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Using fuel station data to predict failures

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Liquid fuels will play an important role in the future mobility as they cannot be completely supplemented. However, they mode of use has several dimensions to develop to increase the sustainability and efficiency. In this study, it is showed the potential of analyzing the data generated by petrol station equipment, and how the data can be used to produce a historical summary, a statement, an analysis to help improve the system, or even a predictive model to help service operations. The data used for the data analysis was made possible by the 2018-1.1.1-MKI - Supporting Innovation Activities of Micro and Small Enterprises - Development of a Fuel Vapour Leakage Monitoring System and Service Interface.

1. Introduction

Several alternative energy opportunities are under introduction in the field of mobility as electricity, hydrogen or advanced fuels [1]. The liquid fuels will have important role in the next decades as the alternatives are barriered technically (not suitable for long haul transportation [2]), geographical unavailability (for example missing electricity grid in Africa [3]).

With the use of cognitive mobility achievements [4] in the liquid fuel technology its efficiency and sustainability can be further improved in the domain of fossil based and alternative fuels as well [5, 6]. The importance of fuel vapour recovery at petrol stations is paramount for environmental protection. The role of the vapour recovery system is to prevent vapours escaping from the vehicle's fuel tank during refueling from being released into the environment. This reduces air pollution, while at the same time allowing the vapour to condense and return to the tank [7].

Monitoring the functioning of the recirculation system is extremely important. Continuous monitoring allows you to maintain the efficiency of the system and helps to identify possible failures and leaks. Thanks to monitoring, fuel losses can be minimized, which is also economically beneficial [8].

Analysis of the data collected during monitoring can provide additional benefits. The data can be used to accurately track how the recirculation system is performing under different conditions, but more detailed analysis can also allow the nature of failures or even predict them. Such analytics can help to optimize system performance and provide early warning of potential failures or wearing parts. In addition, data analysis can be used to fine-tune the design and manufacturing processes of fuel recirculation systems, improving their efficiency and environmental performance.

In this way, monitoring and analyzing the data from the recirculation system not only serves environmental goals, but can also have economic and technical benefits, contributing to sustainable operation and the improvement of fuel systems.[7][9][15]

2. Characterization of Data

2.1 Data Source

The data presented in this study were collected using a monitoring system developed with the help of a grant (www.vapremo.hu). The great advantage of the tools developed is that they can also function as a network tool, so the data can be viewed in real time on the control panel, but can also be downloaded from the database for more detailed analysis. The data source is called a data collector and is identified by the 3-letter code of the municipality, the 2-digit code of the well column and the letter A/B indicating the side of the well column. One device records several data from wells during refueling, the identifiers of which are harmonized with the identifiers of monitoring devices currently in use in Hungary [12][13]. The data identifiers and their content are summarized in the Table 1.

Nº	Data identifier	Content of
1	cut column	Filling point identifier
2	sno	device serial number
3	errcount	error counter
4	fueltrcount	the quantity of fuel dispensed
5	recrate	recovery efficiency
6	meanrecrate	overall efficiency
7	meanvaptemp	steam temperature
8	vapccstatus	control system status
9	vapflowrate	vapour flow rate
10	fuelflowrate	fuel flow rate
11	recratepos	suck-back position
12	recrateneg	average value of recapture
13	time	Time
14	n	serial number

Table 1: Data types

The data were collected during the winter, so one of the key environmental parameters - temperature - was relatively low. The distribution of temperature during each refueling is shown in the histogram below.

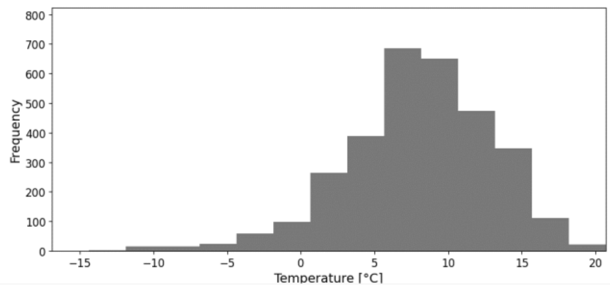

***Figure 1**: Temperature distribution of data records*

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2.2. Data volume

During the period used for the data analysis, the number of refueling operations carried out at each well post is shown in Figure 2, that show the number of refueling operations (in units) at each well post).

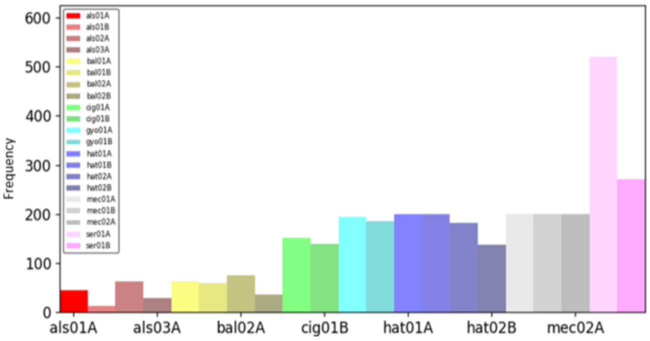

***Figure 2**: Quantity of refueling (units) on each well post*

The total of 3160 refueling operations per well post represents an average of ~200 refueling operations, or ~200-800 per site, depending on the number of well posts surveyed [17].

2.3 Validating Data

In the following, we will often highlight the two data collectors with the largest sample sizes (ser01A, ser02B), which alone represent 800 data and are the most comparable in terms of their data collection conditions. We also discuss separately the data collectors whose measurements can be considered valid in almost all cases. The graph below shows the data points plotted along three variables.

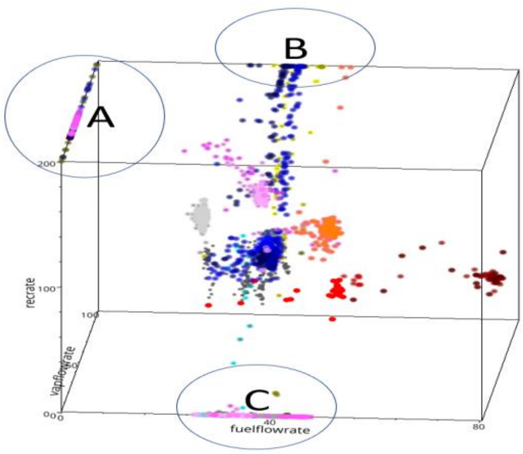

***Figure 3**: Selecting valid data*

Valid data are those that do not fall within the areas marked A, B and C, which indicate partly the error of the back-sampling (C) and partly the measurement limitations of the measuring instrument (A, B). Selecting the middle part of the spatial graph gives the following distribution in each data collector [18].

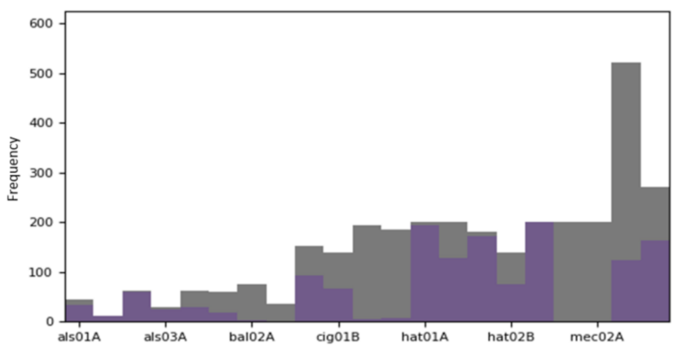

***Figure 4**: Percentage of valid data*

On this basis, we will analyse the following data collectors in particular.

Data collector [ID]	Data volume [pcs]	Validity [%]
hat01A	200	97%
hat02A	181	95%
mec01A	200	100%

***Table 2**: The top 3 valid data collectors*

2.4 Data Analysis Toolkit

The graphs were created partly using Glue data analysis software and partly using Python's PyPlot and Pandas libraries. First, we look at the normalized values of the priority data collectors [18].

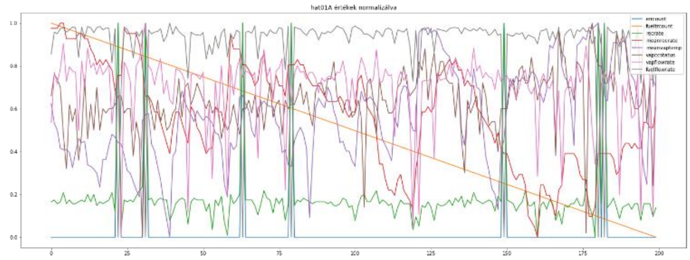

***Figure 5**: Normalized plot of hat01A values*

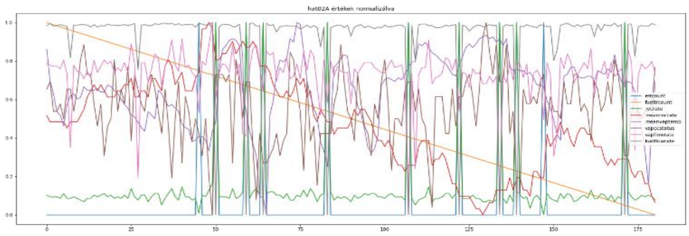

***Figure 6**: Normalized plot of hat02A values*

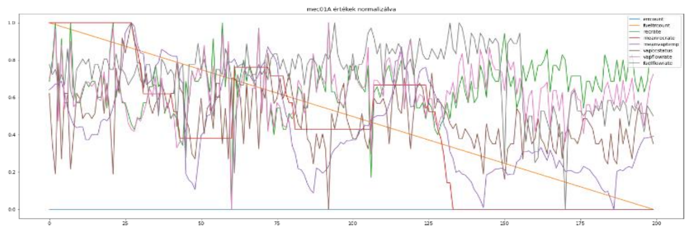

***Figure 7**: Normalized display of mec01A values*

Normalized data visualization can be used to explore the main relationships. For example, it can be seen that the occurrence of errors (errcount) is almost always related to changes in fuel flow rate and recirculation rate [17].

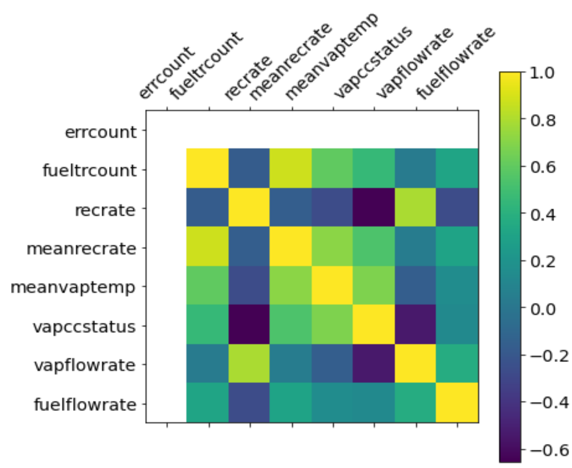

***Figure 8**: Correlation matrix of the mec01A data collector*

After examining the normalized data, we can also examine the correlation of each data point using a correlation matrix. For better visualization, in the correlation matrix, high correlation is indicated by a lighter yellow color and low correlation by a darker two-color. Meaning, on the diagonal, where the correlation of the data with itself is examined, a yellow line is drawn with the two sides mirror symmetric. The cells of interest to us are those that are not part of the diagonal and are the lightest. As a sample, we only present the correlation matrix of the mec01A data collector.

To see the correlations, we extract the data for vapflowrate and recrate from the full data set and show that they do indeed go together to a large extent.

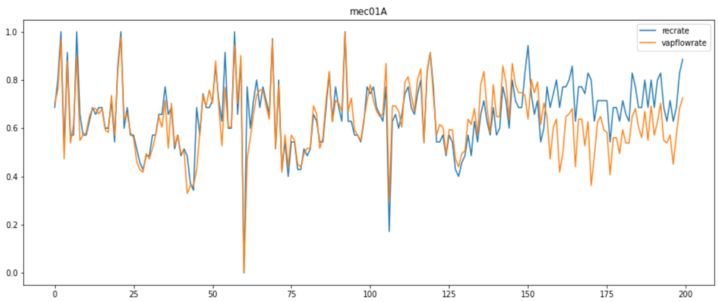

***Figure 9**: Two well correlated data sets for mec01A*

By plotting the two data together, it is also possible to see at which point this close correlation changes, and by examining the instrument, the cause of the error can be identified and deconstructed from the data.

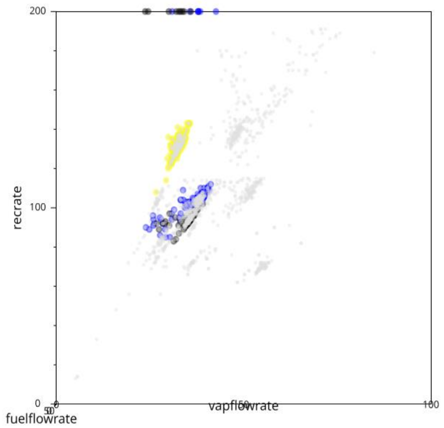

***Figure 10**: Relationship between recrate and vapflowrate*

The Figure 10 shows that the data collector mec01A in yellow and the data collectors hat02A and hat01A for a site show a different slope in the relationship between the two variables shown. These slopes and the location of the point clouds vary from site to site and can therefore be used to identify well poles, since they depend essentially on the efficiency of the suction and recovery. The change in the position of the point cloud, as indicated by these values, is indicative of a change in engine operation [11][12].

4. Conclusions

The data presented in this study were collected using a gun steam monitoring system funded by a research development grant. Using open-source data analysis tools, we have shown that it is possible to validate data using simple methods, and from the validated data, to generate correlations for improvement, reports for reporting and even diagnostics for service.

Analysis of the data collected during measurements in real conditions showed clear correlations between wear or ageing of the main elements of the well column. Knowing this data, the company carrying out the service could better organize the work of its employees due to a better knowledge of the materials needed for the repair. In the future, we would like to test our theory with data collected from a larger number of assets. The results from a larger sample will allow the creation of a manpower and asset optimisation algorithm that can achieve demonstrable cost savings for both the users of the system and the companies that maintain it.

The analytical procedure presented in this paper has supported our hypotheses that the ratio of the amount of vapour recovered to the amount of fuel expelled can be related to a number of mechanical failures, and that the shape of the measured value function can be clearly related to the failure or wear of the device.

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