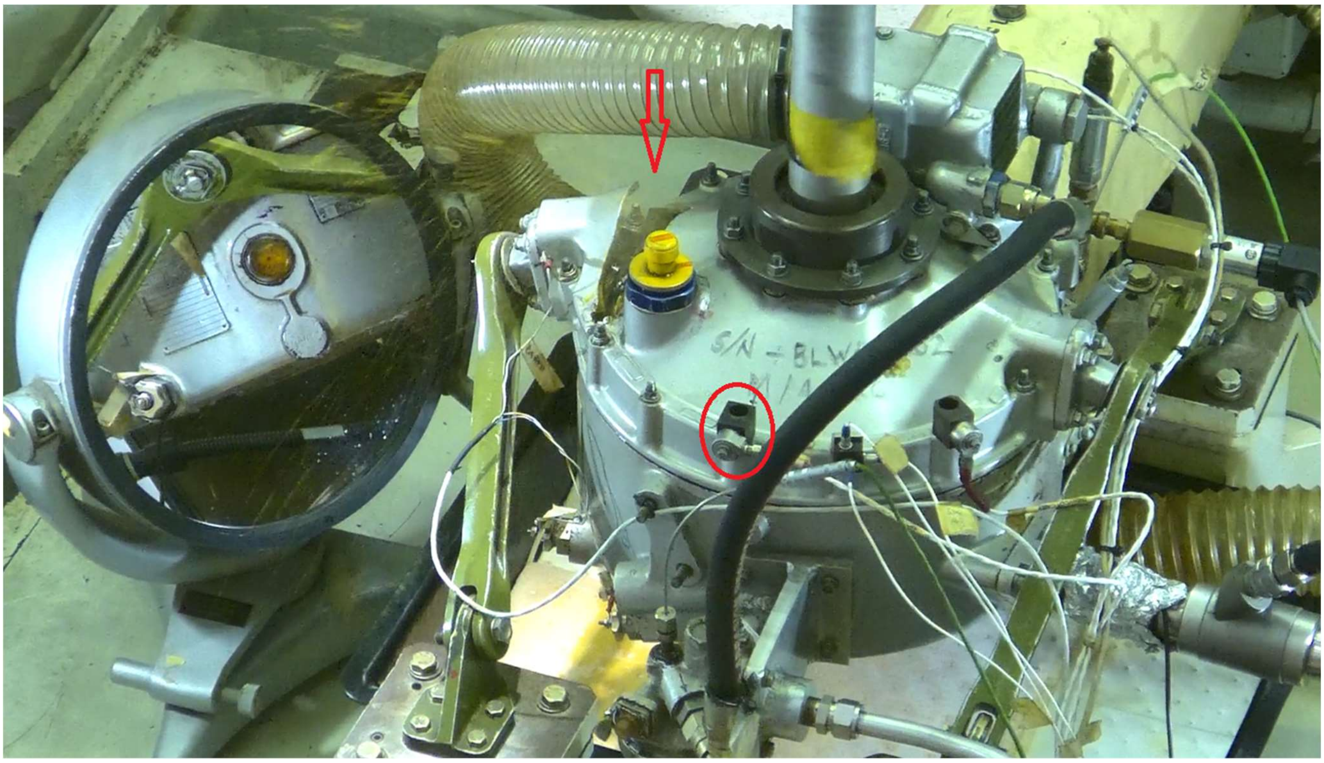

Figure 3 The test article with the location of the casing crack indicated by the red arrow. For reference, the Ring-Front (RF-2) vibration sensor is circled in red. The mirror on the left hand side of the picture was used to have visibility of that side of the gearbox from the control room.

The accelerometer locations are listed in Table 2 (also refer to Figure 1). The sensitive axes of the ring gear accelerometers were radially aligned to the planetary stage, and the input gear accelerometer was radially aligned to the input shaft. A 1/rev tachometer reference signal from the input shaft was acquired for the synchronous signal averaging (SSA) process.

Table 2 Accelerometer locations (also refer to Figure 1)

Sensor	Description
IP-1	Input pinion flange
RF-2	Front of the gearbox (upper housing flange near ring gear)
RL-3	Left side of the gearbox (upper housing flange near ring gear)
RR-4	Rear of the gearbox (upper housing flange near ring gear)

The Dataset

Helicopter gearbox casing cracks are seldom reported in the literature. Being able to detect and track this rare and critical failure mode has very significant implication for helicopter reliability and safety. Therefore, the aim of the HUMS2025 Data Challenge is for the participants to develop the best method to detect and trend the progression of the casing crack using the dataset that relates to a very realistic but rare/critical failure mode. With each individual raw data file (87 MB) acquired at intervals of approximately 4 minutes, the test thus far has generated some 156 GB of raw vibration data. The HUMS2025 dataset was extracted from the raw dataset in a similar manner to the HUMS2023 dataset.

To keep the dataset size modest, we curated a dataset that incorporates 86 load cycles of data starting from Day #3 of the test (note that a rig control circuit board failed in Day #2). The dataset contains the selected raw data files at 100% and 125% rated torque, which are also accompanied by the hunting-tooth synchronous signal averages (H-SSA) of the pinion/bevel gears for the four vibration channels from Day #3 to Day #22 of the test. In the selected raw vibration data files, a tachometer channel is also provided along with the four vibration channels for SSA analysis. The reason for choosing 100% and 125% loads is that the 150% load is considered too extreme compared to real-world helicopter operations, and we prefer to see the capability of detecting the casing crack at more realistic load levels. In the dataset, there are 1830 four-channel pinion/bevel hunting tooth synchronous signal average (H-SSA) data files (2.55 GB) at all three torque levels; 204 selected raw data files at 100% rated torque (5.38 GB) and 210 selected raw data files at 125% rated torque (5.66 GB). The total size for the dataset is 13.6 GB.

Each H-SSA file contains four column-vectors of 48,564 resampled[1] data points for each vector (or channel), which is a hunting tooth period of 71 revolutions of the pinion gear at 684 points per revolution, or 19 revolutions of the bevel gear at 2,556 points per revolution (i.e. 684×71 = 2,556×19 = 48,564). The H-SSA is designed such that both the pinion gear synchronous signal average (P-SSA) and the bevel gear synchronous signal average (B-SSA) can be further derived from it. For example, if we re-arrange the vector of 48,564 samples into a matrix of 684×71, then a column-wise average will give us the P-SSA of 684 samples, and the B-SSA can be obtained in a similar manner.

No images of the fracture surfaces are released with the dataset. However, some photographs of the fracture surfaces and a video that captured the moment of fracture of

[1] Synchronously resampled with respect to the input shaft once-per-rev signal.

the upper casing will be presented by the host in the last presentation at HUMS2025 Data Challenge result presentation session.

The Data Challenge

The Data Challenge is open to all participants of HUMS2025, and the dataset will only be accessible to HUMS2025 Data Challenge participants. Competing teams can come from one single institution or across multiple institutions. Interested people/teams should show their intention of participating in the Data Challenge at the HUMS2025 website and agree to the terms and conditions for the data release. The HUMS2025 Committee will then send out a personalised link for participants to download the dataset.

Analysis results should be submitted by the final due date for HUMS2025 conference papers, which is expected to be in mid-December 2024. The HUMS2025 Committee will announce the winner as the team who provides the earliest convincing detection and demonstrates the best trending of the progression of the casing crack. The winning teams will be awarded with a cash prize of AUD$1000. All results by competing teams will need to be presented in the Data Challenge designated sessions of the HUMS2025 conference. The winner will be announced at the end of the last session of the HUMS2025 conference or at HUMS2025 dinner event (pending on the final program). Please email DSTG.HUMSConference@defence.gov.au if you have any questions about the test or the dataset. The responses to the questions will be posted to the Question and Answer section of the HUMS2025 Data Challenge Website, to ensure that they are visible to all participants.

Any analysis methodology may be used. It can be physics-based, signal processing based, purely data-based, or use hybrid or any other techniques. At least one team member is required to attend the HUMS2025 conference and to present their results. All participating teams are encouraged to submit a paper about their analysis of the dataset.

Key Information

- One team, one entry to the Data Challenge
- At least one team member must participate in the conference and present results
- No restriction on analysis methodology
- One winning team – earliest convincing detection with most accurate trending capability
- A cash prize of AU$1000 to the winning team
- A certificate to the winner and runner-up

- To download the data, you need to register your interest through the HUMS2025 website. On agreeing to the terms and conditions of the dataset release, you will receive an email from HUMS2025 Committee with the download link
- If there are questions about the test and dataset, please email the questions to dstg.humsconference@defence.gov.au

- The HUMS2025 Data Challenge dataset contains vibration data from the last 86 load cycles where each cycle has the loading sequence 100%-125%-150%-125% with 20 minutes at each load level
- The 1830 pinion/bevel hunting-tooth synchronous signal averages (H-SSA) are provided at the three load levels, i.e. 100%, 125% and 150% rated load (4 vibration channels)

- The 204 selected raw vibration data files are at 100% rate load
- The 210 selected raw vibration data files are at 125% rate load
- Each raw data file has 4 vibration channels, 1 tachometer channel and 30 sec of data sampled at 65573.77049180328 Hz acquired using a NI-PXI-DAQ system (with delta-sigma ADC)
- The naming convention for raw data files is Day0##_Date_Time_Load, e.g. Day022_20240530_132644_125%TT, where TT stands for Turbine (input) Torque and the timestamp refers to the time when the raw data file was saved
- The naming convention for H-SSA data files is Day0##_Hunting_SSA_Pinion_Date_Time_Load, e.g. Day022_Hunting_SSA_Pinion_20240530_133819_151%TT
- A load cycle reference file (Load cycle reference.xlsx) is also appended to the dataset

- Other factors, such as lubrication oil temperature, could be different for each data file due to environmental conditions
- The input pinion speed is 100Hz nominally, the output shaft speed is approximately 5.73Hz
- Gearbox reduction ratio is 17.44
- 4 planet gears in the planetary gearbox
- The tooth numbers are: [Z_{pi}, Z_b, Z_s, Z_{pl}, Z_r] = [19, 71, 27, 35, 99] respectively

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