A MACHINE LEARNING APPROACH FOR OPTIMIZING FLUSHING OPERATIONS IN LUBE OIL MANUFACTURING AND PACKAGING PLANTS

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Introduction
The commercial lubricant industry manufactures over a thousand unique lube oil products by blending different base oils with numerous groups of additives. To meet the growing market demand, the number of product formulations and operation complexities are increasing as well. Therefore, the production system comprising blending vessels, ancillary equipment, and a complex pipeline network must be reused multiple times for numerous batch productions. The lube oil industry poses stringent product quality requirements therefore, it is a necessity to avoid cross-contamination during changeovers and ensure efficient cleaning of the pipeline network. The use of external agents is strictly prohibited therefore, an upcoming product batch is used for cleaning/flushing the residues of the previous product. This results in the formation of commingled/mixed oil that is regarded as a low-value product. The existing operations lack a standardized procedure that results in large volumes of commingled oil leading to economic losses exceeding millions of dollars annually. To achieve desired product specifications, attain quality targets, and maximize the productivity of assets, it is of paramount importance to enhance process control, minimize human errors and improve the resource management footprint of these industries. To this end, we present a machine learning approach to learn from the data of existing operations and strategically optimize the flushing operations.

Methodology
We collaborated with a commercial lube oil blending plant (LOBP) to get insights into their plant configuration and manufacturing processes.

Based on their end-use, the finished products are classified into families such as Engine, Gear, Industrial, Turbine, and Synthetic oils. Each of these oil families has distinguishing features and consists of over 100 different products. To ensure product integrity, the respective family must remain separate from each other. Hence, the pipeline configuration at the partnered facility is separated into five lines for each product family.

Our present study focuses on using machine learning to predict distinguishing features of the lube oil blends, allow better in-line controllability, and minimize the oil downgrade during product changeovers. We performed a cross-validation and based on the score we chose a random forest classification algorithm to solve the classification problem for success/failure of the flushing operation [1]. A total of 1432 data points were used, with 80% being used for training and 20% for testing. The feature set comprised documented flush, kinematic viscosities at 40°C and 100°C, average ambient temperature, product family, and the system type (2 oil/3 oil mixture). After tuning the hyperparameters for the model, the performance was evaluated on the test set using the confusion matrix. The goal was to predict which product batch failed and which passed depending on the compatibility of the consecutive products.

Results
Figure 1 illustrates the results from the model where out of 116 test records, it predicted the classification of 110 records correctly with an accuracy of 96% and a recall value of 0.33.

Summary
Our work will help the lube oil industries to make more informed decisions and predict the pass and fail scenarios depending on the compatibility of the consecutive products and mixture type.

References


Figure 1: Confusion Matrix of the test dataset prediction by Balanced Random Forest Classifier