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Effect of Total Resistance and Speed on Fuel Consumption of Dump Truck HD 465-7 in Coal Mining

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Abstract: *Based on the observation of actual conditions on the HD 465-7 Dump Truck Fuel Consumption in Coal Mining, it turns out that the level of fuel consumption for transportation equipment is still quite high. To find out what is the cause of the high fuel consumption, a study was conducted on the ratio of fuel used in mining activities. The fuel consumption standard set for loading and unloading equipment is 0.5 Liter/BCM. From the calculation of theoretical fuel consumption, if the haul line is repaired by lowering the slope of the road, the fuel consumption can be reduced to close to the target fuel ratio. The amount of fuel used is more influenced by the condition of the haul road with a slope that is too large. The more intersections the conveyance passes through, the more fuel consumption the conveyance will affect due to a reduction in speed for transportation safety This problem can be avoided by making good mine planning, ideal road slopes, maintenance of haul roads so that in the end it is hoped that fuel consumption can be optimized. The specific fuel consumption of the conveyance unit is generally lower than that of the loader. This makes it the most efficient means of transport in the overburden hauling work. For this reason, it is necessary to study the variables that affect fuel consumption in coal mining using multivariable analysis.*

Key Words: *Fuel, Total Resistance, Dump Truck HD 465-7, Mining, Coal.*

INTRODUCTION

At this time the development of the mining industry is growing rapidly, followed by higher demand for fuel. To meet these fuel needs, humans continue to explore the natural resources that exist in the layers of the earth to be used for the welfare of people's lives (Carvalho, 2017).

One of the natural resources that can be utilized today is coal. Coal is one of the strategic minerals which is also a very large energy resource. Kesler et al, (2005); Diesel, (2012) explained that coal is a sedimentary rock derived from dead plants and buried in a basin filled with water for a very long time, reaching millions of years, and is a non-renewable energy source. Furthermore Maulidia et al (2019); Gusman et al (2018); Casson et al (2014) adds, coal is a natural resource with great potential both as an alternative energy source and as a foreign exchange earner. Indonesia has quite large reserves and is spread in almost all regions, especially on the islands of Sumatra and Kalimantan.

The use of transportation equipment as the main equipment in mining operations cannot run without fuel. Fuel is one of the factors that need to be considered because there is a tendency to increase fuel prices which will affect production costs. Gusman et al (2021) explained that the use of diesel fuel is one of the biggest contributors to mining operational costs, so it is required to always evaluate the use of fuel in each working unit so that diesel fuel can be used efficiently. The evaluation step carried out is to compare the amount of fuel used (liters) with the amount of material volume. The objectives of this research are to 1) Analyze changes in Rotation each Minute (RPM) at each change in the slope of the haul road; and 2) Analyze the effect of shift gear and load weight on dump truck fuel consumption.

Methods

Geographically the research location is in the mining of PT. Kuansing Inti Makmur is located in Tanjung Belit Village, Jujuhan Sub-district, Muara Bungo Regency, Jambi Province between the coordinates 101°42' 58” east longitude - 101°45'3” east longitude (east longitude) and 01°24'15” south latitude - 01°25'0” south latitude, for more details, please refer to see in Fig 1 below.

Fig. 1 Map of PT. Kuansing Inti Makmur.

The data needed in this study is primary data consisting of cycle time data from the Komatsu HD 465-7 dump truck, road grade, RPM for each haul road segment, load weight, and travel time for each haul road segment. Before taking data on the transportation equipment circulation time, first, determine what equipment will be taken data. The transportation equipment used for data is a Komatsu HD 465-7 dump truck for the transportation of overburden.

The conveyance cycle time is the time required by the conveyance to complete a material transport cycle. The movements carried out by the conveyance in one cycle are: 1) Waiting Time is the time waiting for the conveyance to be loaded by the excavator; 2) Spot time is the length of time it takes for the movement to turn, back, and find the right position to be loaded by the excavator; 3) Loading time is the length of time it takes to load the material into the dump truck; 4) Hauling time is the length of time required to transport material from the mining area to the material stacking/storage site; 5) Unloading time (dumping) is the length of time required to dump/spill the cargo in the disposal area; and 6) Return time (empty) is the length of time it takes to return to the charging point.

Meanwhile, in this study, the analysis used to control the variables that affect fuel consumption is multivariate analysis. Multivariate statistical analysis is a method of researching more than two variables simultaneously. By using this analysis technique, we can analyze the effect of several variables on other variables at the same time. Based on the relationship between variables, multivariate analysis can be divided into dependence techniques and interdependence techniques. In dependence techniques, there are two types of variables, namely the dependent variable and the independent variable. Dependence techniques are used to solve problems regarding the relationship between the two groups of variables. While in interdependence techniques, the position of each variable is the same, there is no dependent variable and independent variable. Usually, these interdependence techniques are used to see the interrelationships between all variables regardless of the shape of the variables involved (Simamora, 2005).

Results and Discussions

The location of mining activities of PT. Kuansing Inti Makmur is located in the eastern pit. The stripping of the overburden material was carried out at several loading and dumping locations, as shown in the layout map in Fig 2 below.

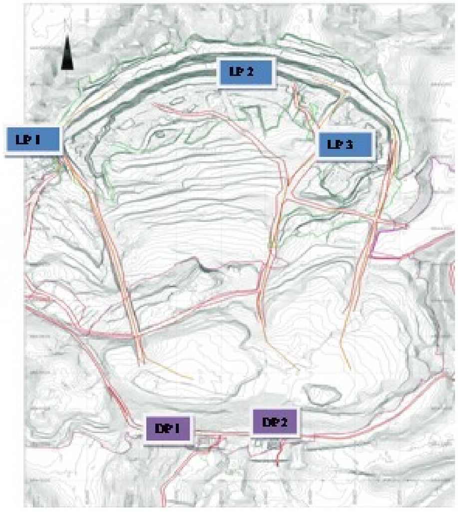

Fig 2. Map of East Pit Mine Layout of PT. Kuansing Inti Makmur.

In the east pit, there are 3 loading locations for overburden material using the Komatsu PC 1250 SP Excavator type loading equipment and Komatsu HD 465-7 transportation equipment, then for the disposal location, there are 2 disposal locations, namely the western disposal and the eastern disposal located in the southern part. The names of each loading and dumping location can be seen in Table 1 below.

Table 1. Names of loading and disposing of overburdened material

Place name	Place Code	Place Elevation (MDPL)
Puncak Barat	LP1	106
Central Timur	LP2	82
Puncak Timur	LP3	117
Disposal Barat	LP4	200
Disposal Timur	LP5	184

Characteristics of material conveyance

Each pair of loading points and dumping points has different characteristics of the road surface, distance traveled, and road slope, this will affect the productivity level of the equipment used and also affect the fuel consumption of the equipment.

Loading site track LP1- DP1 dumpsite: Line LP1-DP1 has a travel distance of approximately 1,917,625 m with a maximum road slope of 12%. Schematically, the shape of the road surface on the LP1-DP1 line can be seen in Fig 3, where the cross-sectional line section LP1-DP1 is divided into 10 segments with different distances for each segment which aims to determine the maximum grade value of the road.

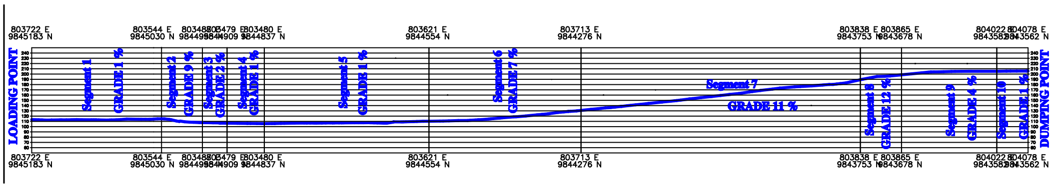

Fig 3. Cross section LP1-DP1

Line LP2 Loading Location DP2 Disposal Site: Line LP2-DP2 has a distance of about 1,889,719 m with a maximum road slope of 10%. Schematically the shape of the road surface on the LP2-DP2 line can be seen in Fig 4, where the cross-sectional line section LP2-DP2 is divided into 8 segments with different distances for each segment which aims to determine the maximum grade value of the road at each segment.

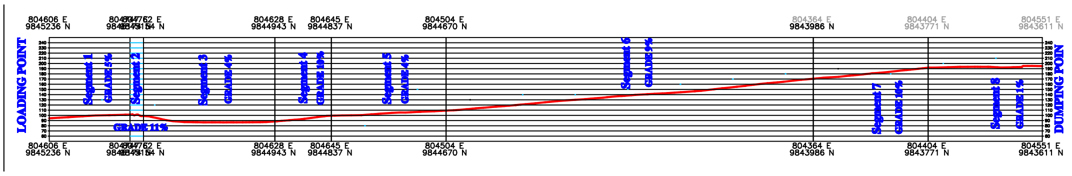

Fig 4. Cross section LP2-DP2

Path of LP3 Loading Location DP2 Disposal Location: Line LP3-DP2 has a travel distance of about 1,468,056 m with a maximum road slope of 7%. Schematically the shape of the road surface on the LP3-DP2 line can be seen in Fig 4 below.

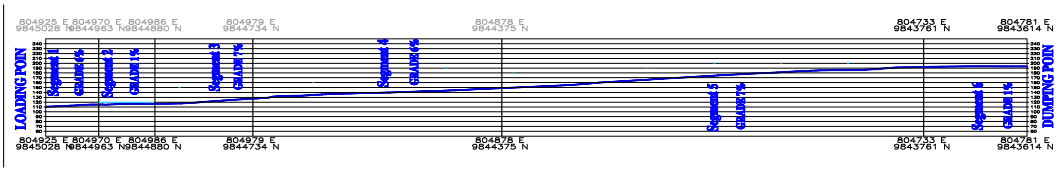

Fig 5. Cross section LP3-DP2

From Fig. 7 above, the cross-line section LP3-DP2 is divided into 6 segments with different distances for each segment, which aims to determine the maximum grade value of the road in each segment, as for the grade value, distance, height difference. from each line section in each segment can be seen in Table 2 below.

Table 3. Recapitulation of values from line section

Locations	Segment	**X**	**Y**	**ΔX (*Distance*)**	**ΔY**(Height Difference)	***Grade***
Line 1 (West) LP1-DP1	1	806999,994	9844963,320	249,844 m	1,453	1%
	2	807249,838	9844964,773	78,656 m	-7,085	-9%
	3	807328,494	9844957,688	47,406 m	-1,180	-2%
	4	807375,900	9844956,508	71,750 m	-0,805	-1%
	5	807447,650	9844955,703	316,938 m	4,578	1%
	6	807764,588	9844960,281	292,593 m	20,563	7%
	7	808057,181	9844980,844	537,688 m	58,297	11%
	8	808594,869	9845039,141	79,187 m	9,367	12%
	9	808674,056	9845048,508	183,407 m	6,789	4%
	10	808857,463	9845055,297	60,156 m	0,445	1%

	¤	808917,619	9845055,742			
	TOTAL			1.917,625 m		
Line 2 (Central) LP2-DP2	1	806999,994	9844644,359	153,531 m	7,157	5%
	2	807153,525	9844651,516	25,719 m	-2,727	-11%
	3	807179,244	9844648,789	249,844 m	-10,359	-4%
	4	807429,088	9844638,430	107,375 m	10,906	10%
	5	807536,463	9844649,336	218,218 m	9,781	4%
	6	807754,681	9844659,117	698,407 m	61,469	9%
	7	808453,088	9844720,586	218,5 m	21,328	10%
	8	808671,588	9844741,914	217,125 m	3,047	1%
		808888,713	844744,961			
	TOTAL			1.888,719 m		
Line 3 (East) LP3-DP2	1	807000,000	9844360,586	79,213 m	4,414	6%
	2	807079,213	9844365,000	84,156 m	1,172	1%
	3	807163,369	9844366,172	146,469 m	10,930	7%
	4	807309,838	9844377,102	372,468 m	21,656	6%
	5	807682,306	9844398,758	631,063 m	43,601	7%
	6	808313,369	9844442,359	154,687 m	1,079	1%
		808468,056	9844443,438			
	TOTAL			1.468,056 m		

From Table 3 above, it can be seen the value of each segment, both grade, distance, height difference and the coordinates of the X and Y axes of each segment, for the LP1-DP1 line, the maximum road grade is 12% which is in segment 8, for The LP2-DP2 line has a maximum grade of 10% located in segments 4 and 7, while the LP3-DP2 line has a maximum grade of 7% located in segments 3 and 5.

Effect of Total Resistance and Speed on Fuel Burn

The effect of total resistance and speed on fuel burn will be analyzed using the multiple linear regression method. Multiple linear regression is a linear regression that has at least three variables. These variables are two independent variables (independent variable) and one dependent variable (dependent variable). In this case, the independent variable is total resistance (X1) and speed (X2), and the dependent variable (Y) is fuel burn.

Table 4. Total resistance data – speed and fuel burn data

UNIT CODE	FB (Y)	TR (X_1)	Speed (X_2)	Y^2	X_1^2	X_2^2	X1.Y	X2.Y	X1.X2
AR-11	49,59	15,11	15,98	2458,97	228,33	255,37	749,31	792,43	241,47
AR-13	49,76	15,14	16,54	2475,97	229,12	273,42	753,19	822,79	250,29
AR-14	48,71	15,11	16,46	2373,13	228,36	270,97	736,15	801,90	248,75
AR-15	49,50	15,13	16,30	2449,84	229,02	265,68	749,04	806,76	246,67
AR-16	49,88	15,18	15,98	2487,62	230,37	255,47	757,01	797,19	242,60
AR-20	49,90	15,19	16,41	2490,01	230,72	269,20	757,96	818,72	249,22
AR-21	46,85	13,32	16,09	2194,50	177,50	259,03	624,12	753,95	214,43
AR-22	46,76	13,29	18,69	2186,03	176,71	349,22	621,53	873,73	248,42
AR-24	47,09	13,35	16,33	2217,63	178,16	266,60	628,57	768,91	217,94
AR-25	48,03	13,58	16,71	2307,07	184,35	279,20	652,16	802,57	226,87

AR-26	47,15	13,32	16,71	2223,33	177,50	279,20	628,20	787,87	222,61
AR-27	46,07	13,29	16,16	2122,81	176,71	261,09	612,47	744,47	214,80
AR-29	45,24	10,84	16,16	2047,06	117,53	261,14	490,50	731,14	175,19
AR-30	44,88	10,64	16,16	2013,86	113,11	261,14	477,27	725,19	171,86
AR-34	45,13	11,02	16,86	2036,27	121,33	284,41	497,05	761,00	185,76
AR-35	44,21	10,38	16,26	1954,66	107,74	264,28	458,90	718,73	168,74
AR-37	45,49	11,07	16,69	2069,16	122,51	278,57	503,47	759,22	184,73
AR-41	44,26	10,20	16,85	1958,95	104,01	283,77	451,39	745,59	171,80
Sum	848,49	235,15	297,33	40066,84	3133,07	4917,76	11148,27	14012,20	3882,15
Average	47,14	13,06	16,52						

Descriptive analysis is an analysis that describes data to be made, either alone or in groups. The purpose of descriptive analysis is to make a systematic description of the data, excluding decision-making through hypotheses. For descriptive analysis can be seen in Table 5 below.

Tabel 5. Descriptive statistics

	Mean	*Std. Deviation*	N
*Fuel*_Y	47,1389	2,03722	18
*TR*_X1	13,0644	1,89289	18
Kec_X2	16,5189	0,61163	18

From Table 5 above, it can be seen that the average fuel value of 18 OHT Komatsu HD465 is 47.13 with a standard deviation of 2.037. The average value of total resistance (X1) is 13.06 with a standard deviation of 1.892. And the average value of speed (X2) is 16.51 with a standard deviation of 0.611. Partial correlation is the correlation between one independent variable and one dependent variable, controlled by one other independent variable, using the Pearson product-moment correlation. In this study, there are two independent variables, namely total resistance and speed, and one dependent variable, namely fuel burn. The calculated partial correlation is the correlation between fuel burn with total resistance and fuel burn with speed, which can be seen in Table 6 below.

Tabel 6. Correlations

		*Fuel*_Y	TR_X1	Kec_X2
Pearson Correlation	*Fuel*_Y	1,000	0,968	-0,163
	TR_X1	0,968	1,000	-0,113
	Kec_X2	-0,163	-0,113	1,000
Sig	*Fuel*_Y	,	0,000	0,259
	TR_X1	0,000	,	0,327
	Kec_X2	0,259	0,327	,
N	*Fuel*_Y	18	18	18
	TR_X1	18	18	18
	Kec_X2	18	18	18

From Table 6 above, it can be seen:

- The magnitude of the relationship between a fuel (Y) and total resistance (X1) is 0.968. This means that the relationship between the two variables is very strong, a positive correlation indicates that the relationship between fuel and total resistance is unidirectional, meaning that if the total resistance is high, the fuel will increase.

Hypothesis test:

- ✓ Ho: Total resistance (X1) is not significantly related to fuel (Y).
- ✓ Ha: Total resistance (X1) is significantly related to fuel (Y).

Based on the significance value/probability of the SPSS output results.

- ✓ If the value of Sig < 0.05 then Ho is rejected, and Ha is accepted
- ✓ If the value of Sig> 0.05 then Ho is accepted Ha is rejected

From the results of the significance test, it can be seen that the probability value is 0.00 < 0.05 so that Ho is rejected and Ha is accepted. That is, the total resistance is significantly related to the fuel.

- ➢ The magnitude of the relationship between a fuel (Y) and speed (X2) is (-0.163). This means that the relationship between the two variables is very weak, a negative correlation indicates that the relationship between fuel and speed is inverse, meaning that if the speed is low, then the fuel is high.

Discussions

The ideal vehicle speed can be calculated using a performance chart published by Komatsu. The average vehicle speed can be calculated based on Gross Machine Weight (empty weight and load) and the total resistance value. The calculation of the average speed with a performance chart for the total resistance of 12%, 13%, and 15% with a Gross Machine Weight of 97 tons can be seen in Fig 6, Fig 7, and Fig 8 below.

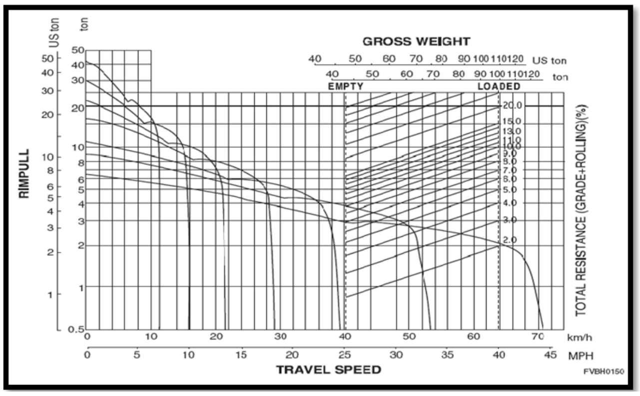

Fig 6. Average Speed of 12% Total Resistance and 97 Tons GWS

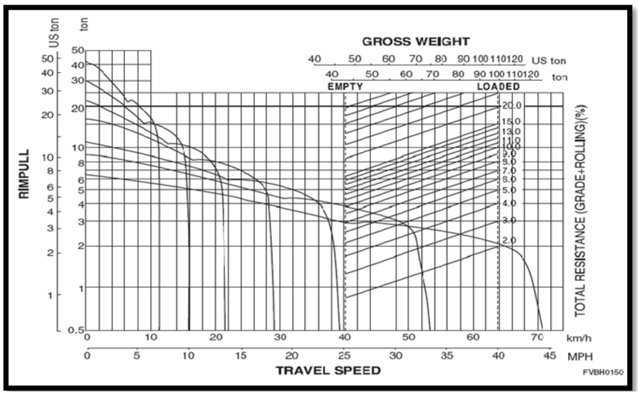

Fig 7. Average Speed of Total Resistance 13% and GWS 97 Ton

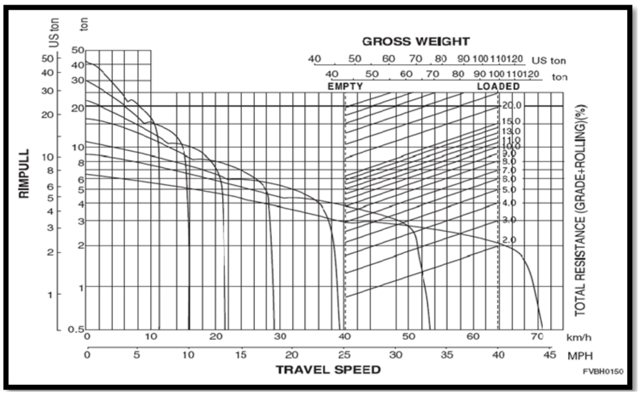

Fig 8. Average Speed of 15% Total Resistance and 97 Tons GWS

Based on Fig 6, Fig 7, and Fig 8, it can be seen that the greater the total resistance value, the slower the truck will go, and the power/rimpull required will be greater, therefore the fuel required will be more and more.

CONCLUSIONS

The conclusions from this study are 1) The transportation route in the East Pit which has the highest slope resistance value is on the LP1-DP1 route with a slope of 12%. The greater the slope of a road, the greater the resistance that must be overcome by the vehicle; 2) The greater the slope resistance value, the greater the rate of fuel consumption of passing vehicles. The relationship between total resistance to fuel burn is categorized as very strong with a correlation coefficient (r) of 0.968. The coefficient of determination is 0.937, meaning that the total resistance has an effect of 93.7% on fuel burn, of which 6.3% is influenced by other factors; 3) The increase in the rate of fuel consumption, caused by the engine's need for fuel that is getting bigger due to the high rotation per minute of the engine to maintain a constant transportation speed when the vehicle is passing through a road with a high slope; 4) The speed of transportation has less effect on the increase in the rate of fuel consumption because it is more influenced by the road slope factor. The relationship between speed and fuel burn is categorized as very low with a correlation coefficient (r) of 0.163. The coefficient of determination is 0.0267, meaning that speed has a 2.7% contribution effect on the fuel burn variable, where the remaining 97.3% is influenced by other factors; and 5) The results of multiple regression analysis show that the coefficient of determination of total resistance and speed on fuel burn is 0.940, meaning that total resistance and speed have an effect of 94% on fuel, the remaining 6% is influenced by other factors not examined, with the regression equation $Y = 36.64 + 1.035X_1 - 0.18X_2$.

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