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CALCULATION OF FUEL CONSUMPTION IN HD 465-7R USING ENGINE RPM METHOD AND APPROACH PER SEGMENT AT MINING INDUSTRY IN EAST KALIMANTAN

PERHITUNGAN KONSUMSI BAHAN BAKAR PADA HD 465 -7R MENGGUNAKAN METODE RPM MESIN DAN PENDEKATAN PER SEGMENT PADA PERUSAHAAN PERTAMBANGAN DI KALIMANTAN TIMUR

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ABSTRACT

Fuel is usually used by engines to move or do work. In this article, the machine is a mining industry vehicle with the code HD 465 – 7R type from the Komatsu company. The vehicle is used to move overburden material from the loading area to the disposal area. Fuel consumption is usually influenced by several factors, the most influential of which are the slope of the road, the type of material used for the road, and the distance from the loading place to the dumping place. There are several methods are used to calculate fuel consumption, the most familiar of which is the vehicle working hours (hour meter) method. In this research, the calculation of fuel consumption uses engine RPM with a segment approach method taken with a segment distance of between 100 - 200 meters. The results of calculating fuel usage on the HD 465 – 7R have a figure of 51.7 liters/hour, with the actual value being 51.9 liters/hour. The conclusion of this research is that by using the engine RPM method, the results of fuel usage calculations are also close to the actual values. Testing by RPM with an hour meter is very different, where testing by RPM is based on the length of duration at that RPM number; the higher the RPM and the longer the duration of time, the greater the fuel released. This is continuous with the road segment, where an uphill road segment will definitely increase travel time due to a decrease in speed, and the RPM will increase.

Keywords: fuel, fuel consumption, RPM machine, segment.

ABSTRAK

Pengunaan bahan bakar biasanya digunakan oleh mesin untuk berpindah ataupun melakukan sesuatu pekerjaan. Pada artikel ini, mesin tersebut ialah kendaraan pada industri pertambangan dengan jenis HD 465 – 7R dari perusahaan Komatsu. Kendaraan tersebut digunakan untuk memindahkan material tanah penutup dari tempat pemuatan hingga ke tempat pembuangan (disposal area)*. Konsumsi bahan bakar biasanya dipengaruhi oleh beberapa faktor, antara lain yang paling berpengaruh adalah kemiringan jalan, jenis material yang digunakan untuk jalan, dan jarak dari tempat loading menuju ke tempat dumping. Terdapat beberapa metode yang digunakan untuk menghitung konsumsi bahan bakar, yang paling familiar ialah metode jam kerja kendaraan (*hour meter*). Pada penelitian kali ini, perhitungan konsumsi bahan bakar menggunakan RPM mesin dengan metode pendekatan persegment yang diambil dengan jarak persegment antara 100 – 200 meter. Hasil perhitungan pengunaan bahan bakar pada HD 465 – 7R memiliki torehan angka sebesar 51,7 liter/jam, dengan nilai aktualnya sebesar 51,9 liter/jam. Kesimpulan dari penelitian ini ialah dengan menggunakan metode RPM mesin, hasil perhitungan pengunaan bahan bakar juga mendekati nilai aktual. Pengujian secara RPM dengan* Hour meter *sangat berbeda, dimana pengujian secara RPM didasari dari lamanya durasi pada angka RPM tersebut,*

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semakin tinggi RPM dan semakin lama durasi waktu, maka bahan bakar yang dikeluarkan semakin besar. Hal ini berkesinambungan dengan segmen jalan, dimana segmen jalan yang menanjak pasti akan membuat waktu tempuh menjadi lama karena penurunan kecepatan, dan RPM menjadi naik.

Kata kunci: bahan bakar, konsumsi bahan bakar, RPM mesin, segment.

INTRODUCTION

Vehicle fuel consumption is a significant factor in the modelling and estimation of vehicle operating costs and traffic congestion costs (Ramli *et al.*, 2015). In the research of Murdianto (2016), he stated that fuel consumption is the amount of fuel per time for producing one horsepower (HP). So fuel consumption is a measure of the economy of fuel use (Murdianto, 2016).

Almost all material transportation activities in mining use diesel-powered engines. According to Saepuloh (2017), a diesel engine is an engine whose internal combustion system is the choice of many combustion engine users for their vehicles because of its superior fuel efficiency.

Fuel consumption in the mining sector is divided into several areas, such as mining equipment, mining operations, the needs of mining workers (human resources), as well as equipment in the office, such as air conditioning (cooling equipment) and space heating (heating equipment) (Attari *et al.*, 2021).

Fuel consumption can significantly vary from one vehicle to another, even when comparing two vehicles from the same make, model, year, and fuel type. This is caused by different factors that may increase or decrease the amount of fuel consumed during the same trip (Barbado and Corcho, 2021).

Fuel consumption on the transport vehicle is influenced by several factors (Dindarloo and Siami-Irdemoosa, 2016 on Attari *et al.*, 2021), including:

1. Payload (PL)
   The amount of cargo a dump truck can carry is called the capacity, which affects the fuel consumption of the vehicle.
2. Loading Time (LT)
   The time it takes for a truck (dump truck) to fully load to reach its cargo capacity is one of the factors affecting fuel consumption. Consequently, the longer it takes to load, the more fuel consumption will be.
3. Idled While Empty (ES)
   The amount of time a loading truck (dump truck) is waiting in line to arrive at the loading location.
4. Empty Travel Time (ETR)
   The amount of time a loading truck (dump truck) spends after its load is discharged on its way back to the loading location. In this period, as the vehicle is empty, it is faster and consumes less fuel.
5. Idled While Loaded (LS)
   It includes the amount of time a truck has been loaded but is in the queue to exit the mine and is not yet in a position to travel to the discharge destination or factory; also because of the lack of placement of facilities within the mine and the existence of hills and ramps temporarily formed due to various factors in the intra-mine routes, this time can be prolonged.
6. Loaded Travel Time (TR)
   The time it takes for a loaded truck (dump truck) to get out of the mine and reach the discharge location.
7. Distance (D)
   The length of the route the trucks (dump trucks) pass will affect their fuel consumption.
8. Driver Behavior (DB)
   This factor is related to the driver's behavior along the route of the mine, depending on the environmental conditions and shows how the driver behavior leads to more fuel consumption. These behaviors include reactions to weather conditions and the use of air conditioners or heaters or working with a clutch pedal, etc., depending on the skill and ability of the driver. Appropriate training will also be very effective in controlling and reducing this factor.
9. Ground (G)
   The type of mining roads is also an important factor in fuel consumption. Clean and smooth paths influence the adhesion force of the tires. Routes which in their construction and design road quality factors are considered would be ideal for mines.
10. Slope (S)
    Due to the passage of trucks which are fully loaded and the tractive force and

friction affecting the trucks, the slope of the mine roads is a factor that will affect fuel consumption.

Time and distance are major contributors to consumption of total fuel and are categorized in travel-related groups. Effective use of fuel and development action-based improvements surgery will be significantly profitable for the mining economy and other industries that involve material movement and transportation activities (Nurkhamim *et al.*, 2023). This paper explains that monitoring and evaluating dump truck production and fuel consumption levels is critical to the financial sustainability of open pit mines, as fuel costs are a major contributor to operational costs. Therefore, tactical and strategic solutions regarding fuel use can bring observable benefits to mining companies.

In calculating the fuel consumption of the HD 465-7R transport vehicle using engine RPM, the following equations from (Indonesianto, 2014) are used:

$$\text{Machine Hp} = \frac{\text{Torque} \times \text{RPM}}{5252} \quad \text{.....(1)}$$

$$\text{Load Factor} = \frac{\text{RPM using}}{\text{RPM maximal on machine}} \quad \text{.....(2)}$$

$$\text{FC, in gal/hr} = \frac{\text{weight of fuel} \times \text{brake hp} \times \text{Lf}}{\text{weight of fuel gallon per liter}} \quad \text{.....(3)}$$

Explanation:
Weight of fuel = for solar is 0.5 lb/hp/hr
Weight of fuel = for gallon solar 7.2 lb/gal

Torque is a measure of machine ability to do work. The amount of torque can be determined by measuring the engine load and the length of the torque arm. Measuring the load on the machine is carried out with a dynamometer (Effendi, 2018).

Load factors, defined as the portion of utilized engine power, are used in the estimation of the diesel mining equipment fuel consumption. Every type of equipment is involved in the specific work operation, common in quarrying of crushed stone. Furthermore, load factors are specific to the equipment type and their application/operating conditions (Klanfar, Korman and Kujundžić, 2016).

For mathematical calculations, in this research uses simple multiplication from mathematics, namely cross multiplication, where cross multiplication is an interesting method. The cross multiplication method is a multiplication whose operation is to cross multiply one number by another so that it contains the result of the multiplication (Irawati *et al.*, 2020).

Cross multiplication method emphasizes addition rather than multiplication so that anyone can easily understand and use it in multiplication problems. Meanwhile, the downward multiplication method is a multiplication method that is commonly used in the operation of multiplying numbers, both two digits and three digits (Suherdi *et al.*, 2020).

The last equation uses simple physics calculation from the book (Abdullah, 2016):

$$S = \frac{V}{t} \quad \text{.....(4)}$$

Explanation:
S = distance in km
V = velocity in km/hour
t = time in hour

In this article, the discussion will be more directed towards proving that calculating fuel consumption using the RPM method per segment also gives results that are close to actual; this is the hypothesis in this article. Besides that, the familiar calculation of fuel consumption is using an hour meter.

Finally, the segment approach carried out by researchers was carried out under the pretext of providing more detailed information on each road segment. Referring to the paper (Pataras *et al.*, 2019), that segment is road preservation treatment within the limits of one length of continuous road section, which is carried out to obtain uniform road conditions, namely steady and standard roads along the segment.

METHODOLOGY

The primary data in this research is RPM per segment and traveling time per segment. This data can be obtained by joining riding the HD 465 unit, then tracking travel time using Avenza Map, Strava applications and recording while vehicle is moving, mining software to get a distance segment and making up a segment, to take the RPM by subjectively observing the engine rotation speed on the unit's dashboard and then recording the results. Figure 1 is the collection

of primary data by directly observing the RPM needle in the HD 465 - 7R cabin, which, as mentioned above, uses the segment method, which is assisted by using a map software application with coordinates in Figure 2, then recording the segment times is assisted by using an application, Strava as in Figure 3.

Secondary data obtained from the second party or company are the mine design, road and disposal designs, as well as the latest contours for making road maps and tracks, HD 465-7R specifications from the manual book of Komatsu company, and fuel usage data from the units used.

Figure 1. Point of view in HD 465-7R while recording data

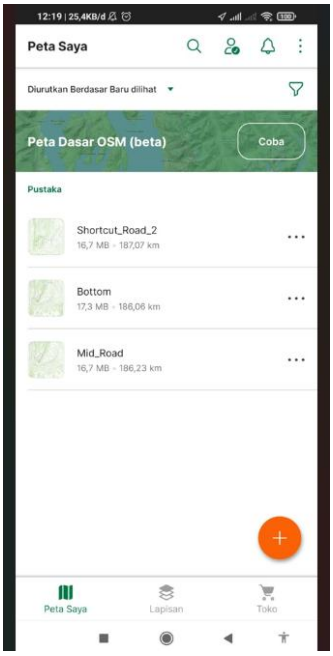


Figure 2. Avenza map

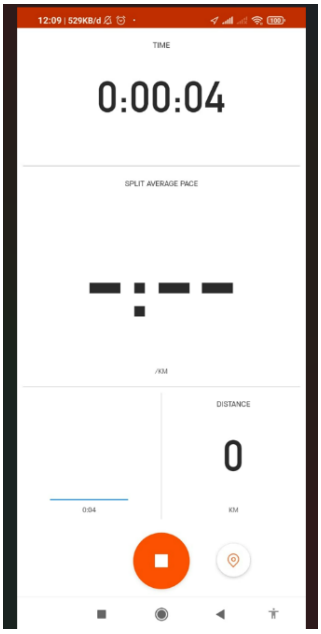


Figure 3. Strava

Both applications will get the split screen and record by using the recording application. The results of data collection are engine rpm and segment travel time which will later be processed in the next chapter with the equation (1), (2), (3), (4) and work reference from Nurrochman (2019) research.

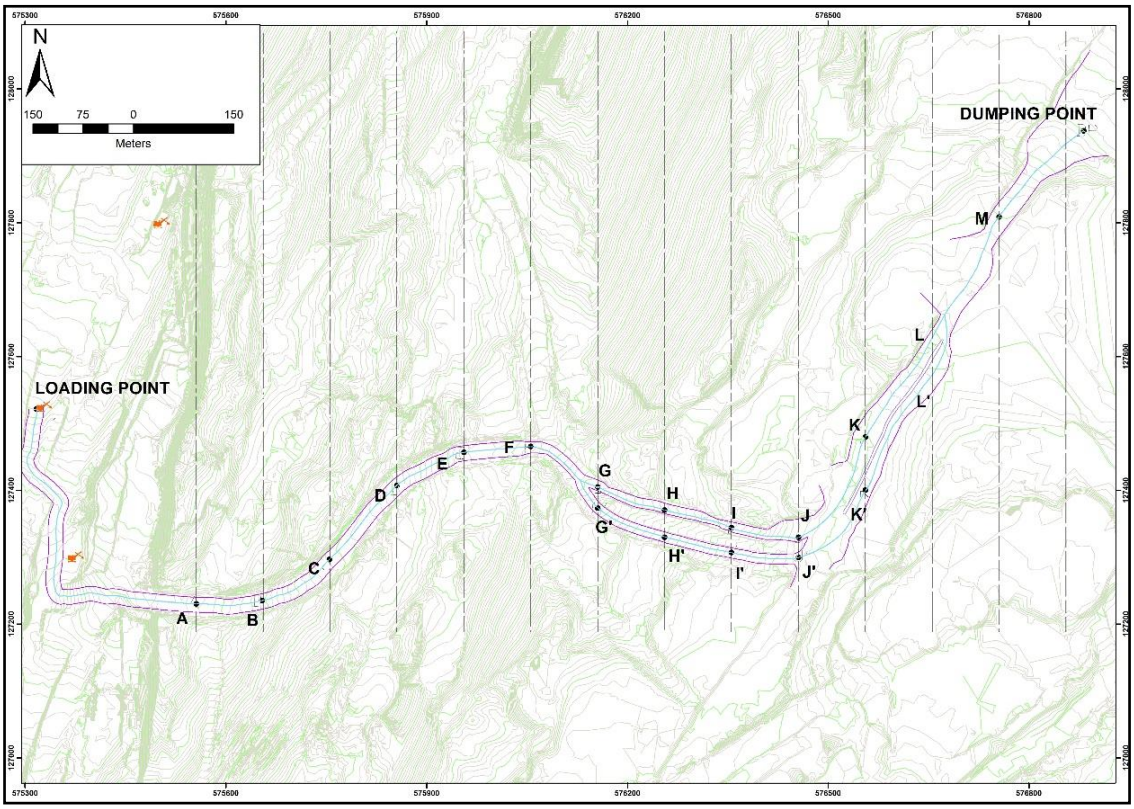
RESULTS AND DISCUSSION

In collecting data, researchers use references to maps that have been created using software. In dividing the segments, the researchers used a distance between segments of 100 meters consistently; therefore, if a long distance between segments is found in the cross-section, it means that the road is in a cornering condition.

The results of data collection as described in the methodology are presented in Figure 4 and Table 1, where Figure 4 provides an overview of which road segments were taken, while Table 1 provides a description of the road segments.

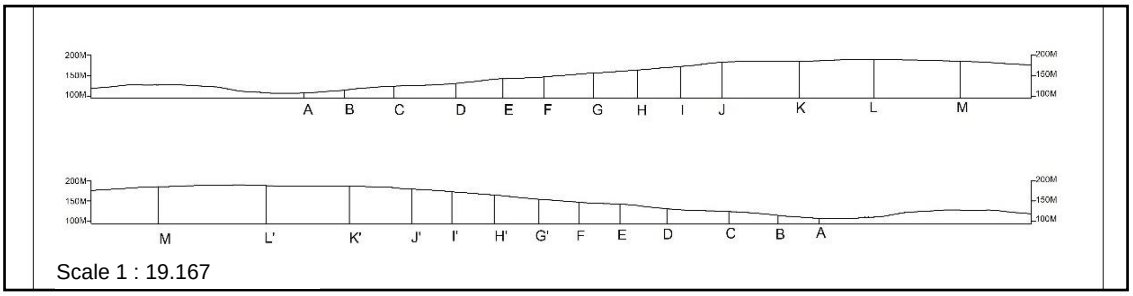
Table 1 shows the results of the calculation of fuel consumption in 1 hour and per segment. Then, as stated in the methodology regarding travel time segments, the travel time segment data will be cross-multiplied with the results of fuel consumption calculations for each

segment. For example, in one hour, a machine consumes fuel 67.07 liters in 3600 seconds, then if the travel time is 103 seconds, the fuel consumption will be 1.9 liters. More precisely, the calculation uses the simple principle of mathematical cross multiplication. Table 2 show calculation of fuel consumption per segment by projecting all fuel per hour and travel time.



Source: Company Topography Data

Figure 4. Segment from loading point to dumping point



Source: Company data

Figure 5. Cross section from loading point to dumping point

Table 1. Calculation of fuel consumption

Location	Segment Information		Calculation of Fuel Consumption							
			Hauling				Empty			
	Distance (m)	Slope (%)	Rpm	Bhp (kW)	Lf	Fc (liters)	Rpm	Bhp (kW)	Lf	Fc (liters)
LP - A	514.61	-4.06	1633	312.2	0.82	67.07	1525	302.7	0.79	60.40
A - B	99.58	6.81	1800	344.1	0.90	81.46	1750	334.6	0.88	51.65
B - C	119.75	8.07	1683	321.8	0.84	71.24	1700	325.0	0.85	60.40
C - D	150.80	4.37	1850	353.7	0.93	86.05	1800	344.1	0.90	59.11
D - E	150.80	10.06	1750	334.6	0.88	76.99	1533	293.1	0.77	72.66
E - F	113.52	4.39	1817	347.3	0.91	82.97	1683	321.8	0.84	74.09
F - G	98.74	7.88	1717	328.2	0.86	74.09	1767	337.7	0.88	79.96
G - H	107.32	6.83	1783	340.9	0.89	79.96	1783	340.9	0.89	78.47
H - I	104.75	8.27	1767	337.7	0.88	78.47	1717	328.2	0.86	71.24
I - J	99.76	10.45	1733	331.4	0.87	75.54	1700	325.0	0.85	59.11
J - K	188.08	1.45	1933	369.6	0.97	93.97	1533	293.1	0.77	81.46
K - L	180.44	2.69	1933	369.6	0.97	93.97	1550	296.3	0.78	72.66
L - M	210.70	2.32	1900	363.2	0.95	90.76	1433	274.0	0.72	76.99
M - DP	178.25	5.5	1750	334.6	0.88	76.99	1550	296.3	0.78	63.03

Table 2. Calculation of fuel per hour and travel time per segment

Location	Hauling			Location	Empty		
	Fuel Per Hour (liters)	Travel Time (s)	Fuel Per segment (liters)		Fuel Per Hour (liters)	Travel Time (s)	Fuel Per segment (liters)
LP - A	67.07	103	1.92	Dp - M	60.40	24	0.41
A - B	81.46	17	0.38	M - L'	51.65	31	0.45
B - C	71.24	24	0.47	L' - K'	60.40	37	0.62
C - D	86.05	32	0.76	K' - J'	59.11	40	0.66
D - E	76.99	31	0.67	J' - I'	72.66	13	0.26
E - F	82.97	24	0.55	I' - H'	74.09	12	0.24
F - G	74.09	25	0.52	H' - G'	79.96	11	0.25
G - H	79.96	21	0.47	G' - F	78.47	14	0.31
H - I	78.47	24	0.52	F - E	71.24	12	0.24
I - J	75.54	34	0.71	E - D	59.11	13	0.21
J - K	93.97	40	1.05	D - C	81.46	16	0.36
K - L	93.97	38	1.00	C - B	72.66	14	0.29
L - M	90.76	48	1.20	B - A	76.99	9	0.20
M - DP	76.99	20	0.43	A - Lp	63.03	24	2.07
Total		482	10.67	Total		365	6.56

Table 2 shows that the fuel burn per segment projection results show that the total fuel usage when loaded is 10.67 liters, while when empty it is 6.56 liters. When accumulated in one trip or round trip, it consumes 17.23 liters of fuel.

In collecting RPM data, the researcher also collects HD 465-7R cycle time data, where in one cycle, the loading time is 100 seconds, dumping 66 seconds, queue 160 seconds, etc. 27 seconds and when adding up the load time and The total empty time in one cycle takes 1200 seconds or 20 minutes per one cycle. In one hour, if one round trip takes 20 minutes, then in one hour an HD 465-7R can take three round trip (cycle trip) on average.

The results of the calculation of fuel consumption in one cycle show a value of 17.23 liters, if there are three cycles in one hour then using theoretical and mathematical calculations the result of HD 465 – 7R fuel usage in one hour is 51.70 liters/hour. from the data recorded by dispatch, it shows that the results of the HD 465 – 7R vehicle under study used 51.90 liters of fuel/hour, where the theoretical calculation results for the engine rpm had a difference that was not far from the actual value, only difference 0.20 liters.

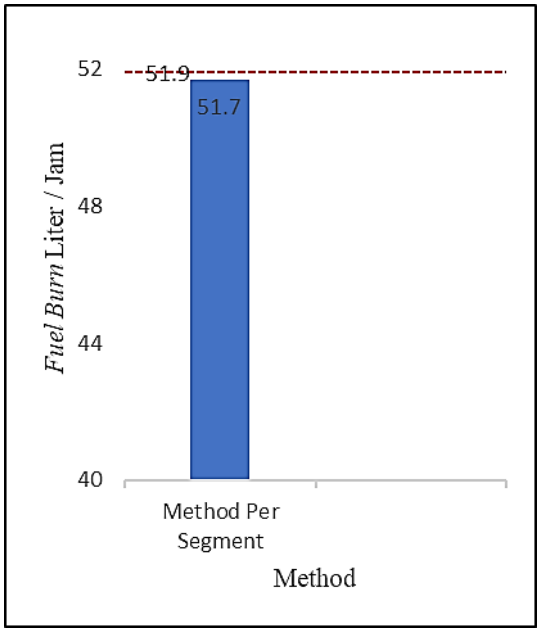


Figure 6. Comparison chart of engine RPM method and actual value

CONCLUSIONS AND SUGGESTION

Conclusions

The conclusion that can be drawn is that calculating fuel consumption using the engine RPM method using a segment approach also produces results that are close to the actual value; with a theoretical result of 51.70 liters/hour while the actual value is 51.90 liters/hour, only a difference of 0.20 liters. With the results of data processing, the hypothesis is answered. However, engine RPM calculations are still on subjectivity, not objectivity measurement.

The main factors that affect fuel consumption, as mentioned in the introduction above, include road slope, ground, and distance.

Suggestion

It is proven that the result of calculating fuel consumption with the HD 465 – 7R vehicle using the engine RPM method are close to actual. Therefore, it is suggested the possibility to test this method on hauling truck or dump trucks with other series and types.

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