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IDENTIFYING TRENDS OF VARIOUS BOILER PARAMETERS USING DATA ANALYSIS

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Abstract: Boilers are a critical part of various industrial systems. The failure of boilers can cause financial and productivity losses. With the use of data analysis, industrial processes can be made more efficient. The trends of various boiler parameters were identified and analysed using Spyder IDE. Gradual declining trends were observed across all the parameters. The identified trends will be further utilized to build forecasting models for monitoring boiler health. Data analysis is an emerging field that is being increasing applied in mechanical engineering systems to increase process and system efficiencies. Using data analytics, we can identify the trends of the parameters directly affecting boiler performance. Data analytics driven forecasting assumes importance when critical infrastructure is concerned
Keywords: industrial systems, boilers, parameters, trends, Spyder IDE

1. INTRODUCTION AND LITERATURE REVIEW

Steam is a vital constituent of many modern industrial processes and systems. Boilers are the main steam producers for industrial processes and hence boilers are a critical part of many industrial systems. Modern day boilers are complex systems requiring the interconnected working of many components. A boiler failure or boiler breakdown can shut down the plant and lead to enormous financial and productivity losses. Therefore, regular boiler maintenance is necessary to keep it functioning properly. Conventional methods for boiler care are not exceptionally reliable at identifying boiler failure. Repairs and critical maintenance are carried out only if impairment in boiler performance is found. Catastrophic failure of boiler leads to unscheduled maintenance and repairs, which increases downtime and the ensuing productivity and financial losses. However, scheduling maintenance without proper input leads to wastage of time and resources. If real time trends for boiler parameters can be devised, then breakdown could be accurately forecasted by prediction models. Thus, boiler maintenance can be scheduled accordingly to pre-empt failure. It will lead to reduced downtime and increase overall operation efficiency and productivity [1].

Data analysis is an emerging field that is being increasing applied in mechanical engineering systems to increase process and system efficiencies [2]. Using data analytics, we can identify the trends of the parameters directly affecting boiler performance. Data analytics driven forecasting assumes importance when critical infrastructure is concerned. Chayalakshmi et al. used multiple linear regression analysis to predict boiler losses and boiler efficiency to gauge boiler performance [3]. Using relatively simple data analytic methods they were able to make perfectly accurate predictions. Modern day data analysis is mainly carried out using python. It is the most suitable computer programming language for the emerging fields of big data analysis, machine learning, deep learning, and AI [4]. It has various features that are custom made for data science applications [5] [6]. Python is a versatile language and can adapted to various IDE applications like Jupiter, PyCharm and Spyder. The syntax of code in python is simple as compared to other languages. Hence python is overwhelmingly preferred for data science applications [7].

2. METHODOLOGY / PARAMETERS OF STUDY

The data was obtained and validated from a boiler of a reputed industrial plant in Pune using their proprietary data acquisition system. The trend analysis for the various boiler parameters has been carried out in Spyder IDE 4.0.1 using the Python programming language. The Python language was preferred due to its vast array of libraries suitable for data analytics and simple syntax.

The data of the required parameters was downloaded daily from the data acquisition interface in .csv format for the entire duration. The data was consolidated into a single excel worksheet. Graphs were created in excel for the individual boiler parameters to visualize the basic trends. Topographical prominence was used as algorithm for peak and trough finding. Using python programming language, a code was written in Spyder IDE to obtain peaks and troughs for the data points of the individual boiler parameters. The difference between the peak and troughs was obtained as well as the time difference for the peaks and troughs. The peak and trough difference were divided by the time difference and is plotted on a graph to obtain a gradient. Thus, accordingly the trends were analysed.

Table. 1: - Boiler Specifications

Sr. No.	Specification	Value
1	Boiler Type	Horizontal fire tube type
2	Capacity	2 TPH
3	Fuel	Furnace Oil (FO)
4	Burner	Monobloc type
5	Overall length	4250 mm
6	Overall width	2630 mm
7	Overall height	2450 mm
8	Full weight	9600 kg
9	Unladen weight	8800 kg
10	No. of Safety valves	2
11	Main steam stop valve	80 DN
12	Blowdown valve	25 DN
13	Auxiliary valve	25 DN
14	Water level gauge	20 DN
15	Pressure gauge dial	150 mm
16	Pressure gauge range	0-40 kg/cm^2
17	Chimney diameter	305 mm
18	Feedwater pump	Multistage stainless steel centrifugal pump
19	Flow rate	2500 LPH

Table.2: - List of abbreviations

Abbreviation	Full Form
TPH	Tonne Per Hour
mm	millimetre
kg	kilogram
DN	Diameter Nominal
Kg/cm^2	Kilogram per centimetre squared
LPH	Litres Per Hour

Table.3: - Parameters of study

Sr. No.	Parameter	Description
1	Boiler parameters studied	Oil temperature, steam pressure, oil pump supply pressure, oil pump return pressure.
2	Data Acquisition System	Proprietary data acquisition system developed by the company.
3	Data logging frequency	1 minute
4	Duration	6th February 2020- 11th March 2020. 9:00 to 18:00 hours daily.
5	Datapoints	15675 per parameter
6	Analytical medium	Spyder IDE 4.0.1
7	Data filtering	No

3. RESULTS AND DISCUSSION

— Trend analysis for oil temperature

The primary graph denotes the normal working cycles for oil heater during the boiler operation. As listed in the experimental setup, the boiler is a Furnace Oil (FO) fired boiler. The furnace oil needs to be heated before it reaches the oil burner for combustion so as to reduce its viscosity and improve its circulation through the boiler's oil circuit.

The normal cut off point for oil temperature is around 120°C, however due to residual heat of the oil heater further inertial heating takes place and hence oil temperature peaks slightly higher as seen in the graph. The oil heater turns on at the beginning of every boiler cycle throughout the entire period and hence it produces the characteristic oil temperature peaks and troughs as seen in the graph. A complete flat line is obtained on the graph during non-working days when the boiler is turned off and the oil temperature remains low.

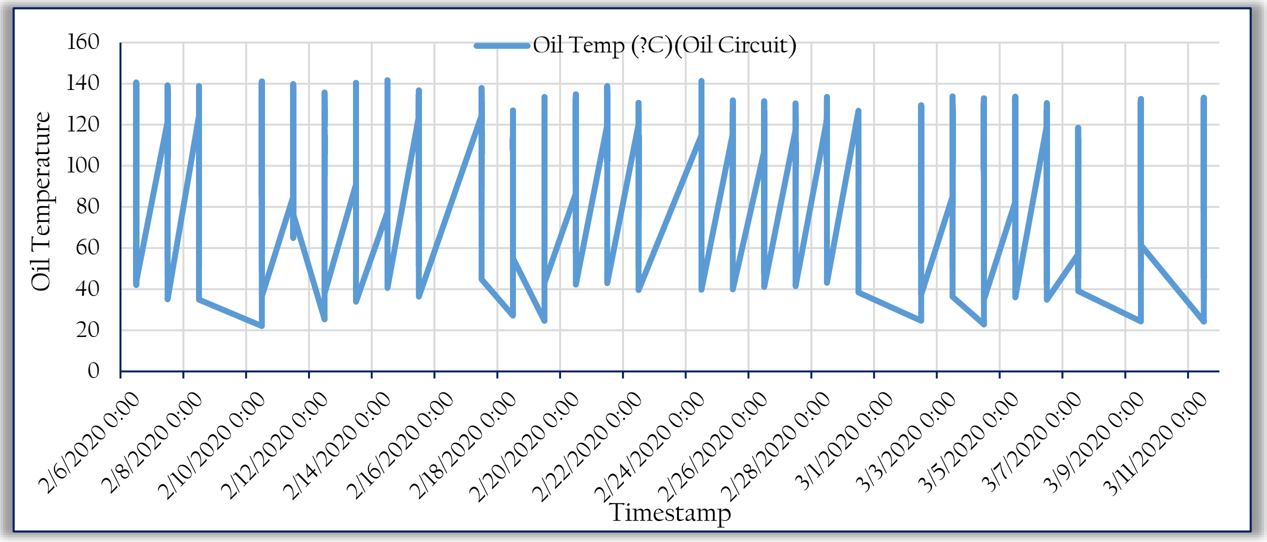

Figure 1: Oil temperature primary graph

The oil heater has the highest electrical power consumption out of any component of the boiler system. The electrical power graph shows almost identical trends vis a vis the oil temperature graph. The electrical power consumed is at its highest just as the oil temperature reaches its peak. The peaks and troughs of both graphs have almost identical trends. Thus, we can say that oil temperature and electrical power have a definite correlation

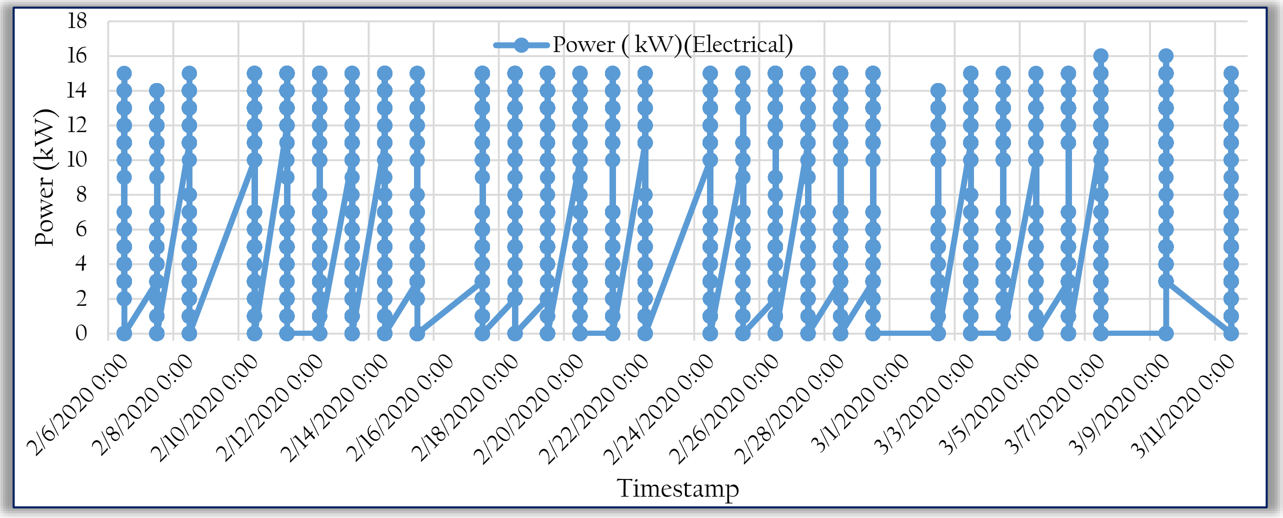

Figure 2: Electrical Power primary graph

By the above-mentioned algorithm, we use a code of Python programming language in Spyder IDE to identify the peaks and troughs in the primary graph of oil temperature. The peaks and troughs are obtained on the graph as below. The code also sorts the values of oil temperature at the peaks and troughs as well as the corresponding timestamp of the values.

The differences in the values of peaks and troughs are obtained and a graph is plotted in Excel. The graph thus obtained is a gradient wherein a gradual trend can be observed.

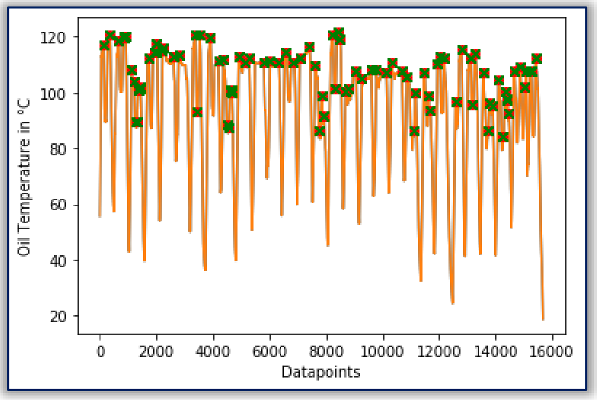

Figure 3: Oil Temperature Peaks

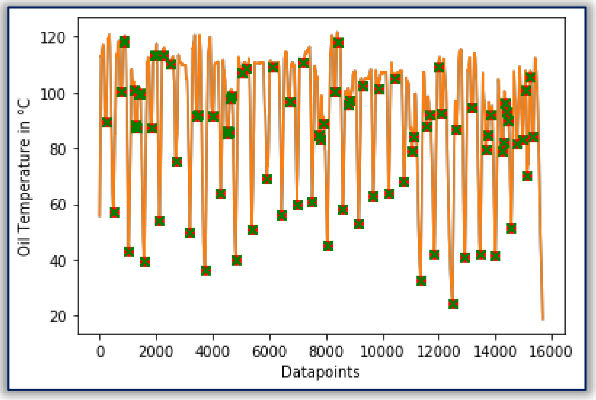

Figure 4: Oil Temperature Troughs

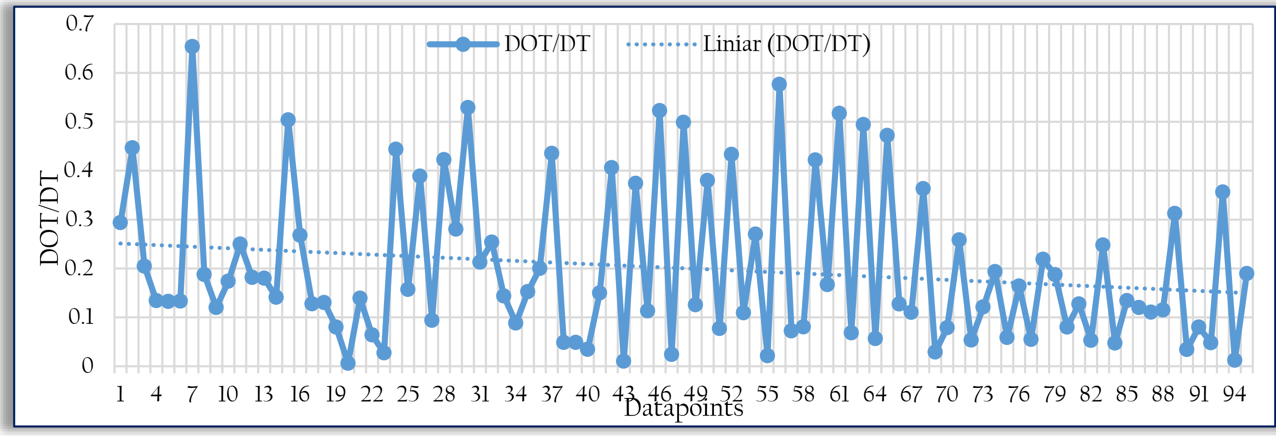

Figure 5: Trend analysis graph; DOT- Difference in Oil Temperature.DT- Difference in Time.

The trend analysis graph for oil temperature shows a gradual declining trend with a linear trendline. This might suggest oil heater issues as a gradual declining trend is observed.

— **Trend analysis for steam pressure**

Steam pressure refers to the pressure of the steam being generated by the boiler. The boiler is a low pressure boiler, hence the peak steam pressure generated is below 25 bars. This manifests as uniform peaks on the graph. The steam pressure varies according to the boiler operation cycle. The steam pressure is at its lowest at the beginning of boiler cycle, when the boiler operation starts generating steam. It increases with increase in steam generation and reaches its peak when steam generation reaches the rated capacity of the boiler (2tph). The boiler is then shut down, the steam generation stops and the steam pressure drops.

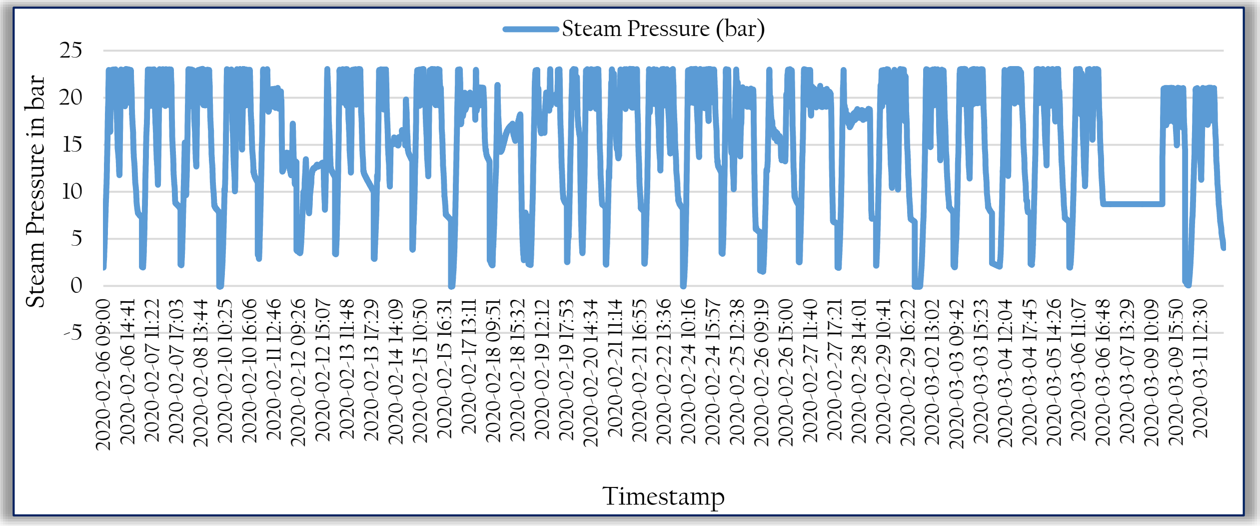

Figure 6: Steam pressure primary graph.

Using the algorithm, we use a code of Python programming language in Spyder IDE to identify the peaks and troughs in the primary graph of steam pressure. The peaks and troughs are obtained on the graph as below. The code also sorts the values of steam pressure at the peaks and troughs as well as the corresponding timestamp of the values. The differences in the values of peaks and troughs are obtained and a graph is plotted in Excel. The graph thus obtained is a gradient wherein a gradual trend can be observed.

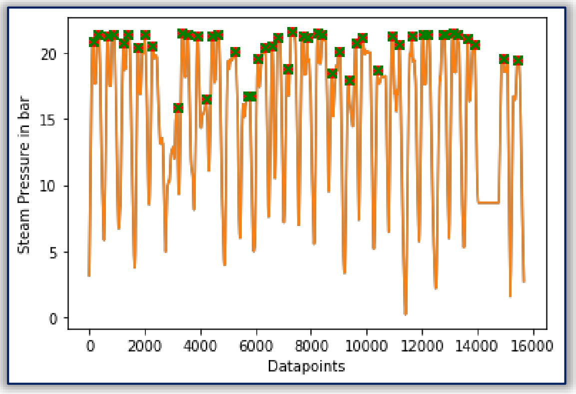

Figure 7: Steam Pressure Peaks

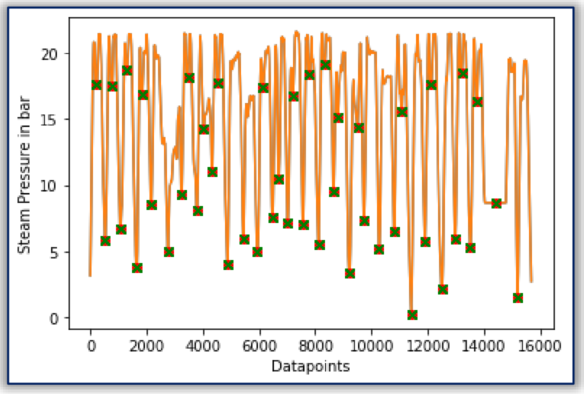

Figure 8: Steam Pressure Troughs

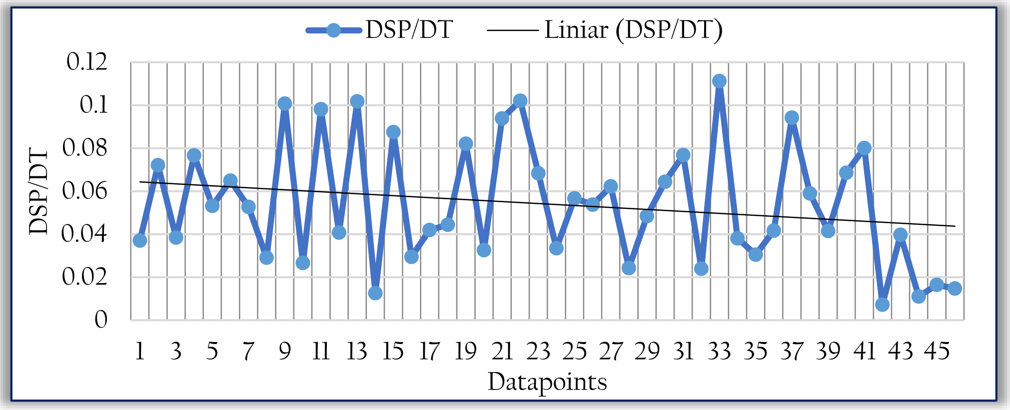

Figure 10: Trend analysis graph; DSP- Difference in Steam Pressure; DT- Difference in Time

The trend analysis graph for steam pressure shows a declining trend with a linear trendline, thus validating the hypothesis that the declining trend in flue gas temperature was due to a decline in steam pressure. This further confirms the correlation of steam pressure and flue gas temperature. The declining trend in steam pressure may be attributed to overall declining steam production. It might also indicate that insufficient heating of water due to oil burner issues led to decrease in steam production.

— **Trend analysis for oil pump pressure**

Oil pump pressure refers to the pressure at which oil is pumped by the oil pump to the oil burner for combustion. The supply pressure varies according to the boiler cycle. The pressure starts increasing sharply at the beginning of the boiler cycle when the boiler is turned on and starts generating steam. The oil pump pressure peaks when steam generation is at its highest and declines dramatically when boiler is shut down and steam generation stops. Thus, the characteristic sharp peaks and troughs of the primary graph of oil pump pressure are obtained.

Using the algorithm, we use a code of Python programming language in Spyder IDE to identify the peaks and troughs in the primary graph of oil pump supply pressure. The peaks and troughs are obtained on the graph as below. The code also sorts the values of oil pump pressure at the peaks and troughs as well as the corresponding timestamp of the values. The differences in the values of peaks and troughs are obtained and a graph is plotted in Excel. The graph thus obtained is a gradient wherein a gradual trend can be observed.

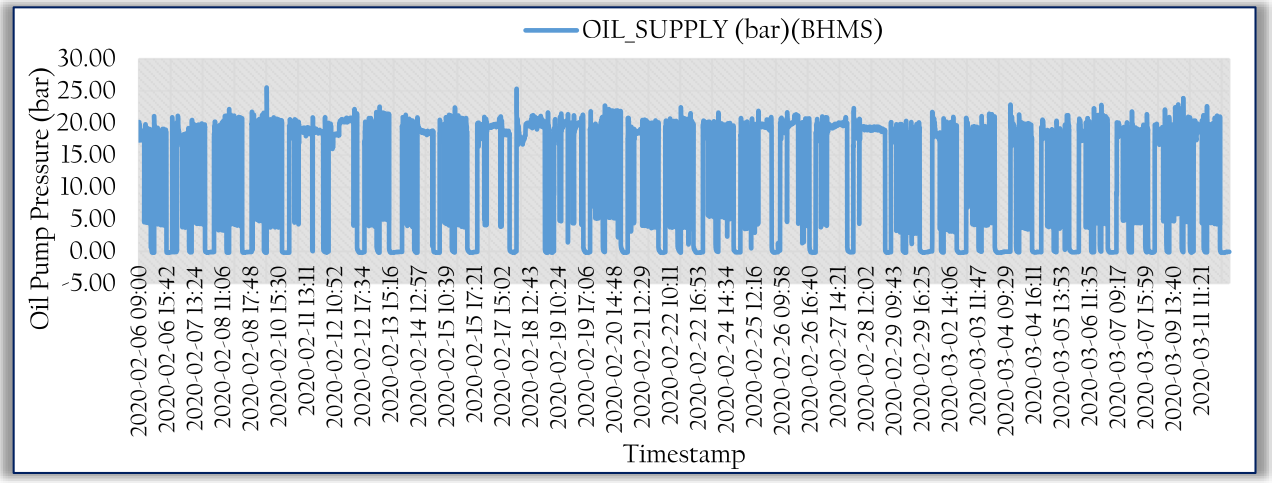

Figure 11: Oil pump pressure primary graph.

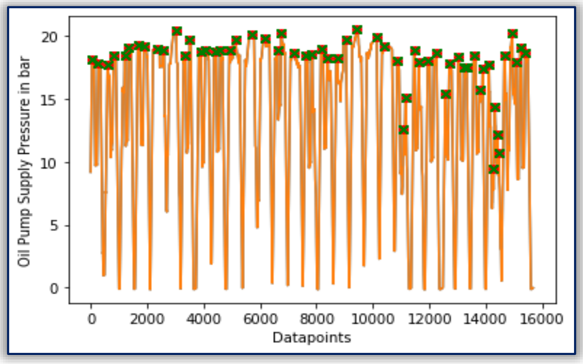

Figure 12: Oil Pump Pressure Peaks

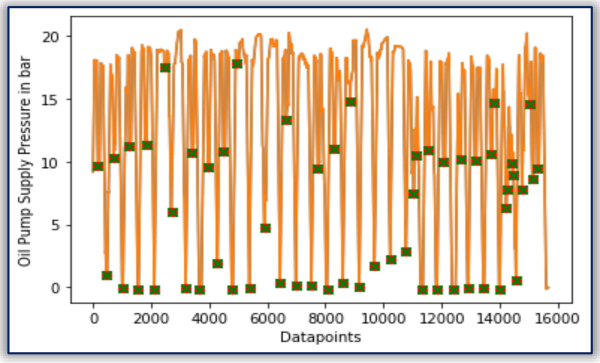

Figure 13: Oil Pump Pressure Troughs

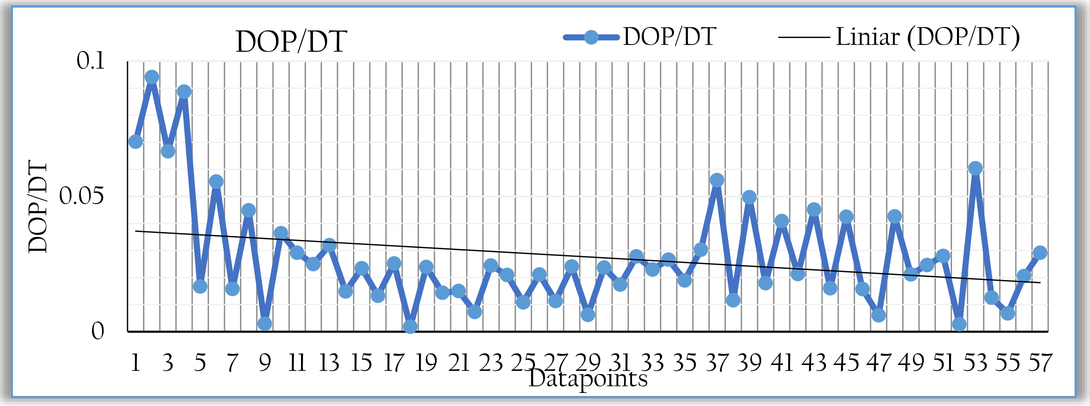

Figure 14: Trend analysis graph; DOP- Difference in Pressure; DT- Difference in Time

Oil pump pressure shows a declining trend with a linear trendline. A gradual declining trend in pressure might indicate problems with the oil pump as it may be unable to sustain the required pumping pressure. Also, build-up of debris in the oil over time would also affect pumping pressure and cause a decline in pressure.

4. CONCLUSION & FUTURE SCOPE

≡ Trend identification was carried out on data using peak and trough algorithm.
≡ Spyder IDE with python was used for the work.
≡ Declining trends were observed with all the boiler parameters under consideration.
≡ Further research to try, identify and validate correlations among the observed trends of boiler parameters.
≡ Building prediction models based on the identified trends to accurately forecast failure for various boiler components and thus overall state of boiler health.
≡ Testing and validation of the prediction models.

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