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Effect of Operating Temperature on Marine Fuel Oil (MFO) Quality Parameters

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Abstract
Marine Fuel Oil (MFO) is a residual fuel widely used in heavy industries, whose quality is influenced by refining operating conditions. This study aims to evaluate variations in key quality parameters of MFO, namely flash point, density, and viscosity, using samples obtained from a petroleum refinery in Riau, Indonesia. Data were collected through direct observation and laboratory testing during a 10-day industrial internship period using standardized ASTM methods. The results indicated that the flash point ranged from 61.83 to 73.50 °C, density ranged from 922.7 to 928.8 kg/m³, and viscosity ranged from 132.7 to 185.0 cSt. Variations in these parameters were observed during the monitoring period. However, further statistical analysis is required to confirm the strength and significance of the relationship between operating temperature and product quality. These findings highlight the importance of consistent monitoring and control of operating conditions to maintain product quality within industrial specifications.

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INTRODUCTION

The petroleum refining industry plays a critical role in supplying energy for industrial applications, particularly in the production of residual fuels such as Marine Fuel Oil (MFO). MFO is widely used in heavy-duty systems, including boilers and steam power plants, due to its high calorific value and economic efficiency. However, the performance and safety of MFO are strongly dependent on its physicochemical properties, particularly flash point, density, and viscosity.

According to international fuel standards, MFO must meet specific quality requirements to ensure safe handling and efficient combustion. The flash point is a critical safety parameter, with a minimum requirement typically above 60 °C to prevent ignition hazards during storage and transportation. Density generally falls within the range of 920–990 kg/m³ depending on fuel grade, while viscosity must be controlled within an acceptable range to ensure proper fuel flow and atomization during combustion. Excessively high viscosity may hinder pumping and reduce combustion efficiency, whereas low viscosity may indicate the presence of lighter, more volatile fractions.

Operating conditions in the refinery, particularly temperature, play a crucial role in determining the distribution of hydrocarbon fractions during the distillation process. Temperature influences the vapor-liquid equilibrium in the distillation column, thereby affecting the separation of light and heavy components. Higher operating temperatures can shift the cut point and increase the incorporation of heavier fractions into the product stream, resulting in higher density and viscosity values. Conversely, insufficient temperature control may lead to the presence of lighter fractions, affecting safety parameters such as flash point.

Previous studies have extensively discussed the relationship between refining conditions and fuel properties. For instance, Gary et al. (2007) reported that variations in distillation parameters significantly influence the physicochemical characterristics of residual fuels. However, most studies are based on controlled experimental or simulation conditions, with limited emphasis on real-time operational data obtained from refinery laboratories.

Although flash point, density, and viscosity are routinely monitored in refinery laboratories, limited studies have examined how daily variations in operating temperature are associated with MFO quality parameters in actual refinery operation data. Therefore, this study aims to evaluate the relationship between operating temperature and MFO quality parameters based on observational data collected during industrial practice at a petroleum refinery in Riau, Indonesia. The findings are expected to provide practical insights into the importance of operational control in maintaining consistent fuel quality.

METHOD

The material used in this study was Marine Fuel Oil (MFO) obtained directly from the production stream of a petroleum refinery located in Riau, Indonesia. Sampling was conducted at the product outlet line prior to storage in the fuel tank to ensure that the collected samples represented the final product quality. The sampling process was carried out over a ten-day observation period, during which one sample was collected each day under normal operating conditions, resulting in a total of ten samples. All samples were obtained from the same sampling point to maintain consistency and minimize variability caused by differences in sampling location.

The operating temperature considered in this study refers to the bottom temperature of the distillation unit, which reflects the condition of heavy fraction separation. Temperature data were obtained from the refinery's Distributed Control System (DCS) panel and recorded simultaneously with the sampling process, representing actual plant operating conditions rather than direct laboratory measurements.

The quality analysis of MFO samples was performed using standardized methods established by ASTM International. The flash point was determined using ASTM D93 (Pensky–Martens closed cup method), in which the sample was heated at a controlled rate and periodically exposed to an ignition source until a flash was observed. The viscosity was measured using ASTM D445 by recording the time required for the sample to flow through a calibrated capillary viscometer at a controlled temperature. Meanwhile, density was determined using ASTM D1298 using a hydrometer to measure the mass per unit volume at a specified temperature.

To ensure data reliability and reproducibility, all measurements were conducted in duplicate, and the reported values represent the average of the repeated measurements. The collected data were analyzed descriptively to observe variations and trends in flash point, density, and viscosity throughout the observation period. In addition, a simple correlation analysis was performed to evaluate the relationship between operating temperature and the measured quality parameters. However, no advanced statistical testing was conducted; therefore, the results are interpreted as indicative trends rather than definitive causal relationships.

RESULTS AND DISCUSSION

The observed variations in flash point, density, and viscosity of Marine Fuel Oil (MFO) during the observation period reflect changes in the distribution of hydrocarbon fractions within the fuel. Although the statistical analysis indicates a positive trend between operating temperature and these parameters, the relationship should be interpreted as associative rather than strictly causal, given the complexity of refinery operations.

The increase in flash point observed in this study can be explained by the reduction of light hydrocarbon fractions in the product. Flash point is highly sensitive to the presence of volatile compounds such as low-boiling hydrocarbons. When the proportion of these lighter components decreases, a higher temperature is required to produce sufficient vapor for ignition. This phenomenon is consistent with fuel safety standards established by the International Maritime Organization, which require a minimum flash point of 60 °C for marine fuels.

Table 1. Operating Temperature and MFO Quality Parameters

Date	Temperature (°C)	Density (kg/m³)	Flash Point Data (°C)	Viscosity (cSt)
Day 1	157.0	922.7	61,83	132.7000
Day 2	176.6	924.6	68.16	151.6500
Day 3	197.2	928.8	72.50	160.4333
Day 4	173.1	924.3	63.50	140.8333
Day 5	170.7	925.9	67.10	154.3667
Day 6	247.5	925.5	66.50	158.4000
Day 7	137.0	926,7	73.50	165.1000
Day 8	178.1	923.1	66.50	143.3333
Day 9	182.5	928.6	67.50	185.0000
Day 10	193.1	928.6	70.50	182.2667

The observed values indicate that the product maintains acceptable safety characteristics. The increase in density further supports the interpretation that heavier hydrocarbon fractions become more dominant in the fuel composition. Density is directly related to the molecular weight and structural complexity of hydrocarbons. Heavy fractions, including long-chain paraffins, aromatics, and polycyclic compounds, contribute significantly to higher density values. According to James G. Speight (2014), residual fuels are typically enriched with such high-molecular-weight components, which originate from the bottom fraction of the distillation process.

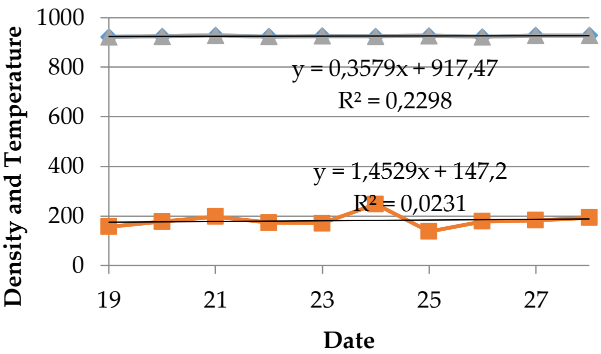

Figure 1. Graph of the Effect of Temperature on Density

Viscosity shows the most pronounced variation among the measured parameters, which is a typical characteristic of residual fuels. The increase in viscosity can be attributed to the higher concentration of asphaltenes and resins, which are complex, polar, and high-molecular-weight compounds. These components enhance intermolecular interactions, leading to increased internal resistance to flow. As reported in studies published in Fuel (journal), viscosity is one of the most sensitive parameters in residual fuels and plays a critical role in determining fuel handling, storage, and combustion efficiency. High viscosity may require preheating to facilitate pumping and atomization, especially in industrial combustion systems.

From a thermodynamic and process engineering perspective, operating temperature influences the vapor–liquid equilibrium within the distillation column. An increase in temperature generally shifts the equilibrium toward the vapor phase for lighter components, allowing them to be separated more effectively and preventing them from remaining in the bottom product. Consequently, the remaining product becomes enriched with heavier fractions, which explains the observed increases in flash point, density, and viscosity. However, this mechanism is highly dependent on other operating parameters such as column pressure, reflux ratio, and feed composition. As discussed by Gary et al. (2007), the interaction between these variables determines the actual cut point and product distribution. Therefore, it is important to emphasize that temperature alone does not fully control the final product characteristics.

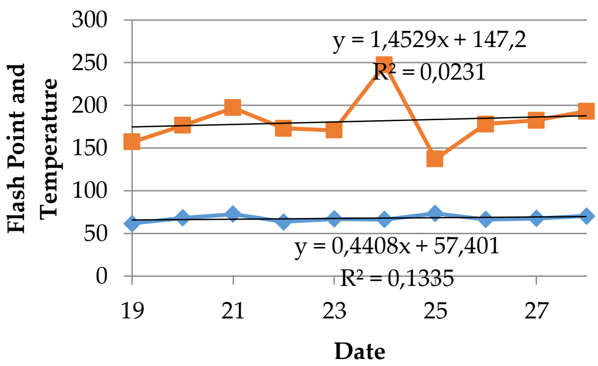

Figure 2. Graph of the Effect of Temperature on Flash Point

The observed trends in this study suggest that the refinery operation during the sampling period may have favored conditions that allowed heavier fractions to accumulate in the MFO product stream. This could be related to operational adjustments aimed at optimizing product yield or meeting specific product specifications. However, without detailed process control data, such as reflux ratio or feed variability, this interpretation remains indicative rather than definitive.

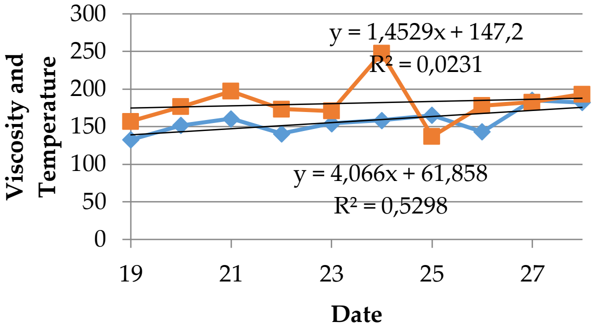

Figure 3. Graph of the Effect of Temperature on Viscosity

In addition, the quality parameters obtained in this study should be evaluated against applicable fuel standards. The flash point values consistently exceed the minimum safety requirement, indicating that the fuel is safe for storage and handling. Density and viscosity values fall within typical ranges for residual fuels as specified in standards such as ISO 8217, referenced by the Energy Institute. This indicates that, despite the observed variations, the overall product quality remains within acceptable industrial limits.

Another important aspect to consider is the variability of the data. The scatter observed in the relationship between temperature and quality parameters suggests that the system is influenced by multiple interacting variables. This variability highlights the importance of implementing comprehensive process monitoring and control strategies in refinery operations. Relying on a single parameter, such as temperature, may not be sufficient to ensure consistent product quality.

Furthermore, the findings of this study are consistent with previous literature, which indicates that residual fuel properties are influenced by both process conditions and feedstock characteristics. However, unlike many previous studies that rely on controlled laboratory or simulation data, this study provides insight into real operational conditions in a refinery environment. This strengthens the practical relevance of the findings, although it also introduces limitations related to data variability and control.

Finally, it is important to acknowledge the limitations of this study. The absence of detailed statistical significance testing and limited sample size restrict the ability to draw definitive conclusions regarding causality. Future studies are recommended to incorporate a larger dataset, more frequent sampling, and advanced statistical analysis, such as multivariate regression, to better isolate the effect of temperature from other influencing variables.

CONCLUSION

Based on the research results, it can be concluded that operating temperature has a significant influence on the quality of Marine Fuel Oil (MFO). An increase in temperature leads to higher values of flash point, density, and viscosity. This indicates that higher temperatures promote the dominance of heavier hydrocarbon fractions in the product. Therefore, controlling the operating temperature is crucial to ensure that the product quality remains in accordance with established standards.

RECOMMENDATION

Future studies should include a longer observation period, clearer process variables, repeated laboratory measurements, and statistical correlation or regression analysis to verify the relationship between operating temperature and MFO quality parameters.

BIBLIOGRAPHY

Alomair, O., et al. (2016). Heavy oil viscosity and density prediction at normal and elevated temperatures. Journal of Petroleum Exploration and Production Technology, 6, 253–263

ASTM International. (2020). *ASTM D93-20: Standard test methods for flash point by Pensky-Martens closed cup tester*.

ASTM International. (2024). *ASTM D445-24: Standard test method for kinematic viscosity of transparent and opaque liquids*.

ASTM International. (2017). *ASTM D1298-12b: Standard test method for density, relative density, or API gravity of crude petroleum and liquid petroleum products by hydrometer method*.

Hamzah, N., Saini, M., & Makbul. (2020). Penggunaan bahan bakar High Speed Diesel dan Marine Fuel Oil terhadap biaya operasi PLTD. SINERGI, 18(1), 8–19.

James G. Speight (2014). *The Chemistry and Technology of Petroleum*. CRC Press.

James H. Gary, Handwerk, G. E., & Kaiser, M. J. (2007). *Petroleum Refining: Technology and Economics*. CRC Press.

Komariyah, N. (2022). Perbandingan hasil pengujian pour point pada crude oil menggunakan metode uji ASTM D 97 dan ASTM D 5853. PPSDM Migas

Mohamed, M. A. E., et al. (2021). Effect of biodiesel blending on residual fuel oil properties. RSC Advances, 11, 33837–33846.

Nelson, W. L. (1958). *Petroleum Refinery Engineering* . McGraw-Hill.

Nwufo, M. A., et al. (2026). A laboratory investigation of the effect of temperature on densities and viscosities of residual fuel oil (RFO). Vubeta Journal, 3(1)

Qomara, W. F., Musfiroh, I., & Wijayanti, R. (2023). Review: Evaluasi stabilitas dan inkompatibilitas sediaan oral liquid. Majalah Farmasetika. 8(3), 209–223.