A machine learning approach to load tracking and usage monitoring for legacy fleets

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Objectives

With increasing demands on aircraft to fly expanded roles and missions, aircraft often operate differently than their manufacturers intended upon design. Monitoring aircraft usage is therefore an important task to track how the aircraft are flown, in order to ensure safety of the aircraft and passengers, as well as to strive towards effective usage of components. Many modern aircraft are now equipped with some type of health and usage monitoring system (HUMS) for usage monitoring activities; however, many older and even some modern aircraft fleets have minimal or no HUMS nor any other data capture systems installed. Despite the absence of HUMS, these aircraft still require usage monitoring activities to verify that the operational usage of the aircraft is consistent with the designed usage.

The National Research Council Canada (NRC) has developed an approach to load estimation [1], which is targeted at legacy aircraft fleets and is not specific to a particular aircraft manufacturer to acknowledge the diversity and vintage of the Canadian Forces' aircraft fleets. The methodology adapts to the input data available so is not constrained to one particular system or platform, and enables the estimation of loads through the duration of a manoeuvre instead of assuming a constant load for an entire manoeuvre. The latter is the standard practice in safe life methodology used for most helicopters. Sikorsky's Virtual Monitoring of Loads (VML) provides a real-time estimation of loads in a helicopter dynamic or airframe component based on data recorded by HUMS [2-3]. While real-time usage monitoring is a priority for some operators and original equipment manufacturers (OEM), many operators do not have that requirement and may additionally have limited data capture or onboard recording capability.

In this paper, results are presented for a larger amount of flight data than previously reported. Further analysis of the outputs of the load estimation process is considered to address how this approach can be leveraged for improved aircraft fleet usage, including individual aircraft tracking. For many operators, access to component material information that supported initial design analysis is very limited, so the outputs provided do not assume that this type of information is readily available but demonstrate that valuable insights can still be obtained using this analysis.

Results

NRC has been carrying out ongoing research to provide a load monitoring solution that uses existing flight data from existing aircraft instrumentation (e.g. flight data recorder) to predict aircraft component loads based on actual usage through machine learning techniques. This approach estimates component load, from which fatigue damage and load exceedance curves are determined based on actual usage. This methodology is illustrated in Figure 1 with the fatigue analysis outputs shown in Figure 2. Indirect methods of estimating component loads and fatigue life analysis based on existing aircraft sensor data have been in development at NRC using flight data from an Australian Black Hawk (S-70-A-9) helicopter and CH-146 (Bell 412) Griffon helicopter. The load and fatigue life results obtained thus far have shown tremendous potential for accurate and consistent estimates using the same methodology on both platforms [1]. The potential benefits of more accurate load and usage monitoring include reduced maintenance and ownership costs, increased safety, better aircraft availability, improved fleet management, and life extension, while accounting for new mission types being assumed by legacy aircraft.

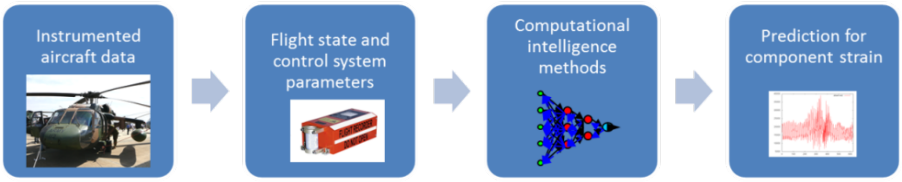

Figure 1: Component load signal prediction from flight state and control system parameters

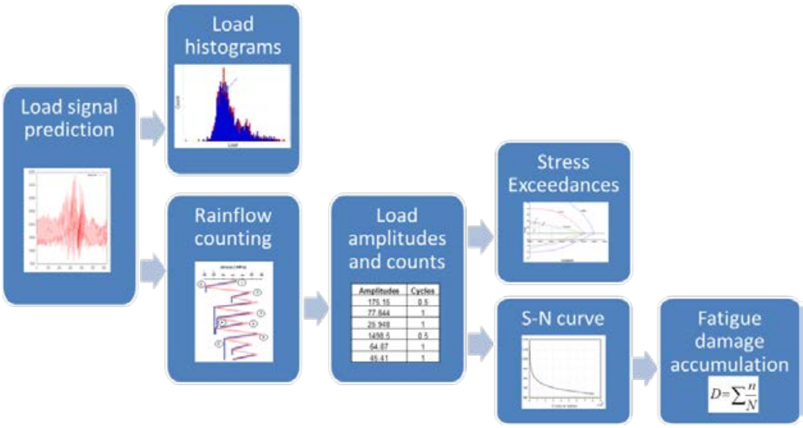

Figure 2: Fatigue life analysis

Sample results from the Black Hawk main rotor push rod, main rotor blade normal bending, main rotor lateral stationary servo and Griffon main rotor yoke are presented in this paper. The total amount of flight data processed for the Black Hawk and Griffon was 7 hours and 31 hours, respectively. Figure 3 shows an example of the time history prediction using NRC's baseline prediction method (BPM) for the Black Hawk main rotor pushrod for 4 hours of unseen testing data.

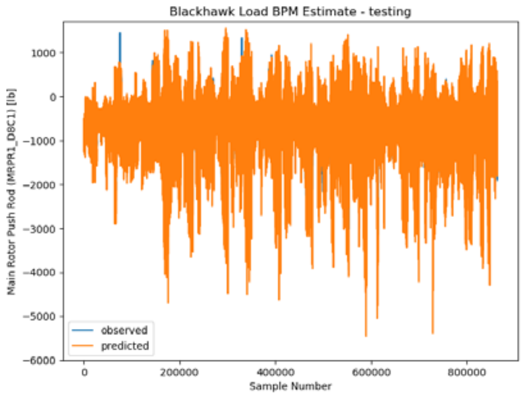

Figure 3: Black Hawk Main Rotor Pushrod Load Estimate

Innovative steps and significance of work

NRC's approach to load and usage monitoring is centered on leveraging the data recorded by existing instrumentation using data-driven models and data mining techniques. This flexible approach has been demonstrated on several helicopter platforms manufactured by different OEMs. For many operators, access to component material information that supported initial design analysis is very limited, so the provided outputs do not assume that this type of information is readily available, but demonstrate that valuable insights can still be obtained using this analysis.

Many ICAF member nations operate smaller legacy aircraft fleets similar to those of the Canadian Forces. Accurate load and usage monitoring is a universal goal that is not easily achieved on older aircraft without the sophisticated and powerful Health and Usage Monitoring Systems that are available today. This research targets these smaller legacy fleets to help satisfy their usage monitoring requirements and ensuring structural integrity.

References

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