MORFAI JOURNAL Multidisciplinary Output Research For Actual and International Issue
Multidisciplinary Output Research For Actual and International Issue (MORFAI Journal) ISSN (e): 2808-6635
Volumes 6 No. 3 (2026)

EXPERIMENTAL-BASED OPTIMIZATION MODELING OF COAL BLENDING USING PROXIMATE ANALYSIS TO MEET MT-47 POWER PLANT FUEL STANDARDS

Taufik Arief [1]*, Eddy Ibrahim[2], IE. Frasetyo[3], Maulana Yusuf[4].
Sriwijaya University, Indonesia
E-mail: taufikarief@ft.unsri.ac.id, eddyibrahim@ft.unsri.ac.id, istiglal.prasetyo@gmail.com.

Received	: 01 January 2026	Accepted	: 10 February 2026
Revised	: 17 January 2026	Published	: 28 February 2026

Abstract
This study aims to evaluate the feasibility of using blended coal as fuel for steam power plants (PLTU) by examining the quality of MT-47 coal from PT Bukit Asam through proximate analysis and statistical trend analysis. High-calorie coal (A) and low-calorie coal (B) were blended at ratios of 30:70, 40:60, 50:50, and 60:40, and then tested in the laboratory to determine the intrinsic moisture (IM), ash content, volatile matter (VM), and fixed carbon (FC) content. The test results showed that the IM value ranged from 24.78–27.93%, ash from 4.52–5.79%, VM from 36.05–39.21%, and FC from 30.22–31.50% (adb). Regarding the quality of MT-47, only the ash parameters at the 30:70 and 40:60 ratios meet the standard limits, while the IM, VM, and FC at all ratios do not comply with the MT-47 specifications. Linear regression analysis and Pearson correlation coefficients show a very strong linear relationship between the blending ratio and all proximate parameters, with high correlation values (|r| > 0.95) and coefficients of determination above 95%, thus indicating a consistent trend of quality changes due to variations in the blending ratio. Overall, the 30:70 ratio is the composition closest to the quality of MT-47, although this coal mixture still requires further quality improvement processes to be suitable for direct use as PLTU fuel.

Keywords: Coal blending; Proximate analysis; Linear regression; South Sumatra

INTRODUCTION

Coal remains the dominant energy source for electricity supply in Indonesia due to its abundant availability, relatively low operating costs, and adaptability to various combustion technologies. The International Energy Agency (2022) reports that coal remains a crucial component of the global energy mix, particularly in developing countries that are expanding the capacity of their national electricity systems. In Indonesia, this role aligns with data from the Ministry of Energy and Mineral Resources (2023), which shows that national coal reserves are found primarily in Sumatra and Kalimantan, with South Sumatra in particular accounting for 45% of the national reserves. Coal quality varies significantly depending on its geological conditions. Variations in coal quality are strongly influenced by the degree of coalification, mineral composition, and geological history. South Sumatran coal, for example, is dominated by low- to medium-rank coal, which generally has a high moisture content and moderate calorific value. Handayani et al. (2020) state that moisture content is directly related to the decrease in calorific value, thus affecting combustion efficiency. To systematically assess coal quality, proximate analysis is an international standard method as established by ASTM International (2021). Proximate analysis includes measurements of inherent moisture, ash, volatile matter, and fixed carbon, which determine combustion characteristics and energy efficiency, respectively.±

Improving the quality of low-rank coal is a challenge for the energy industry due to its volatile characteristics. Magister et al. (2024) noted that various quality improvement methods have been developed, such as thermal drying and advanced processing technologies, although these methods often incur high costs. One more economical approach is coal blending, which involves mixing coal from different sources to achieve a quality that meets user specifications. Cahyono et al. (2023) demonstrated that blending can improve quality consistency and reduce coal quality variability.

In the context of power plants, the quality of coal blending needs to be adjusted to established quality standards, one of which is the MT-47 specification. Ronal et al. (2023) emphasized that external factors such as weather can affect the quality of as-received coal, making composition control through blending a crucial step in maintaining stable power plant operations. Furthermore, Pangestu et al. (2025) demonstrated that blending can produce coal with more uniform quality and meet domestic energy market demand.

This study was conducted to determine the results of proximate testing of mixed coal with several variations in composition ratios, as well as to analyze the trend of changes in proximate properties against the mixture ratio used. Testing was carried out in a laboratory with one test (single run) for each variation, without repetition (duplo/triplo) due to time and facility limitations. Therefore, the analysis in this study is descriptive and exploratory, with a focus on the trend of changes in coal quality characteristics. Optimization modeling of coal blending quality parameters is expected to contribute to knowing and transmitting coal quality in South Sumatra as a national energy development center whose characteristics differ in each coal-producing district so that it can be developed for coal gasification, coal liquefaction and coal briquettes in the future as well as providing coal supplies in the country

METHOD

Research Design and Methodological Framework

The research design involved three key stages: field survey, sampling, and laboratory experimental testing, including preparation and proximate analysis experiments. Preparation and experiments were conducted at the Mineral Materials Processing Laboratory, Faculty of Engineering, Sriwijaya University. The methodology was designed to ensure logical consistency and laboratory-scale experiments to model high- and low-quality coal handling procedures through the coal blending process. This included sample preparation, sample preparation, initial characterization, dry separation, proximate analysis, and data analysis. A schematic illustration is shown in Figure 1. The specific sequence can be seen in Figure 2.

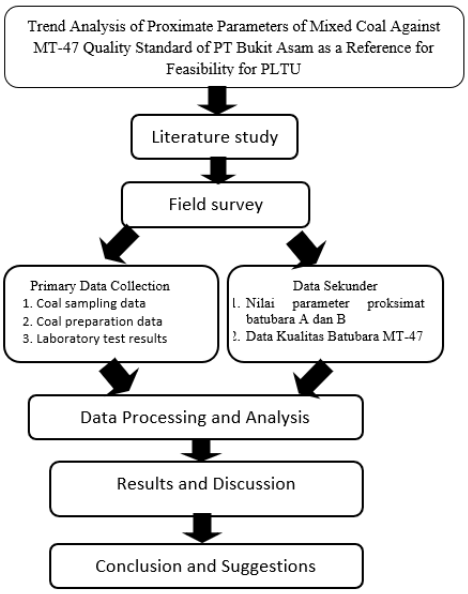

Figure 1. The Study Flowchart

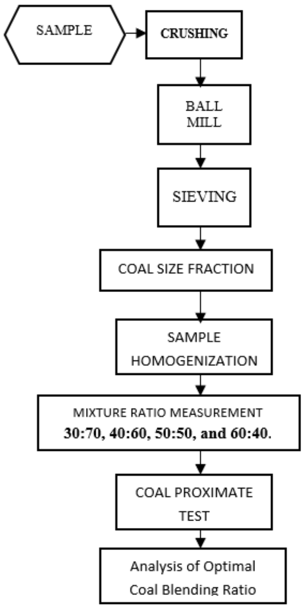

Figure 2. Design Coal Blending Ratio

Data Collection Techniques

This research was designed and implemented through a series of steps including sampling, preparation, mixing, laboratory testing, and data processing and analysis. The activities were conducted at two main locations: the Mining Engineering Materials Processing Laboratory of Sriwijaya University for sample preparation, and the Geolab Engineering Implementation Unit (UPTD) of the South Sumatra ESDM Office for proximate testing. Both facilities were selected because they have standard equipment and support calibrated coal property testing.

Figure 3. Sampling activities at PT Bukit Asam, Tbk and PT. Wijaya Energi

Representative samples were obtained from two mine sites. Coal Sample A, from PT Bukit Asam Tbk in Tanjung Enim, is a higher-calorie coal, while Coal Sample B, from PT Sinar Wijaya Energi in Lahat, is a lower-calorie coal (Figure 3).
The research used was descriptive-experimental, aiming to describe changes in the proximate characteristics of coal due to variations in the blending of two coal sources with different heating values. The research stages included literature review, sampling, preparation, laboratory testing, and analysis and interpretation of the results.

Sample Preparation
Sample preparation begins with the crushing stage. Samples were crushed using a jaw crusher (JB0024FFA) to a particle size of <10 mm as the initial processing step. Subsequently, the samples were ground using a ball mill to reduce the particle size and improve homogeneity. The ball mill operating speed was set at 85% of the critical speed, which is calculated using the equation:

$$Nc = \frac{42,3}{\sqrt{D-d}} \qquad (1)$$

Where: Nc = critical speed (rpm); D = ball mill diameter (m) and D = diameter of the ball (m)

After the refining process, the samples were sieved using a sieve shaker with a total weight of 1.5 kg to obtain a uniform size distribution. The fraction passing 75 mesh was selected as the test fraction, as required for proximate analysis. The samples were then homogenized using the cone and quarter method to ensure even particle distribution before the mixing stage.

The mixing process was carried out with four mass ratios between coal A and B: 30:70, 40:60, 50:50, and 60:40. Each composition was weighed at 300 grams, mechanically mixed, and labeled according to its ratio. These mixed samples were then tested in the laboratory to determine their inherent moisture (IM), ash, volatile matter (VM), and fixed carbon (FC) values.

Figure 4. Figure 4. Coal Mixing Ratio Experimentation

Proximate Analysis

Inherent Moisture (IM) is tested by heating 1 gram of sample at 105°C for 1 hour until constant weight. The IM value is calculated using the following equation

$$IM = \frac{W1-W2}{W1} x100\% \text{.......(2)}$$

Where: IM = Inherent moisture; W1 = Sample weight (grams) and W2 = Remaining drying results (grams)

Ash Contenttested by heating 1 gram of sample at a temperature of 900 ± 15ºC for 7 minutes in a closed atmosphere. Ash value is calculated using the following equation:

$$Ash = \frac{W2}{W1} x100\% \text{.......(3)}$$

Where: Ash= Ash content; W1 = Sample weight (grams) and W2 = Remaining drying results (grams)

Volatile Matter(VM) is tested by heating 1 gram of sample at a temperature of 400 – 450ºC for 1 hour, then the temperature will be raised to 750ºC and heated again for 2 hours. The VM value is calculated using the following equation:

$$\text{VM} = \frac{W1-W2}{W1} x100\% \text{.......(4)}$$

Where: VM = Volatile matter; W1 = Sample weight (grams); W2 = Remaining drying results (grams)

Fixed Carbon(FC) is obtained by subtracting the results from the water content, ash content, and volatile matter. FC is calculated using the following equation:

$$FC = 100 - (IM + Ash + VM) \text{.......(5)}$$

RESULTS AND DISCUSSION

Particle Size Distribution

The particle size distribution was obtained from a milling process using a ball mill and a 75-mesh sieve. The measurement results showed that approximately 52% of the sample passed the 75-mesh sieve after 30 minutes. The particle size distribution can be seen in Figures 5 and Figure 6 below: Graph of distribution of retained weight of sample A against sieving time for total fraction (mesh)

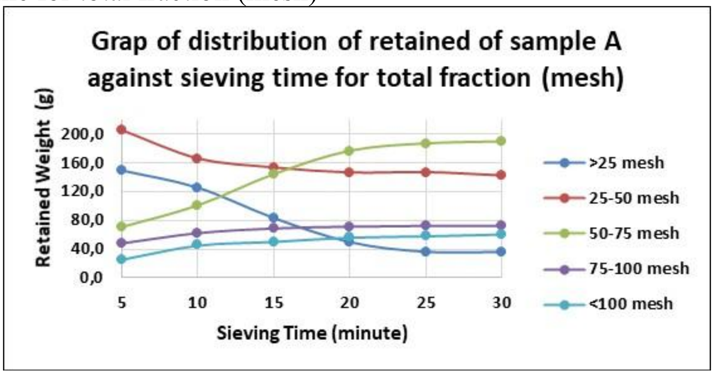

Figure 5. Graph of distribution of retained weight of sample a against sieving time

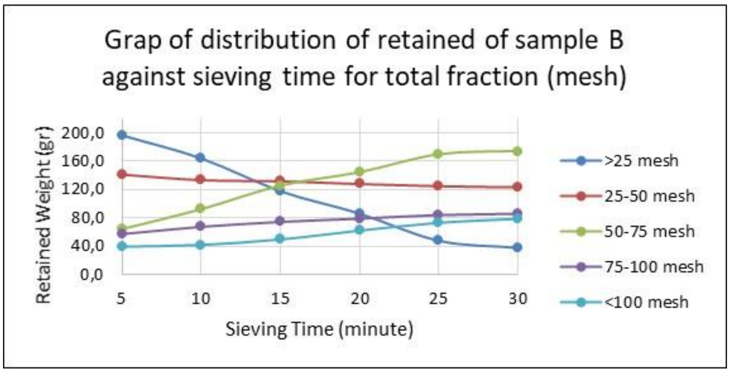

Figure 6. Graph of distribution of retained weight of sample b against sieving time

Particles measuring 75 mesh were then mixed based on the coal mass ratio A:B of 30:70, 40:60, 50:50, and 60:40 with a total weight of each sample of 300 grams.

Proximate Test Results

nalysis of the proximate test results was carried out to assess the quality of blended coal based on the parameters of intrinsic moisture (IM), ash content, volatile matter (VM), and fixed carbon (FC) which can be seen in Table 1 and Figure 7 below showing the inherent moisture (IM) value against the coal blending ratio:

Table 1. Results of proximate analysis of mixed coal (adb)

Mixture Ratio (A:B)	IM (%)	Ash (%)	VN (%)	FC (%)
30 : 70	27.93	4.52	36.05	31.50
40 : 60	27.31	4.79	36.67	31.23
50 : 50	25.69	5.31	38.30	30.70
60 : 40	24.78	5.79	39.21	30.22

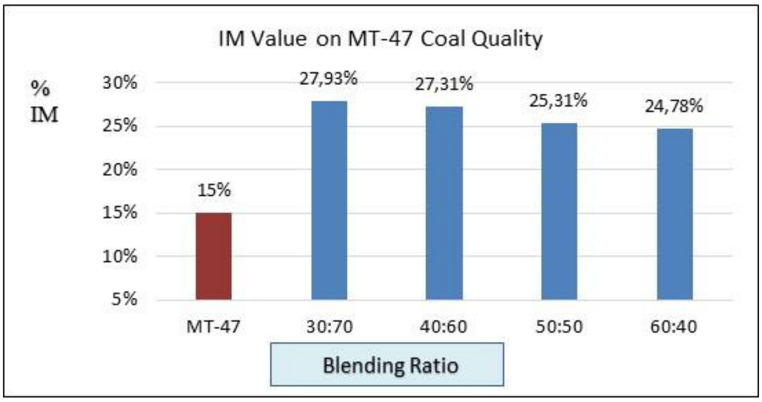

Figure 7. Graph of IM value against MT-47 coal quality

Test results showed that all IM values for the entire coal mixture were above the standard limit. The high moisture content in these test results was likely due to the suboptimal drying process of the samples prior to analysis. Water was still retained within the coal's pore structure, resulting in higher measured inherent moisture (IM) values.

Ash Content Analysis (AC) of MT-47

Test results show that the 30:70 and 40:60 ratios still meet the maximum standard ash limit, while the 50:50 and 60:40 ratios have exceeded this limit (Figure 8). This condition indicates a tendency for ash content to increase as the proportion of coal A in the mixture increases.

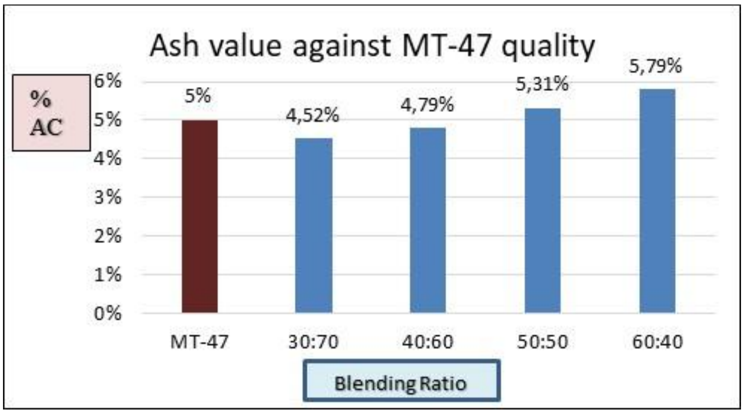

Figure 8. Graph of ash (AC) value against MT-47 coal quality

Volatile Matter Analysis of MT-47

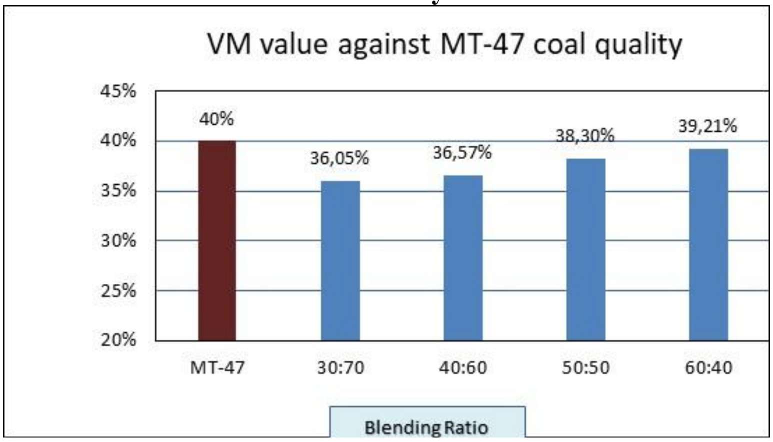

Figure 9. Graph of VM value against MT-47 coal quality

The test results show that all MT-47 Volatile Substance Analysis values are below standard (Figure 9). This is likely due to the high levels of IM still present in the sample that absorbs energy, causing the volatile substances that should be fully released to be measured less than optimally

Fixed Carbon Analysis of MT-47

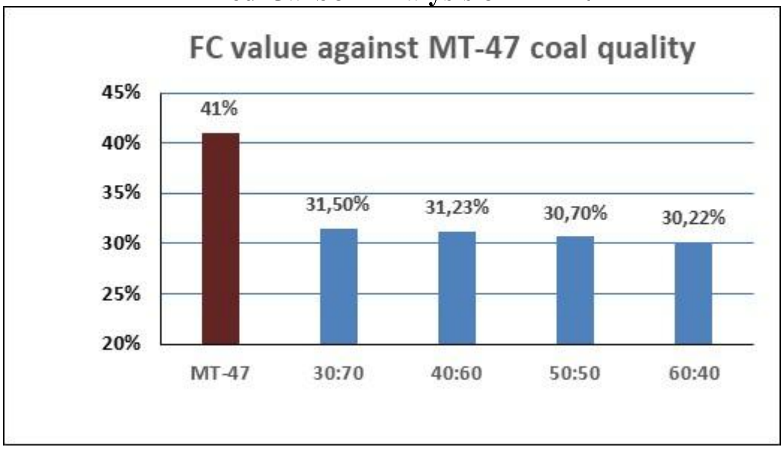

Figure 10. Graph of FC value against MT-47 coal quality

From the test results, it was found that all FC values of all mixtures were far below standard. This indicates that the blended coal has a relatively low fixed carbon content, meaning the amount of carbon remaining after volatile combustion is lower than standard. This also results in lower heat energy production (Figure 10).

Regression Analysis of Mixed Coal

To understand the relationship between coal blending ratio and its proximate characteristics, a simple regression analysis was performed on each parameter (moisture content, ash content, volatile matter, and fixed carbon). This analysis aims to determine the direction and strength of the relationship between parameter changes and variations in the coal blending ratio.

Inherent Moisture Trend

Linear regression yields the equation $y = -0.11x + 31.41$, indicating that every 1% increase in coal A composition causes a 0.11% decrease in IM. The correlation value of $r = -98.66\%$ indicates a very strong negative relationship, while $R^2 = 97.34\%$ indicates that almost all variations in IM can be explained by changes in the mixture ratio. Physically, this trend illustrates that coal A has lower moisture content than coal B, so that increasing its fraction reduces the total IM of the mixture (Figure 11).

This pattern is consistent with the characteristics of higher-ranked coals, which generally have lower porosity and less inherent moisture.

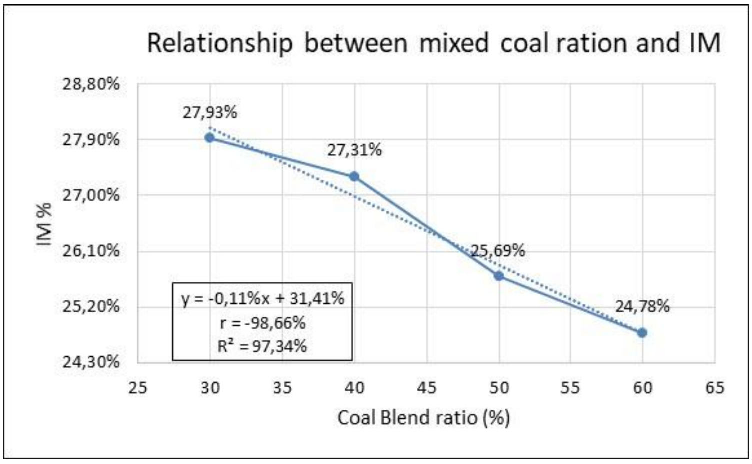

Figure 11. Graph of the relationship between the coal mixture ratio and IM

Ash Content Trend

The Ash parameter follows the regression equation y = 0.04x + 3.15, with a correlation value of r = 99.20%, indicating a very strong positive relationship. Increasing the ratio of coal A consistently increases the ash content by 0.04% for every 1% increase in the mixture ratio. The R^2 value = 98.40% indicates that the regression model has very high accuracy in explaining changes in Ash (Figure 12). This increase indicates that coal A contains higher inorganic minerals than coal B, such as silica (SiO_2), alumina (Al_2O_3), and iron oxide (Fe_2O_3).

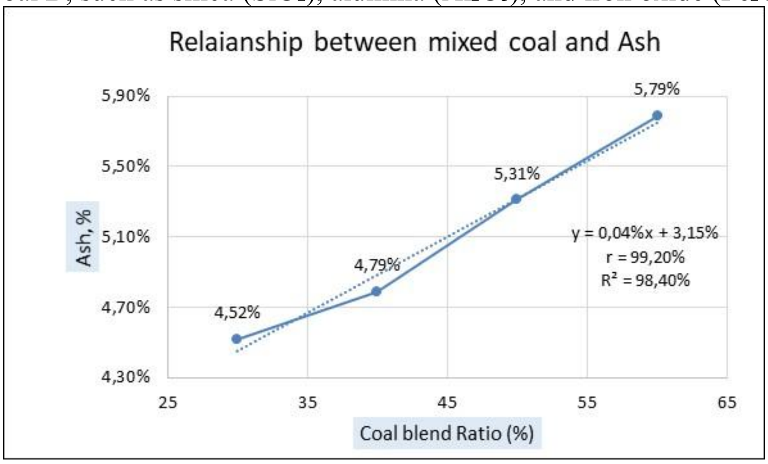

Figure 12. Graph of the relationship between the coal mixture ratio and ash

Volatile Matter Trends

For volatile matter, the equation **y = 0.11x + 32.49** was obtained with an r value of 98.20%, which means that VM increased strongly and in line with the increase in coal composition A. The coefficient of determination R^2 = 96.26% indicates that the regression model is able to describe the behavior of increasing VM very well (Figure 13).

This increase can be attributed to the increased content of volatile compounds, such as light hydrocarbons, which play a role in the initial combustion of coal. Variations in sample homogeneity and drying may also affect the VM value, as some moisture can be released along with the volatile components during heating.

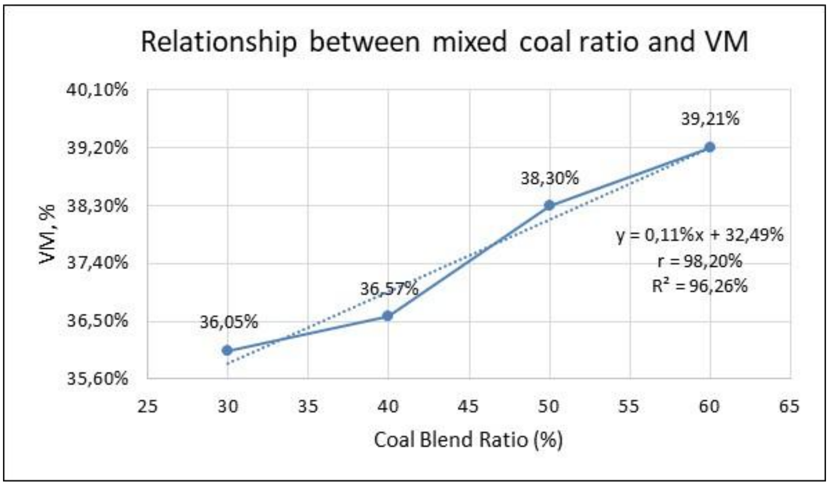

Figure 12. Graph of the relationship between the coal mixture ratio and VM

Fixed Carbon Trends
FC shows the opposite trend with the equation **y = −0.04x + 32.95.** The correlation value r = −97.93% indicates a very strong negative relationship, while **R^2 = 95.91%** illustrates high model accuracy (Figure 14).

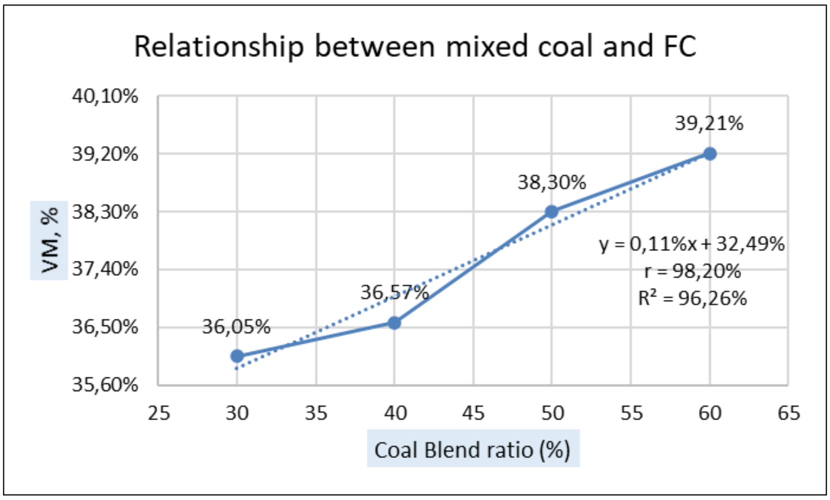

Figure 14. Graph of the relationship between the coal mixture ratio and FC

Every 1% increase in coal A composition decreases FC by 0.04%. This phenomenon indicates that coal A has lower fixed carbon, so that increasing its fraction reduces the overall solid carbon content of the mixture. This phenomenon can be caused by an increase in volatile and ash fractions, which shifts the fixed carbon percentage. Furthermore, FC is also indirectly affected by high moisture content.

CONCLUSION

Based on the results of the research that has been conducted, the following conclusions can be drawn:

1. From the sample preparation process, which includes crushing using a jaw crusher, grinding (ball mill) to obtain a 75 mesh size fraction, the optimal ball mill rotation was obtained at an operating speed of 69.2 rpm and a time of 15 minutes. The homogenization process used the cone and quarter method, producing homogeneous and representative samples. The stability of the particle size distribution after 25 minutes of sieving indicates that the preparation procedure applied is suitable to support reliable proximate analysis.
2. The proximate test results show that the quality of blended coal is greatly influenced by the mixing ratio of coal A and B. The intrinsic moisture and fixed carbon values of all samples are outside the MT-47 standard range, while the ash content parameters still meet the standards at the ratios of 30:70 and 40:60. The volatile matter values of all samples are slightly lower than the MT-47 standard. Among all the ratio variations, the

30:70 mixture is the most similar to the characteristics of MT-47 coal, although it does not meet all parameters simultaneously.

3. Linear regression analysis and Pearson correlation coefficients indicate that the blending ratio has a very strong linear relationship with all proximate parameters. The correlation coefficient ($|r| > 0.95$) and the coefficient of determination ($R^2 > 95\%$) confirm that changes in blended coal quality can be well predicted based on variations in the blending ratio. However, the results indicate that coal blending alone is not sufficient to produce quality equivalent to MT-47 without further quality improvement processes

REFERENCES

ASTM International. (2021). ASTM D3172–13: Standard Practice for Proximate Analysis of Coal and Coke. West Conshohocken, PA: ASTM International.

Cahyono, YDG, et al. (2023). Optimization of coal blending process to meet demand of Suralaya PLTU with market brand BA-48 at PT. Bukit Asam Tbk. Kurvatek, 8(1), 17–42.

Directorate General of New, Renewable Energy and Energy Conservation (EBTKE). (2022). Indonesian Energy Outlook 2022. Jakarta: Ministry of Energy and Mineral Resources.

Fadhilah, A., et al. (2024). The Effect of Rainfall Intensity on the Quality of MT-47 Coal in TLS II Carriages of PT. Bukit Asam, Tbk. Scientific Journal of Engineering and Science, 2(1), 25–32.

Handayani, D., et al. (2020). “Analysis of the Relationship between Water Content and Calorific Value in South Sumatran Coal.” Journal of Mineral and Coal Technology, 16(2), 85–93.

Hidayat, R., Syarifuddin, A. & Pratama, D. (2022) 'Coal Quality Analysis of the Muara Enim Formation in Lahat Regency', Journal of Mineral Technology, 14(2), pp.101–112.

International Energy Agency (IEA). (2022). World Energy Outlook 2022. Paris: IEA Publications.

Iskandar, A., Nugraha, R., & Fathoni, M. (2020). Effect of Blending Ratio on Calorific Value of Low-Rank Coal. Indonesian Mining Journal, 23(1), 55–64.

Ministry of Energy and Mineral Resources (KESDM). (2023). Indonesian Coal Statistics 2023. Jakarta: Directorate General of Minerals and Coal.

PT Bukit Asam Tbk. (2021). Annual Report of PT Bukit Asam Tbk for 2021. Tanjung Enim: PT Bukit Asam Tbk.

Saputra, D., & Fadilah, R. (2022). Correlation of Proximate Analysis and Ultimate Analysis Parameters on Coal Calorific Value. Journal of Mining and Environment, 3(2), 47–54.

Saputra, Dimas, Agus Triantoro, Riswan. 2014. Simulasi Blending Batubara di Bawah Standar Kontrak dalam Blending Dua Jenis Grade Beda Kualitas pada PT Amanah Anugerah Adi Mulia Site Kintap. Jurnal Ilmiah Fisika. 11(1). Hlm. 4-52.

Sepfitrah. 2016. Proximate Analysis of Mining Results in Riau (Case Study of Logas, Selensen and Pangkalan Lesung). Jurnal Sainstek STT Pekanbaru. 4(1), 18–26.

Speight, J. G. (2020). The Chemistry and Technology of Coal. CRC Press.

Speight, James G. 2005. Handbook of Coal Analysis. A john Wiley & Sons.Inc, Publication. USA.

Syurdilah, D., Rahman, A. and Abuamat, H.A.K. 2017. Evaluation of the Causes of Unachieved Coal Blending Quality at Banko Barat PT Bukit Asam (Persero) Tbk. Tanjung Enim, South Sumatra. Mining Journal. 1(5), pp. 7-13

Suparny, Eny. 2016. Study of Optimization of Mixing Coal of Different Qualities to Meet Consumer Demand at PT Berau Coal, Berau Regency, East Kalimantan Province.

Suprapto, H., & Saputra, D. (2020). Proximate Analysis and Its Relationship with Calorific Value of South Sumatran Coal. Journal of Mineral and Coal Technology (TekMIRA), 16(2), 63–72.

Timothy. LD, Determination of Coal Ranking Based on ASTM D388-99 Classification and Coal Quality Recommendations on Coal Samples at PT Bukit Asam Tbk. Tarahan Port Unit. ResearchRepository – ITERA.https://repository.itera.ac.id/depan/submission/SB2406120014/

Ward, C. (2016) Coal Geology and Coal Technology. Elsevier.