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## Correlation Analysis Between Engine Power and Bollard Pull of Tugboats in Indonesia

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### ABSTRACT

*This study aims to analyze the correlation between engine power (horsepower) and bollard pull capacity of tugboats operating in Indonesian ports. The empirical data utilized in this research was gathered from online tugboat specifications, encompassing a sample of 12 tugboats with diverse propulsion systems and engine power ratings. A correlational analysis was employed to determine the relationship between engine power and bollard pull capacity. The analytical estimates demonstrate a strong positive correlation ( $\beta = 0.0125$ ;  $R^2 = 0.936$ ), indicating that 93.6% of the variation in bollard pull can be explained by variations in engine power. These findings provide precise guidance for selecting tugboats that align with the operational requirements of Indonesian ports. Furthermore, the results suggest that strategic tugboat fleet planning, based on the relationship between engine power and bollard pull, is essential for improving port operational efficiency. This study is expected to enrich the literature regarding tugboat capacity in Indonesia and contribute to port technical and operational planning.*

**Keywords:** Tugboat, engine power, bollard pull, port operations correlation analysis.

### ABSTRAK

*Penelitian ini bertujuan untuk menganalisis korelasi antara tenaga mesin (horsepower) dan kapasitas bollard pull pada kapal tunda (tugboat) yang beroperasi di pelabuhan-pelabuhan Indonesia. Data empiris dalam penelitian ini diperoleh dari spesifikasi teknis kapal tunda yang tersedia secara daring, mencakup sampel sebanyak 12 kapal tunda dengan berbagai jenis sistem propulsi dan daya mesin. Analisis korelasional digunakan untuk menentukan hubungan antara tenaga mesin dan kapasitas bollard pull. Estimasi analisis menunjukkan adanya korelasi positif yang sangat kuat ( $\beta = 0,0125$ ;  $R^2 = 0,936$ ), yang mengindikasikan bahwa 93,6% variasi dalam bollard pull dapat dijelaskan oleh variasi daya mesin. Temuan ini memberikan panduan yang lebih akurat dalam pemilihan kapal tunda yang sesuai dengan kebutuhan operasional pelabuhan di Indonesia. Selain itu, hasil penelitian ini menyarankan perlunya perencanaan armada kapal tunda yang didasarkan pada hubungan antara daya mesin dan bollard pull guna meningkatkan efisiensi operasional pelabuhan. Penelitian ini diharapkan dapat memperkaya literatur terkait kapasitas kapal tunda di Indonesia serta berkontribusi dalam perencanaan teknis dan operasional pelabuhan.*

**Kata Kunci:** Kapal tugboat, daya mesin, daya tarik bollard, analisis korelasi operasi pelabuhan.

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## INTRODUCTION

Tugboats are a type of ship that have a significant function in many port activities. These operations involve securing vessels, going in and out of docks, and moving large ships from one harbor to another or to new places. The role of tugboats is essential to increase the safety of navigation, most particularly in regions with intense ship traffic or severe weather.

The bollard pull test is one of the most significant criteria for measuring the capacity of a tugboat. This is a method for calculating the maximum tensile force that can be developed by a tug designed to operate statically. Bollard pull tests, or 'Tug Tests', are commonly used to establish the towing power a tug will have in certain conditions when working at a port and conducting specific operations [1]. In practice, bollard pull is used to assess the extent to which a tugboat can control a larger ship in static conditions, as well as to estimate the tugboat's capacity in real operational conditions in ports or open waters. It serves as an industry standard requirement in many ports for determining the type of tugboat to be used and for designing safer, more efficient port operations [2].

However, bollard pull capacity is subject to many parameters and is not solely dependent on the installed engine power. While brake horsepower (BHP) is the core power developed by the ship's engine to generate the required pull, the final capacity is also significantly affected by propulsion systems, propeller efficiency, and hull design [3]. From the existing literature, most studies discussing the relationship between engine power and bollard pull utilize mathematical models, simulations, or field experimental methods. For example, research by international publications and authors such as Diesel Duck shows that an increase in engine power generally corresponds to an increase in bollard pull [4, 5]. Other works by Heinke and Mertes (2008) or Carlton indicate that advanced propulsion designs—such as azimuth propulsion (ASD), nozzles, or hull fins—can optimize this pulling efficiency and reduce absolute dependence on raw engine power [6, 7]. Similarly, empirical formulas and estimation models have been developed to help designers estimate capacity without high-cost field testing, although they often require ship-specific adjustments and field verification [8, 9, 10].

Despite extensive discussion in international literature, research focusing on the specific operational specifications of tugboats in Indonesia remains limited. Existing studies often rely on data from regions with more advanced shipping infrastructure, and few empirical studies utilize direct data from Indonesian ports. One relevant study by Soelistijono [11] compared simulation and experimental field tests on tugboats in the Port of Surabaya, concluding that field data remains the most valid approach for reflecting actual conditions. However, linear regression analysis measuring the precise strength of the relationship between engine power and bollard pull across tugboats operating in Indonesia has not been widely applied, leaving a clear research gap.

To fill this information gap, this study focuses on using secondary empirical data obtained from the specifications of tugboats operating across Indonesian ports. By applying linear regression analysis, this study aims to identify and analyze the correlation between engine power and bollard pull in the local operational context. The results are expected to provide

practical guidance in selecting appropriate tugboats for various port needs in Indonesia, as well as yield useful insights for future fleet planning and operational management.

The remainder of this paper is organized into the following main sections. Sect. 2 Literature Review discusses relevant literature on bollard pull, tugboat engine power, and the theoretical correlation between them. Sect. 3 Research Methodology outlines the techniques and tools utilized throughout the research project. Sect. 4 Results and Discussion describes the linear regression analysis and evaluates the correspondence between bollard pull and engine power. Finally, Sect. 5 Conclusions presents the main findings and suggestions for further study.

## **METHODOLOGY**

This study adopts a quantitative approach utilizing simple linear regression analysis to investigate the correlation between engine power, measured in horsepower, and bollard pull, measured in tons, for tugboats operating in Indonesia. The secondary data was gathered from tugboat specifications published on ship manufacturer and port websites, capturing engine brake horsepower and bollard pull metrics for twelve vessels deployed across various Indonesian ports and encompassing an engine capacity range from 2,000 HP to 12,000 HP. The research evaluates two main parameters: engine power as the independent variable and bollard pull as the dependent variable.

Data collection relied on online literature searches and specification reviews, with consistency verified across multiple sources. The gathered information was processed using the pandas library in Python, while simple linear regression was applied via scikit-learn to determine the regression coefficient, R-squared value, and statistical significance based on p-values, with matplotlib utilized for graphical visualization. The regression model's explanatory power and significance were assessed through R-squared and p-value metrics. However, the model does not account for external variables such as specific propulsion designs or real-world operational field conditions, meaning the findings are constrained strictly to the analyzed dataset and may not encompass every factor influencing bollard pull capacity.

## **RESULTS AND DISCUSSION**

### **Descriptive Statistics**

Table 1 shows the data used in this study, which includes 12 entries from tugboats with engine power (BHP) and bollard pull (tons). Based on statistical analysis, the results show that the average bollard pull is 74.25 tons with a range between 32 and 150 tons. Meanwhile, the average engine power is 5365.83 HP with a range of 2000-12000 HP.

### **Correlation between Engine Power and Bollard Pull**

A simple linear regression analysis shows a significant positive relationship between engine power (BHP) and bollard pull (BP). The regression coefficient (slope) obtained is 0.0125, with an intercept of 7.32 and an R-squared value of 0.936. This indicates that this linear

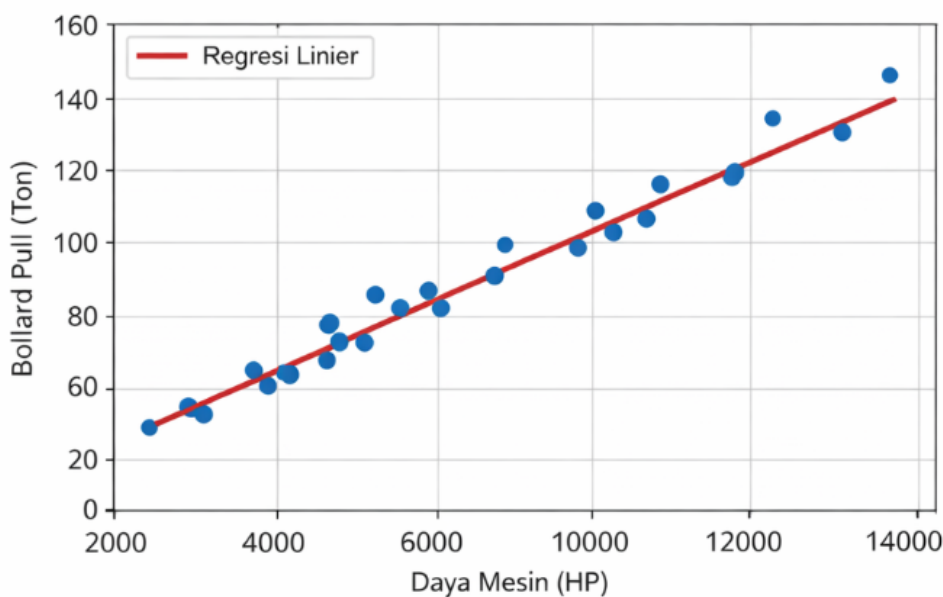
regression model can explain approximately 93.6% of the variation in bollard pull based on engine power. These results indicate that an increase in engine power is significantly followed by an increase in bollard pull on tugboats operating in Indonesian ports.

**Table 1. Tugboat and bollard pull data.**

Vessel	Engine Power (BHP)	Bollard Pull (tons)
AHTS1	12000	150
AHTS2	6000	80
AHTS3	8080	129
Tug1	10070	140
ASD1	6020	70
ASD2	5020	65
ASD3	4800	50
Harbour1	2000	42
Harbor2	2800	38
Harbor3	2200	32
Harbor4	2400	40
Tug2	3000	55

**Visualization of Analysis Results**

To facilitate understanding of the relationship between engine power and bollard pull, the following two graphs are included.

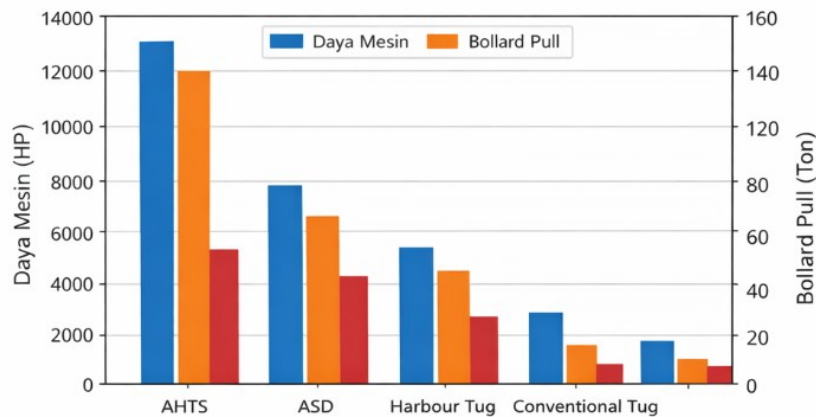


**Figure 1. Relationship between engine power and bollard pull with regression line.**

Figure 1 presents a scatter plot graph of engine output power (BHP) and bollard pull (BP) performances on tugboats operating in Indonesia. Each point on the chart represents one tug, with BHP (brake horsepower) shown along the x-axis and bollard pull in tons along the y-axis. The fitted line indicates bollard pull is increasing whereas the engine power increases. Positive coefficient means that more power from the engine results in higher bollard pull.

Figure 2 shows the distribution of engine power and bollard pull on tugboats operating in Indonesian ports. This graph provides a more detailed picture of the variability of bollard pull based on different engine power categories. From this graph, it can be seen that although

there are some ships with low engine power, some ships with high engine power have very large bollard pull, indicating significant differences in pulling capacity among the tugboats tested.



**Image 2: Figure 2. Graph of engine power and bollard pull distribution on different tugboats.**

### Discussion of Findings

Linear regression analysis results reveal highly positive correlation between engine power and bollard pull. These findings are in line with previous studies that tugboats with larger installed power generally exhibit greater bollard pull capacity [2], [6]. These results have strong relevance for Indonesian ports, where large ports are in need of tugboats with necessary bollard pull to handle big ships like post-Panamax container ships and large oil tankers.

Nonetheless, albeit a clear correlation between engine power and bollard pull seems evident, it is of course obvious that also other factors such as design of the ship propulsion together with efficiency of propulsion systems are significant in the determination of actual pulling capability. For instance, tugs with better propulsion system design (e.g., azimuth propulsion/ASD) can have larger bollard pull even though their engine power is less than that of those tugs with conventional propulsion [7], [8]. That is, although engine power plays a great part of the bollard pull capacity, other design factors are waited and extended to the following study.

### Comparison with Previous Research

This study is in line with several previous studies that link engine power and bollard pull in tugboats. For example, a study conducted by Soelistijono [3] shows that the relationship between engine power and bollard pull is indeed strong, but the influence of ship design and propulsion systems is also very significant [9]. Similarly, the study by Paulauskas [2] shows that although engine power plays a major role, the propulsion efficiency of a ship can increase bollard pull capacity without having to significantly increase engine power [10].

However, this study has the advantage of using empirical data specific to tugboats operating in Indonesia, thus providing a more accurate picture of local conditions. In the future, this study can be expanded by collecting more data from other ports in Indonesia and exploring various other types of tugboats.

## CONCLUSIONS

This study successfully identified and analyzed the relationship between engine power (horsepower) and bollard pull (tons) in tugboats operating in Indonesian ports. The results of the analysis show that there is a significant positive relationship between the two variables, with an R-squared value indicating a very high level of relationship strength. These findings confirm that an increase in tugboat engine power is directly proportional to an increase in bollard pull, which is a crucial factor in port operational planning.

In addition, the results of this study provide practical insights for port managers and tugboat operators in Indonesia in selecting tugboats with the bollard pull capacity required for various port activities. Although this analysis uses limited secondary data, this study introduces a linear regression approach to understand the correlation between engine power and bollard pull in the Indonesian context. Further research with broader field data and a more diverse range of tugboats is needed to strengthen these findings. Overall, this study can be used as a reference in developing tugboat fleet planning policies in Indonesia, as well as improving port operational efficiency and safety.

## REFERENCE

- [1] Paulauskas, V., Paulauskas, D., & Simutis, M. (2024). Estimation of Tug Pulling Power (Bollard Pull) and Number of Tugs Required During Ship Mooring Operations. *Journal of Marine Science and Engineering*, 12(11), 1959.
- [2] Paulauskas, V., Paulauskas, D., & Simutis, M. (2024). Estimation of Tug Pulling Power (Bollard Pull) and Number of Tugs Required During Ship Mooring Operations. *Journal of Marine Science and Engineering*, 12(11), 1959-1-17.
- [3] Kang, H., Li, J. H., Kim, M. G., Jin, H., Lee, M. J., Cho, G. R., & Jin, S. (2025). Estimation of Hydrodynamic Coefficients for the Underwater Robot P-SUROII via Constraint Recursive Least Squares Method. *Journal of Marine Science and Engineering*, 13(9), 1610.
- [4] Carlton, J. (2012). *Marine propellers and propulsion*. London: Elsevier.
- [5] Funeno, I. (2009, June). Hydrodynamic optimal design of ducted azimuth thrusters. In *First International Symposium on Marine Propulsors smp* (Vol. 9). Trondheim: International Symposium on Marine Propulsors.
- [6] Gokarn, R. P. (1969). Tug propeller design. *Marine Technology and SNAME News*, 6(02), 147-155.
- [7] Artyszuk, J. (2013). Types and power of harbour tugs-the latest trends. *Scientific Transactions (Prace Naukowe)-Transport, Warsaw University of Technology*, 98, 9-20.
- [8] Wilkins IV, J. R. (2012). *Propeller design optimization for tunnel bow thrusters in the bollard pull condition* (Doctoral dissertation, Massachusetts Institute of Technology).
- [9] Guijarro, B., Ordines, F., & Massutí, E. (2017). Improving the ecological efficiency of the bottom trawl fishery in the Western Mediterranean: It's about time!. *Marine Policy*, 83, 204-214.
- [10] Vega, A., & Martínez, D. L. (2015). Reenactment of a bollard pull test for a double propeller tugboat using computational fluid dynamics. *Ship Science and Technology*, 8(17), 9-18.