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Technical Study of Production Capacity and Work Efficiency of Conveyer Belt in Coal Delivery to Stockpile at PT. Singlurus Pratama

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Abstract

PT. Singlurus Pratama has a fairly high mining productivity, so a stockpile is needed as a temporary coal storage place. Stockpile owned by PT. Singlurus Pratama has a capacity of 140,000 tons. The crushed coal is carried by a conveyor belt to be transported to the stockpile. Conveyor belt at PT. Singlurus Pratama has different sizes so that the efficiency of each belt for transporting coal varies. In the next planning, an increase in production targets will be carried out, so research is urgently needed on the efficiency value of each type of belt owned. This data is needed to determine the type of belt that is in accordance with the production target so as to provide optimal conveyor belt service life performance. Efficiency calculation begins by measuring the value of the theoretical and actual production capacity of each type of belt to get the value of the production rate index (PRI). PRI is the value of work efficiency based on two load conditions, namely minimum and maximum, then the value of work efficiency for all types of belts at PT. Singlurus Primary is known accurately. In the study, it was found out that the production capacity of conveyor belts in coal delivery to the stockpile for type BC-01, BC-02, BC-03 and Tripper Cars were 1,690, 1,698, 1,742, 2,371 tons/hour, with the lowest value for type BC-01. and the highest value of the Tripper Car type. The minimum load efficiency values for the conveyor belt types BC-01, BC-02, BC-03 and Tripper Car are 22.2, 22%, 22% and 16%, respectively. The maximum load efficiency values for the conveyor belt types BC-01, BC-02, BC-03 and Tripper Car are 37%, 37%, 36% and 26%, respectively. Then the minimum and maximum workload efficiency values are the highest on the BC-01 type and the lowest on the Tripper car type.

Keywords:
Coal, Conveyor Belt, Production Capacity, Work Efficiency, Stockpile

1 Introduction

Conveyor is one of the most prominent mechanical handling equipment, one of *conveying machine* used to transport heavy loads continually [1]. The transported loads consist of mostly *unit load* or *bulk load*, both of which have limited inclination angle [2]. *Belt conveyor* is completely compatible with industrial production capacity, like in mineral mining industry. *Belt conveyor* is commonly used to transport crushed mining materials from *crusher* to storage location [3]. Production increase can be estimated to reach 85% by using *belt conveyor* system compared to *manual handling* system [4].

Besides high production increase and sustained supply chain, *belt conveyor* needs low power to operate and also low noise. Rubber coated layer on the surface of the pulley increases friction coefficient value, therefore prevents from any possible slip accident and failure, and lowering *counter weight* load to decrease tension on belt helps to prolong service life [5]. Commonly found failures on *belt conveyor* are peeled off and cut off coupling, resulting in productivity production [6].

PT. Singlurus Pratama is one of industries involved in coal mining, with 140.000 tons of *stockpile* capacity. *Belt conveyor* is used as coal transporter from and to *stockpile.* Some kind of innovation is urgently needed to fulfill production target, to ensure faster, easier, and more practical system [7]. Increase of production capacity is measured by addition of equipment and worker [8]. *Belt conveyor* capacity relied on belt's width, motor's power, and type of transported materials affecting moving distance and speed [9]. Available *Belt conveyors* with varying sizes at PT. Singlurus Pratama affect production capacity for each *conveyor [3]*.

To handle those aforementioned problems, research to find out production capacity and *belt conveyor* efficiency used by PT. Singlurus Pratama to improve coal transporting, to further compare the results theoretically with working condition.

Estimation of *belt conveyor* capacity could be measured with direct calculation between actual load in regards of *belt conveyor's* geometrical shape during operation [10]. During maintenance, the durability value of *belt conveyor* can be improved with any preventive measures for each sub-systems therefore *belt conveyor's* production capacity must be limited, not higher than 80%. Overcapacity can affect *belt conveyor's* lifetimes [11]. *Belt conveyor* system efficiency is mostly influenced by speed, therefore more accurate data are needed. More precise control of speed can significantly increase efficiency [12].

1.1 Belt *Conveyer*

Belt conveyor is a contraption made to perform material transportation continually with horizontal movement or certain limited inclination angle. *Belt conveyor* is mostly used for many industries to minimize production process time to further increase capacity and production efficiency. For example, in coal mining industry, *belt conveyor* is used to distribute mined raw coal to and from stockpile storage.

1.2 *Pulley*

Within *belt conveyor* system, *pulley* is one of most prominent components during said movement system operating. Pulley is a component functioned to distribute force from motor to belt with the help of shaft. Pulley is also used to convey rotating force or change the direction of incoming movements.

1.3 *Belt*

Belt is one of main components within *belt conveyor* system. Belt has three layers, which are carcass, top cover, and bottom cover. There are direct contacts between transported materials within belt, making belt endured various blows like abrasion and impact. Belt's layers function to distribute tension on belt from operation starting to distribute materials. Within operation, stability is being sustained because of said layers absorb impact caused by material weight and belt's rotating speed. Belt is one of components that is prone to wear. Wear can occur during high speed, making tear or completely cut off from belt, ultimately piling high cost of maintenance expense.

1.4 *Roller* Idler

Roller with cylindrical shape is positioned on two edge of belt conveyor intended to support the belt. Belt moves linear to roller, making belt conveying rotating movement to roller. *Set idler* is a complete unit consisted of many rollers as well as its installation. A roller has its own mounting which is called frame/bracket. Frame is also known as set idler which is a combination between frame and roller unit complete with mounting as a connector between frame and roller.

1.5 Belt Conveyer velocity

Belt conveyor velocity is the measured velocity based on time belt needed to complete one full cycle. A full complete cycle is belt shifting from initial point to final point. The measurement was done with a stopwatch, by embedding some kind of sign on initial point of belt during inactive phase of the belt. Velocity measurement starts from the moment of belt starts operating until the aforementioned sign arrives on final measurement point/ output. Belt's velocity is directly proportional to movement distance. The belt's velocity is measured by using this equation:

$$V = \frac{S}{t} \tag{1}$$

Description:
V= Velocity (m/s)
S= Belt's movement distance (m)
t= Time (s)

1.6 *Conveyer Belt* Surface Area

Fig 1 and 2 both displayed surface area of belt conveyor.

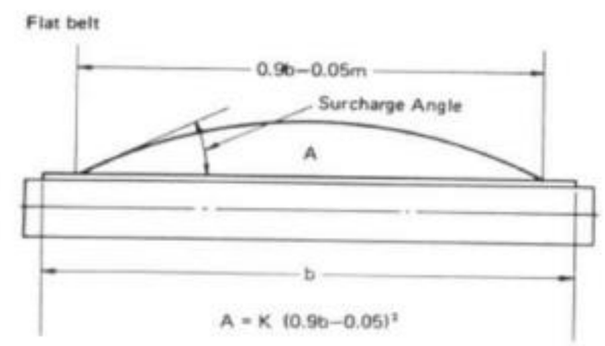

Fig 1. *Cross Section Area*

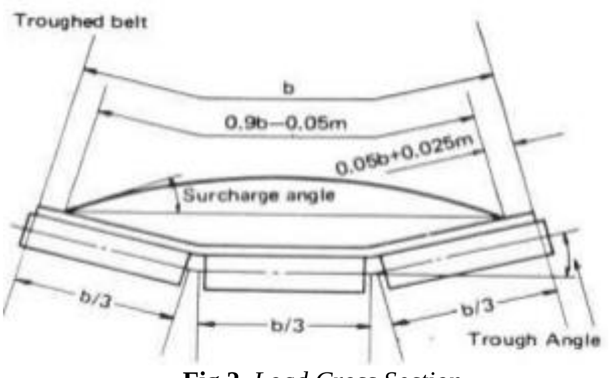

Fig 2. *Load Cross Section*

The arch-like one is called as upper area and the trapezium one is the bottom area. Surface area could be calculated with this formula:

$$A = K\,(0{,}9B - 0{,}05)^2 \tag{2}$$

Description:
A = *conveyor belt* surface area (m^2)
K = *section area* coefficient
B = *belt* width (m)

On Table 1, listed many section area K coefficients based on belt conveyor arrangements and inclination angle from material within the belt.

Table 1. Section area coefficient "K"

Tipe Belt	Sudut *Trough*	Sudut *Surchage*		
		10°	20°	30°
Flat	0°	0,0295	0,0591	0,0906
3- Idler Rolls trough	10°	0,0649	0,0945	0,1253
	15°	0,0817	0,1106	0,1408
	20°	0,0963	0,1245	0,1538
	25°	0,1113	0,1381	0,1661
	30°	0,1232	0,1488	0,1754
	35°	0,1348	0,1588	0,1837
	40°	0,1426	0,1649	0,1882
	45°	0,1500	0,1704	0,1916
	50°	0,1538	0,1725	0,1919
	55°	0,1570	0,1736	0,1907
	60°	0,1568	0,1716	0,1869
5- Idler Rolls trough	30°	0,1128	0,1399	0,1681
	40°	0,1336	0,1585	0,1843
	50°	0,1495	0,1716	0,1946
	60°	0,1598	0,1790	0,1989
	70°	0,1648	0,1808	0,1945

Idler angle inclination also affects the delivery capacity of conveyor belt. The higher an inclination angle of an idler than it would also increase delivery capacity of the conveyor belt respectively. This occurs because inclination angle of idler completely affects surface area of conveyor belt.

1.7 Belt Conveyer Production Capacity

Belt conveyor has production capacity value stated in weight per time unit. Belt conveyor production capacity is greatly influenced by many factors, namely surface area of belt, velocity of belt, density of materials, and inclination angle. The equation to calculate belt conveyor production capacity is listed below:

$$Qt = 3600\, xAxVx\gamma xS \tag{3}$$

Description:
Qt = *belt conveyor* capacity theoretically (tons/hour)
A = Surface area of *belt* (m^2)
V = Velocity of *belt* (m/s)
γ = Density of material (ton/m^3)
S = *belt* inclination coefficient

1.8 Belt's Inclination Angle

Belt conveyor's delivery capacity is greatly influenced by belt's inclination coefficient, and as we know previously that the more inclined the belt's angle is, the more spacious we will find the belt's capacity is. The change to inclination angle of belt influences surface area. The smaller inclination angle is, then the more surface area of belt becomes, as described by Table 2, completed by the list of inclination coefficient (S).

Table 2. Inclination Angle Coefficient "S"

Sudut Kemiringan	Koefisien
2°	1,00
4°	0,99
6°	0,98
8°	0,97
10°	0,95
12°	0,93
14°	0,91
16°	0,89
18°	0,85
20°	0,81
21°	0,78
22°	0,76
23°	0,73
24°	0,71
25°	0,68
26°	0,66
27°	0,64
28°	0,61
29°	0,59
30°	0,56

1.9 Density of Material

Material density is best described as particle mass per volume unit. Particle density ratio to water density is described as material density. For great volume of material, there is a combination of particle and void. To average materials, average particle density can be determined by dividing material mass (solid) with real volume occupied by the particle. Know that real material density is fundamentally different with calculation results from equation theoretically. Loose cubic meters are commonly used as γ value, then we can conclude that coal owned by PT. Singlurus Pratama has a density of 1,002001 ton/m3.

2 Research Method

This research is a study case of PT. Singlurus Pratama, located at East Kalimantan province, Kutai District, Samboja sub-district, starting from July 2021. In this study, theoretical analysis was conducted along with practical field study. The data to be used for final report are divided into two, primary data, which is the result of direct field observation, and secondary data, which is productivity report of company from previous tenure..

2.1 Actual productivity of Conveyor Belt

Actual productivity of conveyor belt is the comparison between the amount of coal transported per one cycle to the stockpile to the amount of time needed for conveyor to work. The amount of coal material is the result of field observation, then the equation to calculate actual productivity of belt conveyor is listed below:

$$\text{Actual productivity} = \frac{\text{Total amount of coal at stockpile in one cycle}}{\textit{conveyer belt's worktime}} \quad (4)$$

Description:

Actual productivity = tons/hour

Total amount of coal at stockpile in one cycle = ton

conveyor belt's worktime = hour

2.2 Work Efficiency of Conveyor Belt

Work Efficiency is essentially a term coined to sustain a life expectancy of certain equipment, at the same time putting some expectation to increase production target in the future based on current performance. *Production rate index* is one of terms and methods to ascertain work efficiency. How Production rate index method works is comparing coal material production capacity which are carried over to be distributed by conveyor belt to the time needed for overall production. Then, the calculation for work efficiency is stated in equation 5 below:

$$PRI = \frac{\text{Actual Production}}{\text{Theoretical Capacity of Conveyor Belt}} \times 100\% \quad (5)$$

Description:

Production rate index (PRI) = %

Actual Productivity = tons/hour

Theoretical Capacity of conveyor belt = ton/hour

3 Results and Discussion

Therefore, results of the research from student field work at PT. Singlurus Pratama is described below:

3.1 Obtaining Data

After conducting field study at PT. Singlurus Pratama, some of raw data can be acquired as shown in table 3

Table 3. *Conveyor Belt* Data

Parameter	BC-01	BC-02	BC-03	Triper Car
Belt Width (mm)	1050	1050	1050	1200
Trough Angle	45°	45°	45°	45°
Surchage Angle	20°	20°	20°	20°
Belt Inclination	20°	20°	20°	20°
Movement Distance (m)	89	115	118	458
Conveyor Belt's movement time time (s)	21	27	27	102

3.2 Data Processing

After acquiring raw data, the next step of the field study and research is processing those data to presentable and desirable secondary data, described below:

3.2.1 Productivity of Conveyor Belt

The next step is determining productivity of conveyor belt as stated below:

1) *Conveyor Belt* BC-01

Secondary data of conveyor belt: Three section idler
conveyor belt type: three section idlers
Thr*ough* angle: 45°
Surcharge angle: 20°
belt width: 1.050 mm = 1,05 m
Material Density = 1,002001 tons/m^3

Answer:

$A = K (0{,}9B - 0{,}05)^2$
$= 0{,}1704 ((0{,}9 \times 1{,}05\ m) - 0{,}05)^2$
$= 0{,}1365\ m^2$

Primary data of belt's movement distance: 89 m
B*elt's velocity*: 21 s
Therefore, we can determine the velocity of conveyor belt with this equation:

Answer:

$$V = \frac{S}{t}$$
$$V = \frac{89\ m}{21\ s}$$
$$V = 4{,}238\ m/s$$

Inclination Angle of Conveyor belt BC-01 is 20°, therefore according to belt inclination coefficient table, we can obtain its coefficient, which is 0,81. Ultimately, capacity of conveyor belt can be determined with this equation below:

Answer:

$Qt = 3600 \times A \times V \times \gamma \times S$
$= 3600 \times 0{,}1365 \times 4{,}238 \times 1{,}002001 \times 0{,}81 = 1.690{,}243$ tons/hour

2) *Conveyor Belt* BC-02

Secondary data of conveyor belt: Three section idler
conveyor belt type: three section idlers
Thr*ough* angle: 45°
Surcharge angle: 20°
belt width: 1.050 mm = 1,05 m
Material Density = 1,002001 tons/m^3

Answer:

$A = K (0{,}9B - 0{,}05)^2$
$= 0{,}1704 ((0{,}9 \times 1{,}05\ m) - 0{,}05)^2$
$= 0{,}1365\ m^2$

Primary data of belt's movement distance: 115 m
B*elt's velocity*: 27 s
Therefore, we can determine the velocity of conveyor belt with this equation:

Answer:

$$V = \frac{S}{t}$$
$$V = \frac{115\ m}{27\ s}$$
$$V = 4{,}259\ m/s$$

Inclination Angle of Conveyor belt BC-02 is 20°, therefore according to belt inclination coefficient table, we can obtain its coefficient, which is 0,81. Ultimately, capacity of conveyor belt can be determined with this equation below:

Answer:

$$Qt = 3600 \times A \times V \times \gamma \times S$$
$$= 3600 \times 0{,}1365 \times 4{,}259 \times 1{,}002001 \times 0{,}81$$
$$= 1.698{,}619 \text{ tons/hour}$$

3) ***Conveyor Belt* BC-03**

Secondary data of conveyor belt: Three section idler
conveyor belt type: three section idlers
Thr*ough* angle: 45°
Surcharge angle: 20°
belt width: 1.050 mm = 1,05 m
Material Density = 1,002001 tons/m^3

Answer:

$$A = K\,(0{,}9B - 0{,}05)^2$$
$$= 0{,}1704\,((0{,}9 \times 1{,}05 \text{ m}) - 0{,}05)^2$$
$$= 0{,}1365 \text{ m}^2$$

Primary data of belt's movement distance: 118 m
B*elt's velocity*: 27 s
Therefore, we can determine the velocity of conveyor belt with this equation:

Answer:

$$V = \frac{S}{t}$$
$$V = \frac{118 \text{ m}}{27 \text{ s}}$$
$$V = 4{,}370 \text{ m/s}$$

Inclination Angle of Conveyor belt BC-03 is 20°, therefore according to belt inclination coefficient table, we can obtain its coefficient, which is 0,81. Ultimately, capacity of conveyor belt can be determined with this equation below:

Answer:

$$Qt = 3600 \times A \times V \times \gamma \times S$$
$$= 3600 \times 0{,}1365 \times 4{,}370 \times 1{,}002001 \times 0{,}81$$
$$= 1.742{,}889 \text{ tons/hour}$$

4) **Tripper Car Conveyor Belt**

Secondary data of conveyor belt: Three section idlers
conveyor belt type: three section idlers
Thr*ough* angle: 45°
Surcharge angle: 20°
belt width: 1.200 mm = 1,2 m
Material Density = 1,002001 tons/m^3

Answer:

$$A = K\,(0{,}9B - 0{,}05)^2$$
$$= 0{,}1704\,((0{,}9 \times 1{,}2 \text{ m}) - 0{,}05)^2$$
$$= 0{,}1808 \text{ m}^2$$

Primary data of belt's movement distance: 458 m
B*elt's velocity*: 102 s
Therefore, we can determine the velocity of conveyor belt with this equation:

Answer:

$$V = \frac{S}{t}$$
$$V = \frac{458 \text{ m}}{102 \text{ s}}$$
$$V = 4{,}490 \text{ m/s}$$

Inclination Angle of Tripper Car Conveyor belt 20°, therefore according to belt inclination coefficient table, we can obtain its coefficient, which is 0,81. Ultimately, capacity of conveyor belt can be determined with this equation below:

Answer:

$$Qt = 3600 \times A \times V \times \gamma \times S$$
$$= 3600 \times 0{,}1808 \times 4{,}490 \times 1{,}002001 \times 0{,}81$$
$$= 2.371{,}922 \text{ tons/hour}$$

Overall calculation results above can be seen on the table 4 below:

Table 4. Production Capability of each Conveyor Belt from crusher to stockpile

No	Conveyor Belt	A (m^2)	V (m/s)	Qt (tons/hour)
1	BC-01	0,1365	4,238	1.690,243
2	BC-02	0,1365	4,259	1.698,619
3	BC-03	0,1365	4,370	1.742,889
4	Tripper Car	0,1808	4,490	2.371,922

From data of Table 4 above, it can be presented a production capacity diagram for each conveyor belt from crusher to stockpile (Fig 3).

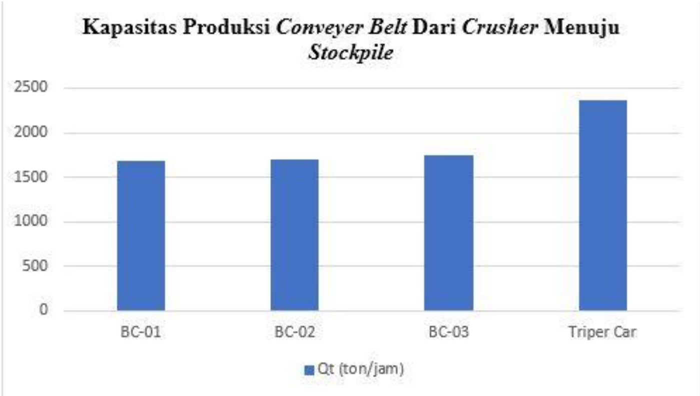

Fig 3. Production capacity diagram for each conveyor belt

Fig. 3 describes about theoretical production capacity for each conveyor per hour. It can be seen that Tripper car type has the highest capacity with 2.371,922 ton/hour, followed by BC-01, BC-02, and BC-03, but unfortunately the three of them did not exceed 2.000 ton/hour value. Based on this calculation, we can conclude that conveyor's surface area and belt's velocity greatly affect theoretical production capacity for each conveyor. On table 4, we can infer that Tripper car conveyor has the highest area and velocity compared to its competitors, therefore it can produce high and significant theoretical capacity, albeit with movement distance of 458 meter.

3.2.2 Actual Productivity of each *Conveyor Belt*

After processing many prominent data above, we can determine actual productivity of each conveyor belt. It can be done by using equation (4), where we can put highest coal production data for one work shift or about 8 hours of work hours, which is about 5000 tons. Ultimately, we can infer the results shown below:

1) **Maximum Actual Productivity**

$$\text{Actual Productivity} = \frac{\text{Total amount of coal at stockpile in one cycle}}{\textit{conveyer belt's worktime}}$$

$$\text{Actual Productivity} = \frac{5000}{8} = 625 \text{ tons/hour}$$

2) Minimum Actual Productivity

$$\text{Actual Productivity} = \frac{\text{Total amount of coal at stockpile in one cycle}}{\text{conveyer belt's worktime}}$$

$$\text{Actual Productivity} = \frac{3000}{8} = 375 \text{ tons/hour}$$

3.2.3 Work Efficiency of each *Conveyor Belt*

Meanwhile the calculation of work efficiency of each conveyor belt is conducted with equation (5), therefore we can infer the results below:

I. Maximum Work Efficiency

1) *Conveyor Belt* BC-01

$$\text{PRI} = \frac{\text{Actual Prodcuctivity}}{\text{Displayed Capacity}} \text{ x } 100\%$$

$$\text{PRI} = \frac{625}{1690,243} \text{ X } 100\% = 36,98\%$$

2) *Conveyor Belt* BC-02

$$\text{PRI} = \frac{\text{Actual Prodcuctivity}}{\text{Displayed Capacity}} \text{ x } 100\%$$

$$\text{PRI} = \frac{625}{1698,619} \text{ X } 100\% = 36,79\%$$

3) *Conveyor Belt* BC-03

$$\text{PRI} = \frac{\text{Actual Prodcuctivity}}{\text{Displayed Capacity}} \text{ x } 100\%$$

$$\text{PRI} = \frac{625}{1742,889} \text{ X } 100\% = 35,86\%$$

4) Tripper Car Conveyor Belt

$$\text{PRI} = \frac{\text{Actual Prodcuctivity}}{\text{Displayed Capacity}} \text{ x } 100\%$$

$$\text{PRI} = \frac{625}{2371,992} \text{ X } 100\% = 26,35\%$$

II. Minimum Work Efficiency

1) *Conveyor Belt* BC-01

$$\text{PRI} = \frac{\text{Actual Prodcuctivity}}{\text{Displayed Capacity}} \text{ x } 100\%$$

$$\text{PRI} = \frac{375}{1690,243} \text{ X } 100\% = 22,19\%$$

2) *Conveyor Belt* BC-02

$$\text{PRI} = \frac{\text{Actual Prodcuctivity}}{\text{Displayed Capacity}} \text{ x } 100\%$$

$$\text{PRI} = \frac{375}{1698,619} \text{ X } 100\% = 22,08\%$$

3) *Conveyor Belt* BC-03

$$\text{PRI} = \frac{\text{Actual Prodcuctivity}}{\text{Displayed Capacity}} \text{ x } 100\%$$

$$\text{PRI} = \frac{375}{1742,889} \text{ X } 100\% = 21,52\%$$

5) Tripper Car Conveyor Belt

$$\text{PRI} = \frac{\text{Actual Prodcuctivity}}{\text{Displayed Capacity}} \text{ x } 100\%$$

$$\text{PRI} = \frac{375}{2371,992} \text{ X } 100\% = 15,81\%$$

Overall results of above calculation can be seen on Table 5.

Table 5. Work efficiency of each conveyor belt from crusher to stockpile

Parameter	BC-01	BC-02	BC-03	Tripper Car
Maximum Actual Productivity (ton/hour)	625	625	625	625
Minimum Actual Productivity (ton/hour)	375	375	375	375
Maximum work efficiency (%)	36,98	36,79	35,86	26,35
Minimum work efficiency (%)	22,19	22,08	21,52	15,81

In Table 5, it can be presented a maximum work efficiency diagram and minimum work efficiency diagram for each conveyor belt from crusher to stockpile (Fig. 4).

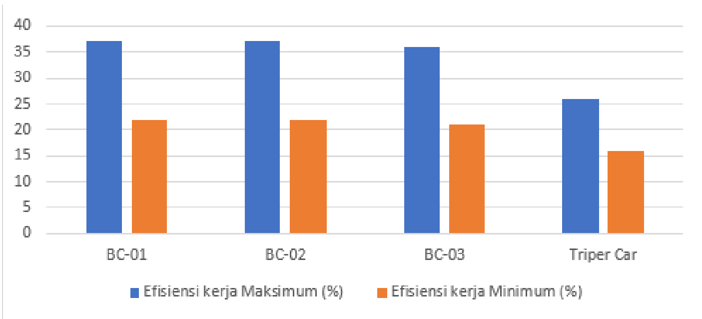

Fig 4. Work Efficiency Diagram of each conveyor belt

Fig. 4 depicts percentage of efficiency value towards actual production based on active working hours. Work efficiency was presented with two conditions, First, within maximum and minimum working condition, which were determined from secondary data obtained from the company. For Conveyor belt type BC-01, BC-02, and BC-03, we can infer efficiency value of each of them to exceed 35% for maximum condition and 20% for minimum condition. Meanwhile for Tripper Car Conveyor Belt, it has the maximum efficiency of 25% and minimum efficiency of 15%. From those results, we can determine that actual production still can be improved for each of conveyor belt types, with consideration of maximum efficiency value of 80% to maintain belt's lifetime. Meanwhile, the consideration of minimum efficiency value is 40% to cover operational expense of said conveyor.

4 Conclusion

According to the aforementioned analysis, then we can conclude many points as shown below:

1. Production Capacity of conveyor belt for transporting coal material to the stockpile has the highest value of 2.371,992 tons/hour by Tripper Car Conveyor Belt and the lowest value of 1.690,243 ton/hour by Conveyor Belt BC-01.
2. Maximum work efficiency for all conveyor belts for transporting coal material to the stockpile is 36,98% as the highest point for Conveyor Belt BC-01, meanwhile the lowest point is 26,35% for Tripper Car Conveyor Belt. For minimum work efficiency for all conveyor belts for transporting coal material to the stockpile is 22,19% as the highest point for Conveyor Belt BC-01, meanwhile the lowest point is 15,81% for Tripper Car Conveyor Belt.

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