Assessment of Productivity and Compatibility of Komatsu PC 2000 Loader and Komatsu HD 785 Transport Equiptment in Overburden Stripping Activities in the North Pit of Muara Tiga Besar Mining Area at PT. Bukit Asam, Tbk. Tanjung Enim, South Sumatra

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Abstract. PT. Bukit Asam, Tbk is a coal mining company with an IUP area of 14,987 Ha (PT Bukit Asam, Tbk, 2018), the mining location is located in Tanjung enim, Lawang Kidul sub-district, Muara Enim Regency, South Sumatra Province which is divided into 3 Mining Business License Areas namely: Air Laya Mine (TAL), West Bangko Mine and Muara Tiga Besar Mine. Coal mining in Muara Tiga Besar Mining area of PT Bukit Asam company. Using Komatsu PC 400 for coal getting activities, while for overburden uses Komatsu PC 2000, PC 1250 and PC 800. For transportation equipment in the form of Dump Truck HINO 500 FM 320 TI for coal getting activities and HD 785 for overburden. The productivity value of the PC2000 digging tool for overburden is 750.02 bcm / hour, while for HD for overburden is 96.866 bcm / hour. For the MF (match factor) value on the PC 2000 with HD 785 for overburden is 0.89, meaning that there is a mismatch between the PC 2000 and HD 785 because the MF value < 1 so that there is waiting time for the PC 2000 digging tool for the HD 785 conveyance.

Keywords: *Digging Equipment, Match Factor, Mineing, Productivity*

1. Introduction

In a mining process, production is an important activity within the scope of mining.

The purpose of production activities is to collect excavated material that has a price or selling value, in coal production activities there are two productions that can be carried out, namely coal production and overburden production. To carry out these production activities, of course, mechanical equipment is needed that can support the production of coal and overburden.

PT Bukit Asam is a company that produces coal mining. PT Bukit Asam in its mining applies theopen pit method.

In coal getting activities, PT Bukit Asam uses Komatsu pc 400 digging equipment and Dt Hino 500 transportation equipment, while in the overburden stripping process, PT Bukit Asam uses Komatsu pc 2000 digging equipment and Komatsu Hd 785 transportation equipment.

Apart from digging equipment and transportation equipment as the main mining equipment, there are also supporting tools such as motor graders, bulldozers, water tanks and fuel tanks to get optimal and maximum results from the production carried out.

One of the problems that occurs in production activities at PT Bukit Asam is the incompatibility between excavation and transportation equipment, which has an impact on the occurrence of waiting time (Delay) when production takes place, so it is necessary to study the compatibility between excavation equipment and transportation equipment in order to achieve production targets.

The purpose of this research is to find the value of productivity and compatibility between the digging and hauling equipment used.

2. Research Location

The Mining Business License Area (WIUP) of PT Bukit Asam Tbk is located in Tanjung Enim, Lawang Kidul District, Muara Enim Regency, South Sumatra Province with a distance of ± 186 km from the city of Palembang.

The regional geology of the South Sumatra Basin is a basin deposited in the Tertiary period which is bounded by major faults, namely, the Semangko Fault and the Bukit Barisan Mountains.

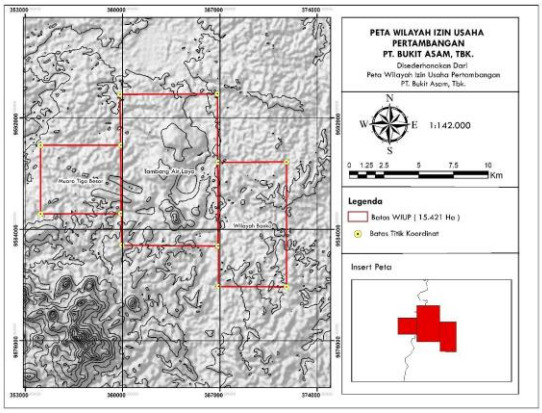

Fig 1. Research location map

3. Basic Theory

3.1 Material Type

The excavation material that will be excavated by the digging and loading equipment is very influential in the optimization of mechanical equipment because each excavation material has different hardness, (Kusrin, 2008) classifying excavation materials as follows:

1. Easy digging materials include: Soil, sand, sandy-clay, clayey sand.
2. Medium hard digging including: Clay, wheathered rocks.
3. Hard dig ging including: Shale, compacted material, conglomerate, breccia.
4. Very hard dig ging or rock including: Rock that requires blasting before excavation

3.2 Fill Factor

In general, the Fill factor is the ratio that occurs between the percentage of volume that can be entered in the loading tool body in real conditions compared to the theoretical percentage.

$$BFF = \frac{Va}{Vt} x\ 100\%$$

Description:
BFF = *Bucket Fill Factor*
Va = Actual Volume (m3)
Vt = Theoretical Volume (m3)

Bucket fill factor (K) (PC78~PC2000)

Excavating conditions	K
Easy excavating	1.1 ~ 1.2
Average excavating	1.0 ~ 1.1
Rather difficult excavating	0.8 ~ 0.9
Difficult excavating	0.7 ~ 0.8

Fig 2. Bucket Fill Factor

3.3 Swell Factor

Material development or Swell Factor is the process of development that occurs in the volume of material that occurs after excavation activities are carried out on the material. To get the swell factor, we can use the formula (Peurifoy, 1970):

$$SF = \frac{D\ losse}{D\ insitu} x\ 100\%$$

Description:
SF = *Swell Factor*
D losse = Actual Volume (m3)
D insitu = Theoretical Volume (m3)

Material		Specific Gravity (ton/m³)	
		Bank	Crushed (Loose)
Basalt		2.95	1.7
Bauxite		1.9	1.42
Caliche		2.26	1.25
Carnotite, uranium ore		2.2	1.63
Cinders		0.86	056
Clay		1.8	1.45
Clay & gravel		2.0	1.45
Coal	Anthracite	1.3	1.0
	Bituminous	0.59 ~ 0.89	0.53 ~ 0.65
Decomposed Rock - 75% Rock, 25% Earth 50% Rock, 50% Earth 25% Rock, 75% Earth		2.0 2.1 2.2	1.75 1.75 1.65
Earth - Dry Wet Loam		1.8 2.0 1.54	1.4 1.6 1.25
Granite		2.8	1.6
Gravel		2.17	1.93
Gypsum		3.17	1.81
Hematite, iron ore		3.5	2.0
Limestone		2.8	1.6
Magnetite, iron ore		5.05	2.9
Peat	Dry	0.60 ~ 0.70	0.40 ~ 0.50
	Wet	1.80 ~ 2.00	1.10 ~ 1.20
Pyrite, iron ore		3.03	2.85
Sand - Dry Dump Wet		1.6 1.9 2.08	1.42 1.69 1.84
Sand & clay	Loose	2.02	1.6
	Compacted	—	2.4
Sand & gravel	Dry	1.93	1.72
	Wet	2.23	2.02
Sandstone		2.7	1.55
Slag		2.94	1.75
Snow	Dry	—	0.13
	Wet	—	0.52
Stone		2.67	1.6
Taconite		2.36 ~ 2.7	1.63 ~ 1.9
Top soil		1.37	0.95
Trap rock		2.50 ~ 2.70	1.60 ~ 1.80

Fig 3. Swell Factor

3.4 Tool Work Efficiency

Equipment work efficiency is the time used by machine users (operators) in production. (Ramadhan Shaddad, 2017). To obtain the work efficiency time, the formula is needed:

$$EK = \frac{Wke}{Wkt} x\ 100\%$$

Description:
EK = Work Efficiency
Wke = Effective Working Time
Wkt = Available Working Time

3.5 Cycle Time

3.5.1 Loading Equipment Ciruculation Time

Cycle time of thedigging tool is how long it takes for thedigging tool to complete its work cycle which consists ofdigging, swinging content, dumping and empty swinging. So that the cycle time of the digging tool can be formulated as follows according to (Partanto, 1996):

$$CTgm = Tg + Tsi + Tt + Tsk$$

Description:

Ctgm = Cycle time of loading equipment (s)
Tg = Digging time (s)
Tsi = Fill swing time (s)
Tt = Dumping time (s)
Tsk = Empty swing time (s)

Cycle Time PC-2000					
NO	DIGGING (Second)	Fill Swing (Second)	DUMPING (Second)	Empty Swing (Second)	CYCLE TIME (Second)
1	10.1	10.5	6	7	33.6
2	11.3	9.5	5.1	6.1	32
3	10.8	9.4	6.4	7.4	34
4	11	9.9	6.3	8.4	35.6
5	11.5	10.3	5.6	7.2	34.6
6	9	10.7	5.1	6.6	31.4
7	10.7	10.1	7.6	7.4	35.8
8	12	8.7	6.7	7.6	35
9	9.7	8.7	6.2	8	32.6
10	11.9	8.4	6	8	34.3
11	11.4	8.3	7	8.5	35.2
12	10.9	8.7	5.9	6.7	32.2
13	12.2	10.3	5.3	7.7	35.5
14	12.7	9.9	6.4	6.3	35.3
15	10.1	10.8	6.1	7.9	34.9
16	9.6	5.9	5.6	6.9	28
17	13.2	8.7	7.8	7.9	37.6
18	10.7	8.4	6.8	7.1	33
19	12.8	8	6.6	7.1	34.5
20	11.6	8.4	6.1	6.9	33
21	10.7	6.9	6.2	8.1	31.9
22	11.6	8.5	6.1	7.4	33.6
23	10.4	9.8	6.7	8.2	35.1
24	13.7	10.1	5.7	5.6	35.1
25	12.7	8.3	5.8	7.7	34.5
26	9.8	9.7	6.1	5.7	31.3
27	9.9	8.4	6.4	9.7	34.4
28	12.5	11	6.2	7.1	36.8
29	12.1	9.3	6.9	6.9	35.2
30	11.5	8.5	6.1	6.7	32.8
Amounts	338.1	274.1	186.8	219.8	1018.8
Averages	11.27	9.14	6.23	7.33	33.96

Fig 4. Cycle Time Data PC 2000

3.5.2 Hauling Equipment Circulation Time

Cycle time of the conveyance is the time required by the conveyance to complete one work cycle consisting of empty maneuver time, loading time, hauling time, loading maneuver time, dumping time and empty hauling time. So that the rotation time of the conveyance can be formulated as follows (Partanto, 1996):

$$CTa = Ti + Ta + Tmd + Td + Tk + Tml$$

Description:

Cta = Cycle time of conveyance (s)
Ti = Loading time (s)
Ta = Fill hauling time (s)
Tmd = Fill maneuvering time (s)
Td = Dumping time (s)
Tk = Empty hauling time (s)
Tml = Empty maneuvering time (s)

Cycle Time HD-785						
Empty Maneuvering	Loading	Empty Hauling	Fill Maneuvering	Dumping	Fill Hauling	Cycle Time
21.00	261.6	710.70	42.60	29.10	782.4	1847.40
23.50	133.2	689.10	35.60	30.40	755.1	1666.90
27.30	147	761.60	40.40	23.00	825	1824.30
20.80	188.4	669.50	40.40	24.20	734.1	1677.40
39.60	210.6	752.30	30.40	23.40	806.1	1862.40
22.10	309.6	693.80	40.50	21.40	755.7	1843.10
34.40	141	784.00	40.50	20.30	844.8	1865.00
25.70	180	649.20	39.00	19.50	707.7	1621.10
27.60	121.8	834.40	25.00	19.00	878.4	1906.20
24.70	130.2	829.30	34.40	21.90	885.6	1926.10
29.30	193.8	751.70	47.40	21.10	820.2	1863.50
24.60	259.2	798.10	23.20	20.80	842.1	1968.00
30.80	130.8	774.80	45.70	31.20	851.7	1865.00
39.50	143.4	747.63	38.63	27.94	814.2	1811.30
31.90	184.8	785.39	23.56	35.25	844.2	1905.10
24.30	207.6	797.74	26.46	26.60	850.8	1933.50
25.40	195.6	819.50	27.50	23.60	870.6	1962.20
29.20	198.6	655.23	31.70	33.67	720.6	1669.00
21.70	201.6	754.75	26.80	45.25	826.8	1876.90
25.70	148.8	837.80	26.98	2.22	867	1908.50
20.60	185.4	773.73	28.60	28.37	830.7	1867.40
23.20	196.8	717.66	30.66	36.18	784.5	1789.00
27.50	192	737.86	27.40	47.74	813	1845.50
21.40	210	686.21	40.60	33.09	759.9	1751.20
26.10	174	670.11	51.30	31.59	753	1706.10
24.20	210	780.30	49.60	30.80	860.7	1955.60
22.40	162	760.35	47.90	41.65	849.9	1884.20
27.30	249.6	777.69	33.60	3.21	814.5	1905.90
30.60	196.8	754.74	22.00	32.06	808.8	1845.00
24.70	214.2	741.93	38.95	27.02	807.9	1854.70
Amounts	5678.4	22497.12	1057.34	811.54	24366	55207.5
Averages	189.28	749,904	35.24466667	27.05133333	812.2	1840.25

Fig 5. Cycle Time Data HD 785

3.6 Productivity

Tool productivity is the ability of production carried out by hauling and loading in a job (Ladianto & Ernawati, 2019). Productivity depends on the capacity and cycle time of mechanical equipment. To estimate the productivity of each digging, loading and transporting equipment, both for coal getting and overburden.

3.6.1 Digging Equipment Productivity

To obtain the productivity of the digging and loading equipment, a formula is needed (Tenriajeng, 2003):

$$Q = \frac{Kb\ x\ Bff\ x\ 3600\ x\ Eff\ x\ Sf}{Ctgm}$$

Description:

Q = Produtivity of digging and loading equipment (bcm/hour)
Kb = Bucket capacity (m3)
Bff = Bucket fill factor
Sf = Swell factor
Eff = Tool work efficiency (%)
Ctgm = Cycle time of the digging tool (s)

3.6.2 Hauling Equipment Productivity

To obtain the produtivity of the conveyance, the formula (Tenriajeng, 2003) is needed.:

$$Q = \frac{n\ x\ Kb\ x\ Bff\ x\ 3600\ x\ Eff\ x\ Sf}{Cta}$$

Description:
Q = Produtivity of the digging and loading equipment (bcm/hour)
n = Frequency of research
Kb = Bucket capacity (m3)
Bff = Bucket fill factor
Sf = Swell factor
Eff = Tool work efficiency (%)
Ctgm = Cycle time of the digging and loading tool (s)

3.7 Match Factor

Match factor is a calculation that aims to see the compatibility between tools that work and operate with each other. To determine the match factor, the formula is needed (Partanto, 1996)

$$Mf = \frac{Na\ x\ Ctgm\ x\ n}{Cta\ x\ Nm}$$

Description:
Mf = Match factor
Na = Number of transportation equipment
Ctgm = Cycle time of loading equipment
n = Number of fills
Cta = Cycle time of conveyance
Nm = Number of loading tools

Each value of MF obtained from the formula The above has different meanings, if;

MF < 1 then, there is a waiting time for loading equipment, meaning that there is a waiting time for loading equipment for the arrival of the conveyance.

MF = 1 then, loading equipment and transportation equipment are compatible

Mf > 1 then, there is a waiting time for the conveyance, meaning that there is a queue between the conveyance waiting for the loading equipment.

4. Research Metodology

4.1 Type of Research

The method used for problem solving is through two methods, namely by studying literature and field observations. Literature study is an activity to understand the theory that is directly related to the problems faced regarding the productivity of loading and hauling excavation equipment.

Field observations are carried out directly for several days, field observations include orientation activities with supervisors and employees in the field. Field observations were carried out in several places, namely MTB 1, MTB 2 (tabu) and BWE (bucket whalle excavator). where the secondary data used included rainfall data, work efficiency and slippery hour data. For primary data taken from the field in the form ofcycle time, the number of filling buckets and the number of tools in a fleet.

4.2 Data Collection Technique

The data collection technique carried out in this study by making direct field observations, by collecting cycle time data as much as 30 data from each conveyance and loading equipment that works.

5. Results and Discourse

5.1 Calculation of Productivity of PC 2000

The following is the calculation of the productivity of the PC2000 digger loader. After entering the existing numbers according to the formula used, the results of the productivity value of the PC 2000 can be obtained in table 1 below.

Table 1. PC 2000 Productivity Value Results

Cycle Time	Result
PC 2000	750.02 bcm/hour

The productivity obtained from the digger for overburden is 750.02 bcm/hour.

5.2 Calculation of Productivity of HD 785 2000

The following is the calculation of the productivity of the HD 785 conveyance tool. After entering the numbers according to the formula used, the productivity value of HD 785 can be obtained in table 2 below.

Table 2. HD 785 Productivity Value Results

Cycle Time	Result
HD 785	96.866 bcm/hour

The productivity obtained from the HD 785 conveyance for hauling overburden with a distance of 3500 m is 96.866 bcm/hour.

5.3 Match Factor Calculation

The following is the calculation of the match factor between the PC2000 digger and the HD 785 overburden hauler.

Table 3. PC 2000 and HD 785 Match Factor Result

Match Factor	Result
PC 2000 and HD 785	0.89

Because the MF value < 1, there is a mismatch between the PC 2000 digger and HD 785. There is a waiting time for the PC 2000 excavator against the HD 785 hauler.

6. Conclusions and Suggestions

6.1 Conclusions

Based on the discussion of the case study and observations made in the field, the following conclusions can be drawn:

1. In overburden mining activities in the Muara Tiga Besar Mining area, PT Bukit Asam company uses Komatsu PC 2000 for overburden, while HD 785 is used for hauling equipment.
2. The results of observations in the field obtained the productivity value of the PC 2000 digging tool for overburden is 750.02 bcm / hour, while for HD 785 for overburden is 96.866 bcm / hour.
3. For the MF (match factor) value on PC 2000 with HD 785 for overburden is 0.89, meaning that there is a mismatch of PC 2000 with HD 785 because the MF value < 1. The occurrence of waiting time for PC 2000 loading equipment against HD 785 transport equipment.

6.2 Suggestions

The following are suggestions that can be done so that further research will be carried out:

1. Increase supervision of heavy equipment operators so that they do not drive heavy equipment too fast.
2. Pay more attention to the handling of coal combustion.
3. For washing mechanical equipment, it should be done when the equipment is standby so as not to hamper coal production activities.
4. Pay more attention to animals that can interfere with mining activities.

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