The Suitability of Vibration Data Loggers for the Development of a Condition-Based Maintenance System for for Rotorcraft and Aircraft Operations

Original Research by Sam Savitt

Introduction – rotorcraft maintenance

Time-Based Maintenance (conventional)

Replacing parts based on time

Can lead to error within the maintenance process

Changing parts too early = unnecessary expenses

Changing parts too late = safety risk

vs.

Condition-Based Maintenance (CBM)

Health Usage and Monitoring Systems (HUMS) monitor part condition in real-time

Active monitoring used to alert operators when a part must be replaced

Allows for most cost-efficient and safe approach to rotorcraft maintenance

Bearings are a great subject for CBM development

Introduction – vibration data loggers

Data Acquisition Units (DAQs) not required

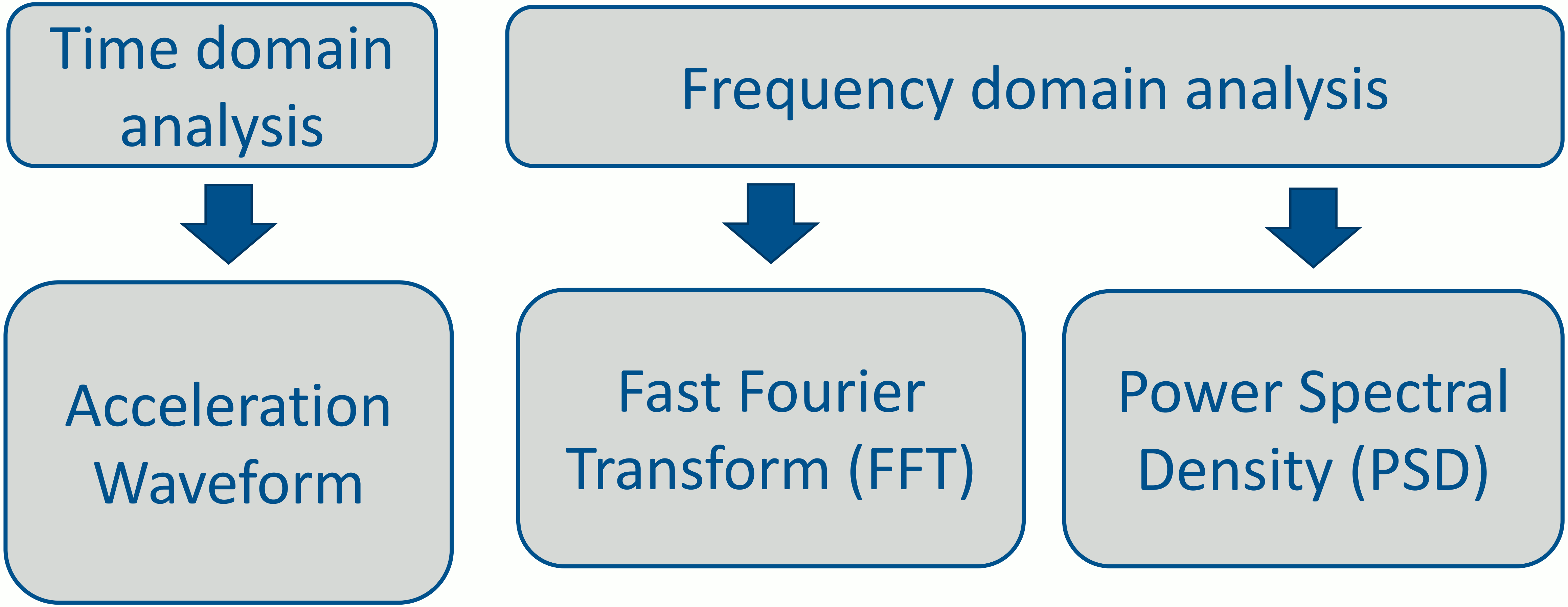
High versatility for maintenance

More cost-effective and less weight

Can be placed on the outside of the system and still monitor the condition of parts inside

Show promising potential as the primary sensing device for a rotorcraft CBM system

Introduction – vibration analysis



Review of Literature

HUMS and CBM has proven themselves to effectively improve aircraft safety and airworthiness while lowering maintenance costs and accident rates

R. Hess, A. Duke, D. Kogut (2001). The IMD HUMS as a tool for rotorcraft health management and diagnostics. Aerospace Conference, 2001, *IEEE Proceedings*, 6, IEEE, 3039-3058

Wireless vibration data loggers can save money, space, and maintenance time due to the lack of a DAQ and have demonstrated such potential in industries such as the automotive, industrial, and shock testing.

Fuentes, M., Vivar, M., Burgos, J., Aguilera, J., & Vacas, J. (2018). Design of an accurate, low-cost autonomous data logger for PV system monitoring using Arduino™ that complies with IEC standards. *Solar Energy Materials and Solar Cells*, *130*, 529–543. doi: 10.1016/j.solmat.2014.08.008

Statement of Purpose

To evaluate the suitability of vibration data loggers to monitor the structural health of rotorcraft bearings and aircraft condition in simulated and real-life inflight environments

Role of Mentor vs. Role of Student

Mentor

- Provided guidance and instruction regarding lab capabilities/technology
- Assisted in the construction of the experimental setup (i.e. using mill)
- Taught student to use data analysis software

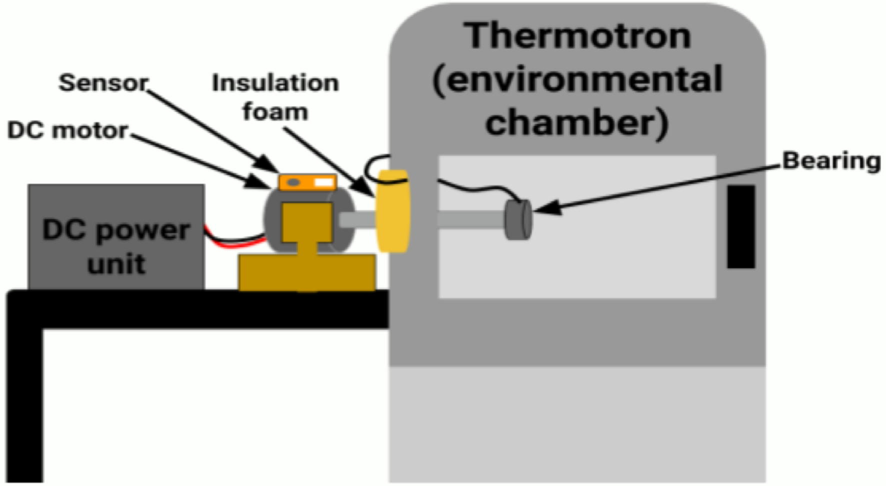
Student

- Selected research topic, conducted background research, designed hypothesis and methodologies
- Pilot in command of the aircraft for second-phase tests (certified under FARs Part 61) and conducted all maneuvers solo
- Analyzed/interpreted results and drew conclusions
- Prepared written report/presentation

Materials and Methods

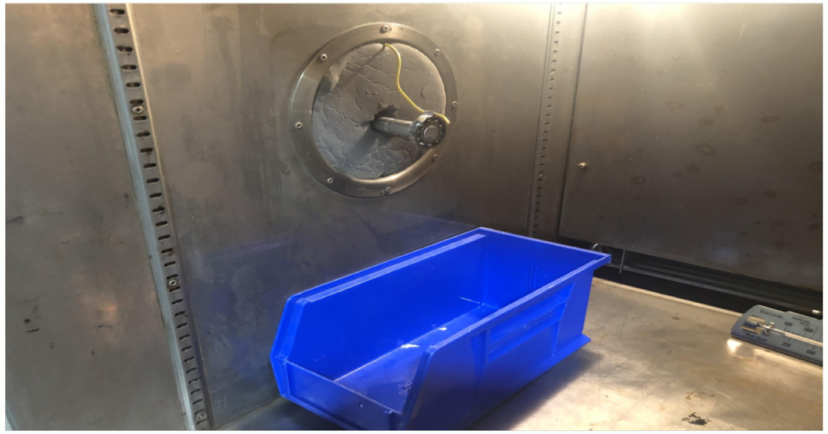
Experimental Setup

Graphical representation



Actual representation (outside chamber)

Actual representation (inside chamber)



Materials and Methods

Data collection procedure

Inducing bearing failure

- Contamination (grit)
- Overheating (fatigue)

2 Main trials

- Standard ball bearing
- Thrust-ball bearing

30 s control (bearing running at target speed)

↓

Environmental chamber heats up 7.5 °C/min

↓

Every 20 °C: 10 mL of grit injected

Repeat until failure

Materials and Methods

In-flight testing – second phase

Monitor aircraft performance in Cessna 172SP

Data from critical stages of flight examined

- **Engine start/shutdown**
- **Takeoff**
- **Landing**

All flights conducted under Part 91 of FARs in calm air (<10 kt winds)

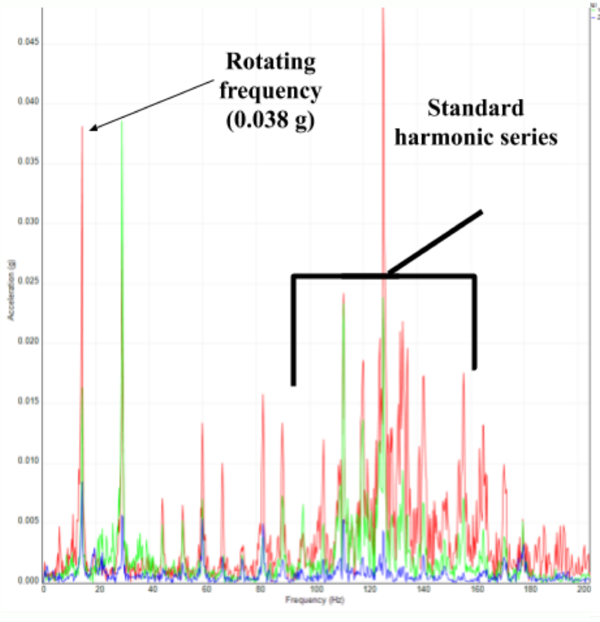
Credit: Daniel Savitt + Sam Savitt

Results

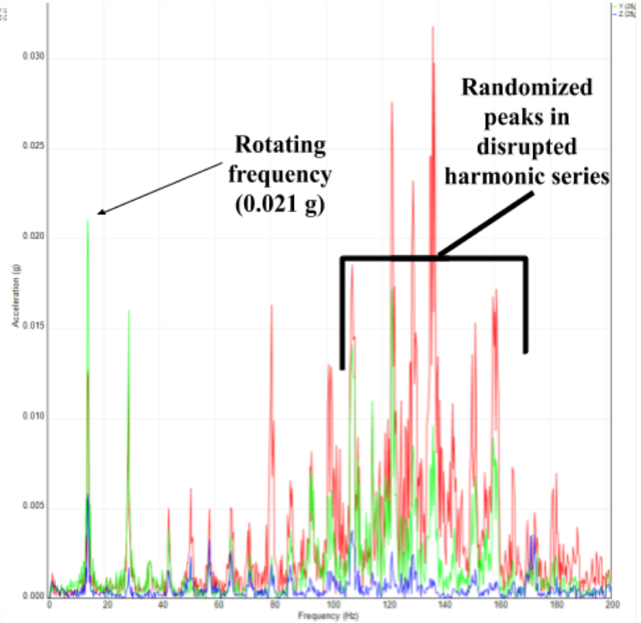
Ball bearing data

FFT

Before failure



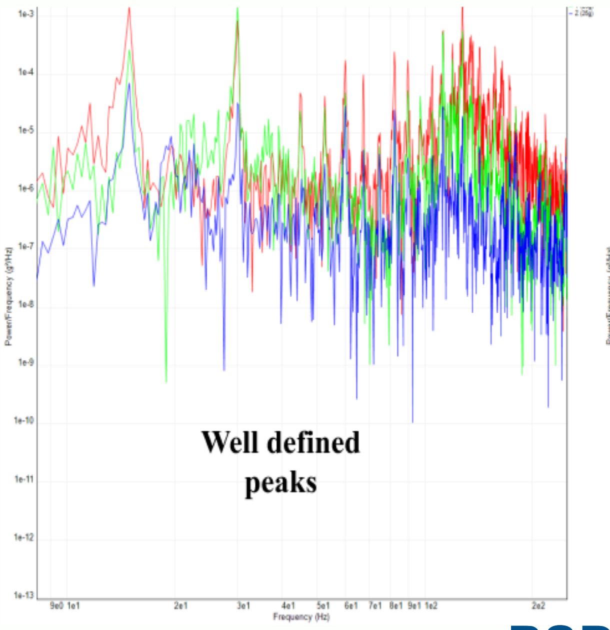
Failure



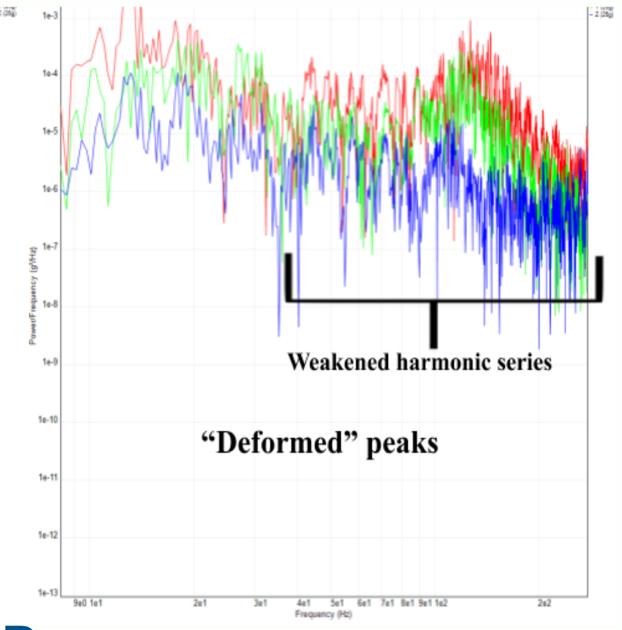
FFT

PSD

Before failure



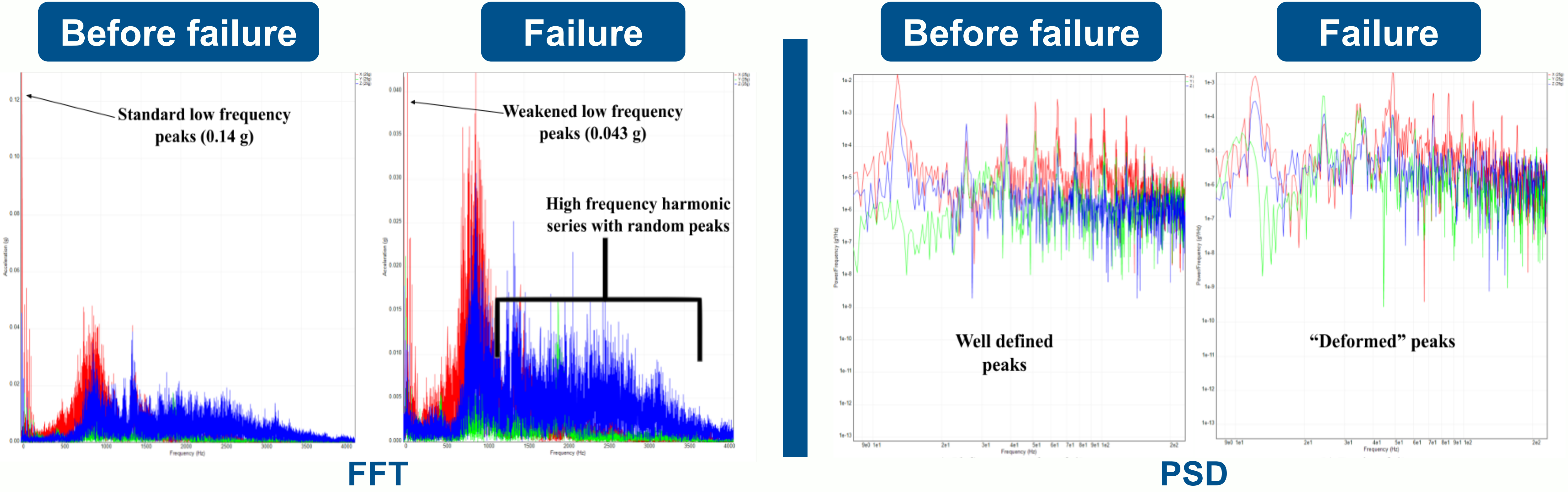
Failure



PSD

Results

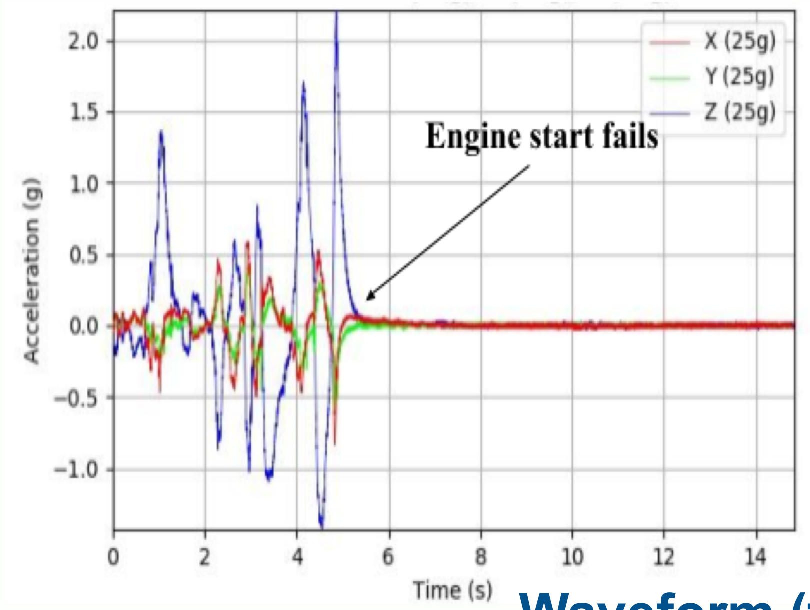
Thrust-ball bearing data



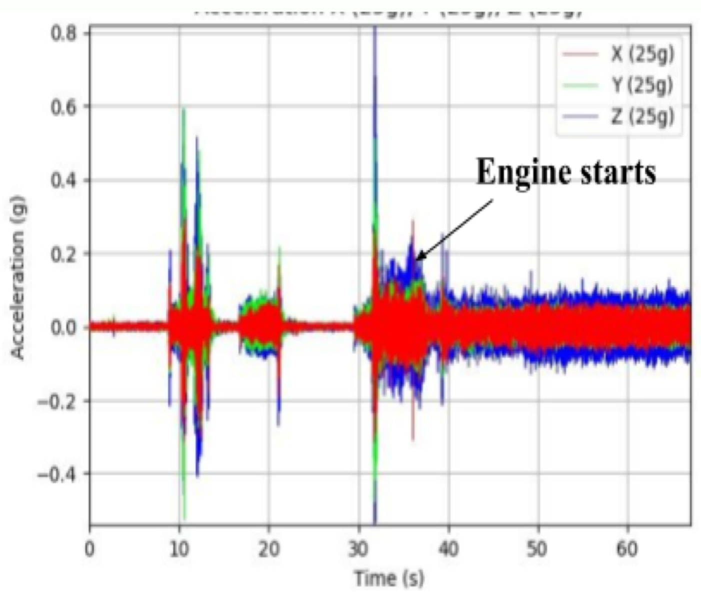
Results

In-flight data (2nd phase)

Failed Engine Start



Successful Engine Start



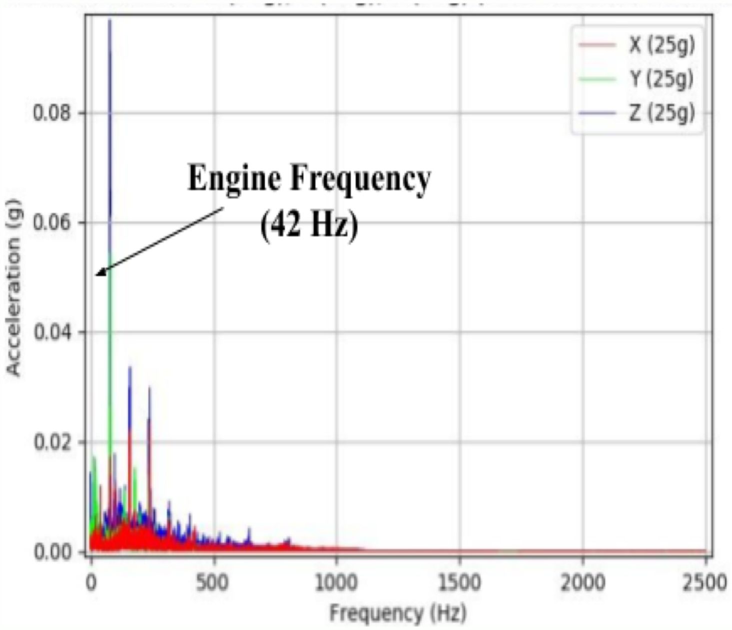
Waveform (time-domain)

Results

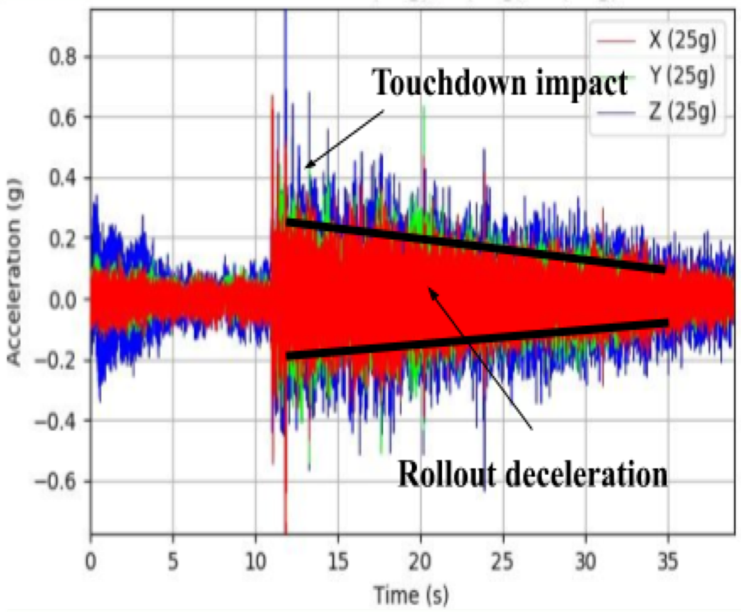
In-flight data cont.

Takeoff

Landing



FFT



Waveform

Discussion

- Data demonstrate the ability of the data loggers to monitor normal operation (pre-failure) and detect key vibration patterns
- Upon bearing failure, FFTs demonstrated disruption of harmonic series and PSDs demonstrated a deformation of peaks
- Inflight vibration data accurately represented aircraft performance during engine start, takeoff, landing consistent with simulations

Conclusions

Condition indicators such as harmonic series patterns and distinctness of peaks accurately represent bearing condition and would be very effective for CBM

The data loggers effectively monitored bearing/aircraft condition in a variety of failure types despite being mounted outside of the main system

Vibration data loggers paired with frequency domain vibration analysis have great potential for aircraft CBM system development

Implications/Significance

The effectiveness of data loggers for aircraft CBM will allow for operators to reduce maintenance times, maximize part life, and improve passenger safety

Data logger CBM systems are very versatile and can be applied to many industries such as the automotive industry, marine industry, and the realm of industrial engineering

Future Research

- Quantification of condition indicators (Q-factor, root mean square, etc.)
- Extensive testing of the data loggers in a large scale environment
- Streamlining the data transfer process for a completely wireless CBM system
- Developing improved process for long-term performance monitoring

Acknowledgements

My mentor and CFI

My Science Research instructor

My family

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