

Monitoring lubrication issues with Dragonfly®

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Abstract

Wormsensing Dragonfly® is a dynamic strain sensor that outperforms conventional strain gauges by a factor of 1000 in sensitivity while maintaining the same form factor (less than 200µm thick flexible PCB). The high sensitivity opens the possibility of measuring dynamic strain in rigid structures and developing condition-based maintenance strategies that rely on force monitoring rather than acceleration measurements. Since force is more closely related to damage in structures, earlier and more accurate failure detection can be implemented. Here, Dragonfly® is used to monitor an alternative machine used in Wormsensing's production facilities to test the fatigue life of our sensors.

Key Words

Piezoelectric Strain Sensor, Lubrication Monitoring



Figure 1 : Picture of the studied machine, designed to cyclically deform glass-fiber bars to study the fatigue life of Dragonfly® sensors.

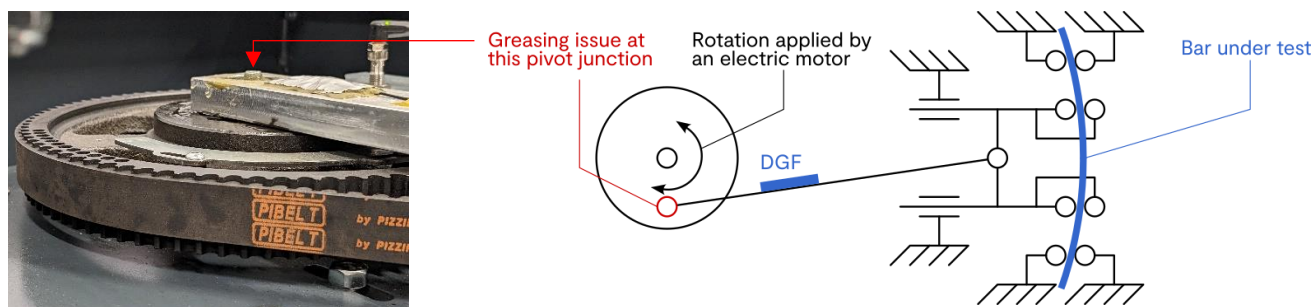


Figure 2 : Schematics of the studied machine. It cyclically applies a known deformation to a glass-fiber bar using a 4-point bending setup.

1 Introduction

Generally speaking, two main types of industrial machines can be distinguished: rotating and alternative ones.

The vibrational behavior of rotating machines is well described in many papers with a set of extracted features generally based on unbalances, clearances, misalignments (partly defined in ISO standards). Repetitive shocks are studied with cyclo-stationary approaches using time synchronous averaging, filtering, noise cancelling or envelop processing. Thousands of academic publications are dedicated to bearings each year.

The second type is shock machines or alternative machines. These machines are less studied and are typically subject to phenomena such as fretting corrosion, wear, shocks, increasing clearance and noise. In bar joints, it is common that rotations occur only within a small angle range instead of full rotations, resulting in uneven grease distribution around the joint.

In this paper, a custom-built shock machine is monitored to detect lubrication problems in rod joints. Dragonfly® sensors are used to provide a signal representative of the dynamic force loading.

2 Setup

The studied machine has been developed specifically for testing the fatigue life of Dragonfly®: it cyclically applies a known strain to glass-fiber bars where the sensors are glued. It relies on a 4-point bending configuration of the tested bar to ensure a uniform strain distribution in the central area where the sensors under test are located. The operating frequency of the machine ranges from 1 to 10Hz, depending on the magnitude of the strain applied to the bar (up to 10000 $\mu\text{m/m}$). Millions of cycles can be applied to the sensors within only a few days of testing.

Since this machine is typically used for a large number of cycle test campaigns, it must be carefully maintained. The most important maintenance operation is the lubrication of the swivel joint that connects the main rod to the motor, as shown in Figure 2. The precise timing when this operation is needed depends on many process parameters and therefore varies from a few hours to many days. In order to warn the technician which operates the machine that lubrication is necessary, the rod is instrumented with a Dragonfly® to measure the strain, which is proportional to the force applied by the rotating lever on the rod.

The acquisition is performed using a Dewesoft DEWE43A data acquisition hardware, at a 20kHz sampling rate.

Two 60s-long measurements are performed before and after a lubrication operation. Three periods of raw time data of Dragonfly® are plotted in Figure 3.

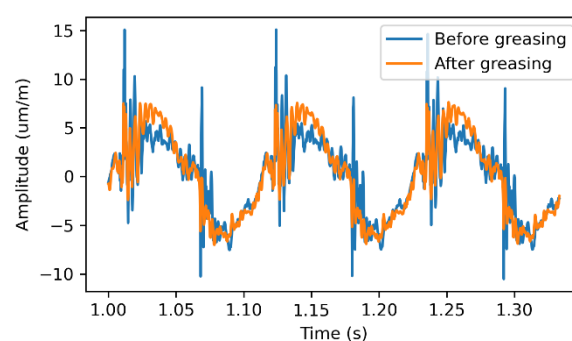


Figure 3: time signals measured by Dragonfly® before and after the lubrication of the main pivot junction.

This figure shows that lubrication reduces significantly the sharp peaks, which may be due to shocks between rod axle and the sleeve in the swivel junction. These impacts are dampened when grease is present in the joint and are certainly due to the clearance that the axle sees in the sleeve during the change in direction. The other numerous impacts seen in Figure 3 may be due to some other

pivots exhibiting the same behavior, or a rebound in the incriminated pivot (more likely).

To further analyze the influence of lubrication, the Power Spectrum Density of Dragonfly® is plotted before and after lubrication in Figure 4.

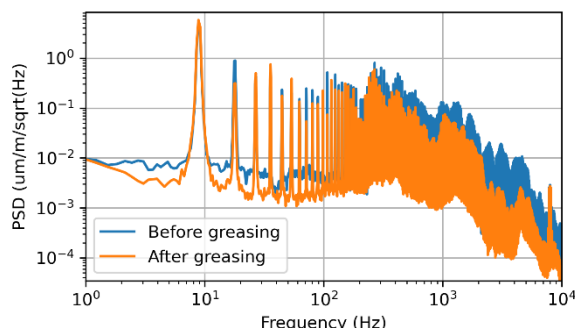


Figure 4: Power Spectrum Density (PSD) of the Dragonfly® signal before and after lubrication.

Figure 4 shows that lubrication has several effects on the PSD:

- It reduces the high frequency level (above 200Hz)
- It reduces the spectrum background at low frequencies (between 20 and 100Hz) which may indicate that less random shocks occur.

Lubrication issues are generally detected by traditional metrics computed from the raw time data, such as:

- **RMS:** Root Mean Square, which describes the overall vibration level.
- **Crest factor:** the ratio of a signal's peak amplitude to its RMS value, indicating the presence of high peaks in a waveform.
- **Kurtosis:** measures the sharpness or "peakyness" of a signal's amplitude distribution, helping to detect abnormal or impulsive events in the data. Here, we are calculating the relative evolution with respect to gaussian noise defined by $K=3$.
- **Relative high frequency level:** ratio of the RMS at high frequency vs at low frequency.

These typical metrics are computed using the Dragonfly® signal and plotted before and after lubrication in Figure 5.

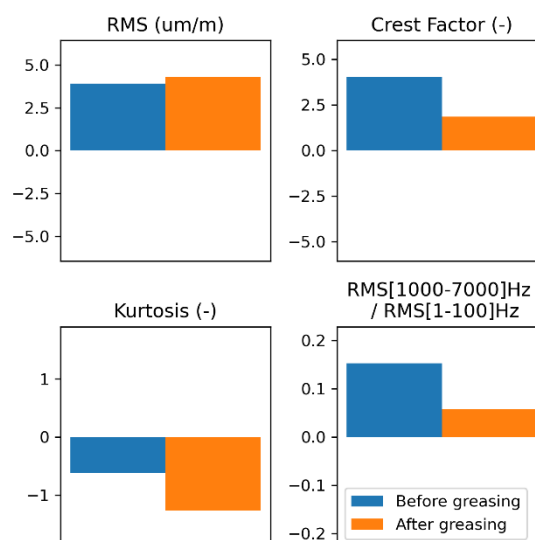


Figure 5: Signal metrics before and after lubrication.

Some of the metrics are relatively insensitive to lubrication, such as the RMS. On the other hand, the crest factor decreases significantly after lubrication, as does the ratio of the high frequency RMS to the low frequency RMS. The kurtosis also decreases, which also indicates fewer sharp peaks in the signals after lubrication. Thus, these three metrics appear to be relevant candidates for detecting lubrication problems on the studied machine.

3 Conclusion

A typical industrial machine with rotating elements and a crank system is monitored with Dragonfly® to detect lubrication problems. Its high sensitivity makes it possible to accurately measure the small strains of around $10\mu\text{m/m}$ that occur in rigid structural parts during machine operation, and to analyze the strain variations caused by defects in the machine, such as lack of lubrication. Thanks to its low thickness ($<200\mu\text{m}$) and flexibility, Dragonfly® opens new possibilities for vibration monitoring on machines where space for sensors is limited.