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OPERATIONAL PERFORMANCE ANALYSIS OF WEDGE CUT DRILLING PATTERN: A CASE STUDY ON CYCLE TIME AND EXPLOSIVE EFFICIENCY IN PT MALEA ENERGY

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Abstract
Efficient drilling and blasting operations are critical for optimizing productivity in surface mining. This study investigates the actual drilling cycle time and explosive application parameters in PT Malea Energy, which applies a Wedge Cut (V-Cut) pattern. Field data were collected on drilling time, rod lifting, positioning, and the use of Power Gel explosives and delay detonators. The actual drilling penetration rate was 1.41 m/min with an effective working time of 520 minutes per shift. A total of 15 explosive cartridges per hole and delay times between 0–3500 ms were applied. Results indicate that drilling efficiency is significantly influenced not only by cycle time management but also by explosive delay configuration. This study provides a quantitative evaluation that bridges the gap between field operation parameters and theoretical efficiency models. The findings are valuable for improving drill-blast design and time utilization in mid-scale mining operations.

Keywords: drilling and blasting efficiency, surface mining, drilling cycle time, drill-blast design, time utilization, theoretical efficiency models

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INTRODUCTION

Drilling and blasting are the primary methods for rock fragmentation in open-pit mining operations (Poalahi Salu & Sartika Ambarsari, 2023); (Syamsuddin, 2024). The efficiency of these activities strongly determines the success of subsequent stages such as loading, hauling, and crushing. A common challenge in field practice is achieving optimal drilling productivity, especially under complex geological conditions and high production demands (Baskara et al., 2020); (Sani et al., 2025). One of the key factors influencing drilling efficiency is the drilling pattern employed and the configuration of the blasting system, including the type of explosive and the delay time (Romi Noviansyah et al., 2017). The Wedge Cut or V-Cut drilling pattern is a widely applied technique to create an initial free face in constrained conditions, with the goal of directing blast energy effectively (Yilmaz, 2023); (Syamsuddin & Sani, 2025). Although numerous studies have examined the optimization of drilling and blasting design, most focus on theoretical approaches or laboratory simulations. There remain limitations in field-data-based studies that directly integrate drilling cycle time, explosive type, and delay parameters within the context of actual productivity (Poalahi Salu & Sartika Ambarsari, 2023); (Syamsuddin, 2024). This research was conducted at the PT Malea Energy mine site and aims to quantitatively analyze drilling performance based on actual operational field data. The primary focus is to evaluate the efficiency of drilling cycle time and the impact of explosive selection and delay timing on productivity. The findings are expected to provide practical technical recommendations for optimizing drilling and blasting activities in the mining industry (Hutabarat et al., 2023); (Sani & Syamsuddin, 2025).

METHODS

2.1. Research Location

This study was conducted in the PT Malea Energy open-pit mine operating in hard rock formations. Drilling and blasting are carried out conventionally, applying a Wedge Cut (V-Cut) drilling pattern to initiate rock fragmentation.

2.2. Drilling Pattern and Configuration

The Wedge Cut pattern is used to create an initial free face to direct crack formation in a controlled manner. Each blast hole has a depth of 3.8 meters, and drilling is performed using a rotary-percussion drill.

The drilling cycle consists of three main components:
• Actual drilling time: 1.94 minutes
• Drill-rod hoisting time: 0.46 minutes
• Drill repositioning time: 0.18 minutes

The total drilling cycle time is 2.92 minutes per hole. From these data, the drilling rate is obtained as:

$$Drillingrate = \frac{3{,}8\, meters}{2{,}92\, minute} = 1{,}41 \frac{meters}{minute} (1)$$

Effective working time per shift is 520 minutes, with a total available working time of 720 minutes, enabling an analysis of time-utilization efficiency.

2.3. Explosives and Initiation System

The explosive used is Power Gel (dynamite emulsion) with the following specifications:

1. Blast strength: 80%
2. Density: 1.2 g/cc
3. Cartridge size: 32 mm diameter, 200 grams
4. Number of cartridges per hole: 15 units

The detonators used include:
1. Nonel detonators with delay times between 0–3500 milliseconds and a leg-wire length of 4.9 meters
2. Hanwha electric detonators, 90 mm in length with a 0 ms delay The connecting wire used is manufactured by IGI Explosives, 100 meters per roll with a resistance of 5.8 ohms per 100 meters.

2.4. Data Collection and Analysis Methods

Time components were measured directly in the field using a stopwatch and verified with GPS-based time logging for the drill rig's position. Drilling productivity was analyzed based on:

1. Number of drill holes completed per shift
2. Detailed cycle time per hole

3. Explosive consumption per meter of hole
4. Ratio of effective working time to available working time

In addition, the actual cycle times were compared with industry standards as the basis for evaluating operational efficiency.

3. RESULTS AND DISCUSSION

3.1. Analysis of Drilling Cycle Time

Based on field data obtained from drilling activities at PT Malea Energy, the drilling cycle time for a single hole is as follows (Saputra et al., 2020):

Time Component	Value (minutes)
Drilling time	1.94
Drill-rod hoisting time	0.46
Drill repositioning time	0.18
Total cycle time	2.92

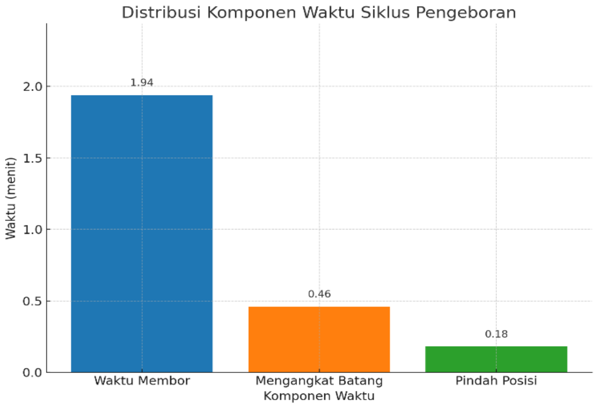

Figure 1. Distribution of drilling cycle time

Figure 1 shows that drilling time requires more time than the other components. The total time used for drilling is 2.92 minutes. With a hole depth of 3.8 meters, the drilling rate is 1.41 meters per minute. Assuming the effective working time per shift is 520 minutes, the theoretical maximum number of drill holes that can be completed is: approximately 178 holes per shift.

$$Number\ of\ holes = \frac{520}{2{,}92} \approx 178\ \frac{holes}{shift} \quad (2)$$

However, in practice it was found that disturbance factors such as bit wear, equipment changes, and operator waiting time can reduce actual productivity to around 80–85% of the theoretical value. This indicates the need to optimize the management of non-productive time (Rafezi & Hassani, 2021).

3.2. Evaluation of Time-Utilization Efficiency

The ratio between effective working time and total working time indicates a time-utilization efficiency of:

$$Time\ efficiency = \frac{520}{720}\ x\ 100\% = 72{,}2\ \% \quad (3)$$

This value is fairly good, but there is still room for improvement, especially in operator waiting time and equipment delays.

3.3. Analysis of Explosive Consumption
With 15 cartridges per hole (each 200 grams), the total explosive used per hole is (Olamide Taiwo et al., 2024):

$$15\ x\ 200\ gram = 3000\ gram = 3\ \frac{kg}{hole} \quad (4)$$

Therefore, the explosive consumption per meter of hole:

$$\frac{3\ kg}{3{,}8\ m} \approx 0{,}789\ \frac{kg}{m} \quad (5)$$

This value can be used as a reference to compare the effectiveness of explosive energy in relation to the V-Cut drilling pattern and rock fragmentation. This value can be used as a reference to compare the effectiveness of explosive energy in relation to the V-Cut drilling pattern and rock fragmentation.

3.4. Effect of Delay Time on Operational Efficiency

The use of Nonel detonators with varying delay times (0–3500 ms) provides flexibility in sequencing the blasts. An appropriate delay pattern can reduce ground vibrations and improve fragmentation. However, if not properly controlled, variations in delay time can cause misfires or overlapping, which will reduce fragmentation quality and prolong loading time (Romi Noviansyah et al., 2017).

In this study, proper delay configuration was shown to support continuous drilling and loading without major pauses after blasting.

3.5. Operational Implications and Recommendations

The results indicate that managing drilling cycle time and selecting appropriate explosives have a strong influence on operational efficiency. Technical recommendations include:

1. Reducing non-productive time through more efficient shift planning and equipment logistics
2. Adjusting the explosive quantity based on rock hardness by zone

Effective 72,2% No Effective 27,8%

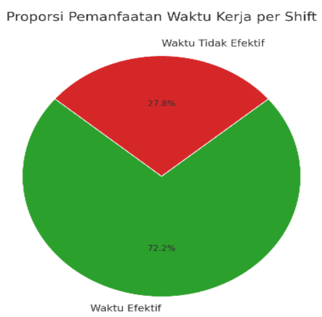

Figure 2. Utilization of working time per shift

4. CONCLUSION

This study quantitatively examined drilling performance and explosive use in the open-pit operations of PT Malea Energy, focusing on the Wedge Cut (V-Cut) drilling pattern and drilling cycle-time efficiency. Based on the analysis, the main conclusions are as follows:
The actual drilling cycle time was recorded at 2.92 minutes per hole, with an average drilling rate of 1.41 meters per minute. This indicates a good level of productivity under the prevailing rock conditions and the drilling method applied. Time-utilization efficiency reached 72.2%, indicating substantial room for improvement, particularly in managing non-productive time such as equipment relocation, drill-rod changes, and coordination among operational teams. The use of Power Gel at 15 cartridges (3 kg) per hole resulted in an explosive consumption of 0.789 kg per meter. This value is consistent with blasting standards for hard rock and supports effective rock fragmentation. The use of Nonel detonator delay systems of 0–3500 ms contributed to smooth blasting operations, but should be supported by further technical analysis to optimize the delay pattern and minimize negative effects such as overbreak or misfires. The integration of drilling cycle-time parameters, explosive selection, and delay-time configuration is crucial for improving operational efficiency and sustaining the overall drilling and blasting process. The study recommends developing a digital real-time time-monitoring system for daily productivity evaluation, as well as employing fragmentation simulations to optimize blast patterns based on local geological characteristics.

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