Railroad Car Wheel Contamination Detection

Dylan Etelamaki; Wayne Helminen; Joshua Manela; Joel Yauk, Michigan Tech.

If contaminants are present on the train wheels during car classification, the retarders won't operate effectively and the cars can blow apart couplers or even derail the train. The goal of this project is to detect contaminants on the train wheels in order to avoid damage during the recoupling process. A test stand was designed and built to measure the coefficient of friction for various contaminants at varying levels of application. It was found that even a very thin film of any contaminant had a significant impact on the coefficient of friction. Machine Learning methods were used to classify contamination state with 70% test accuracy.

Background

In the rail industry, gravity classification yards—colloquially referred to as "hump yards"—are used to separate railroad cars from a single incoming train to different outgoing trains. This is done by pushing the train up a small hill, or hump, releasing the cars one by one at the top, and using a combination of special brakes, called retarders (see Figure 1), and switches to control the cars' descent down the hill and direct them to the right outgoing trains. The retarders brake the cars by grabbing onto the rims of their wheels, a surface which is not used by the cars' internal braking systems.

Problem

Often, railroad car wheels are either contaminated when entering classification yards, or become contaminated from their contents leaking while they sit in the yards prior to the classification process. These contaminants sometimes include fats and oils from food and animal products, mechanical greases, and metal dust and shavings. If contaminants are present on the wheel rims, the retarders may not effectively slow the cars during the classification process. Fast moving cars can damage mechanisms when coupling with outgoing trains, and in extreme circumstances, derail.

Figure 1. Hump yard group retarder

The goal of the project is to develop a reliable method for detecting contaminants present on the railroad cars' wheels prior to the cars decoupling at the top of the hump during the classification process. In order to determine the specifications for the detection system, it is necessary to know which substances cause problems during retardation, and in what quantities. Therefore, an intermediate goal for the project was created; namely, to measure the coefficients of friction between a railroad car wheel and the retarder that result from the presence of various quantities of contaminants on the wheel, and to assess potential detection methods based on the findings. A test stand was designed for the purpose of spinning a railroad car wheel, applying a braking force using a brake shoe made of the same material as the retarders, and measuring the forces in the braking process in order to calculate a coefficient of friction.

Design

Figure 2 shows the initial CAD model of the contaminant testing table. The CAD model was done modeled, assembled, and rendered in UGNX. The wheel and motor displayed in our concept model were used from an open source CAD repository, while everything else was created from scratch. This design was handed off to an outside contractor to construct the physical table.

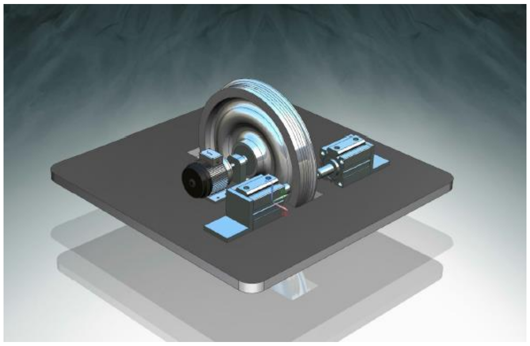

Figure 2. Dungeon Grey

Our realized test stand can be seen in Figure 3. It has slight changes from the initial draft, such as only braking on a single surface of the wheel instead of both sides. The brake box installed on the stand utilizes two load cells to measure the forces need to calculate the coefficient of friction.

Figure 3. Realized Test Stand

Four different contaminants were chosen in order to maximize the variety of viscosities tested within the time constraints of the testing period. The contaminants were:

- 10W30 motor oil
- Vegetable oil
- Corn oil
- Multi-purpose auto grease

Results

Figure 4 shows the mean coefficient of friction displayed from the different tests. By looking at Figure 4, it becomes quite apparent that the coefficient of friction drops dramatically for each of the contaminants, regardless of their respective quantities. In the case of a thick application of motor oil, the coefficient of friction was reduced to approximately 16% of the uncontaminated mean. For a thin film of motor oil approximately 28%. Although the thin film does change the coefficient of friction, the percent difference is not nearly as significant as the difference between the uncontaminated and the contaminated thin film registers. Overall, auto grease expectedly worked as the "best" contaminant, which again makes sense considering it was designed to perform in this manner.

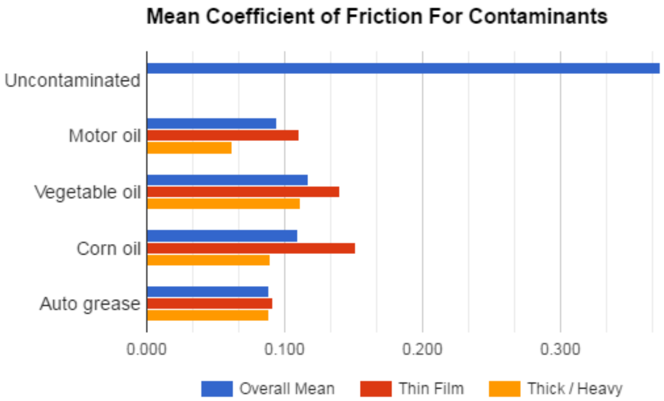

Figure 4. Contamination coefficient results

Analysis

The biggest surprise from the test results was the fact that even a thin film of contaminant (not visible) dropped the coefficient of friction by a factor of 3. This result rules out any type of visual contamination detection method due to the fact that the visual precision required to detect these thin films cannot be achieved in the hump yard environment.

It was noticed that the velocity profile of the wheel as detected by the encoder differed significantly for a clean wheel than a contaminated wheel. A Support Vector Machine (SVM), a commonly used machine learning classifier, was fed frequency data from the encoder. In preliminary testing, leave-one-out cross validation found 70% accuracy in detection (test accuracy).

Recommendations

Fusing the encoder data with sound and/or thermal data could increase the accuracy of the classification. This allows sensor-fusion machine learning methods to be investigated.

The funding for this project was provided by NURAIL, Norfolk Southern, and the MTU Rail Transportation Program.