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Optimization of the transport cycle of coal ore in the SONICHAR Mine (Tchirozerine, Northern Niger)

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ABSTRACT: This research paper is about the optimization of the coal transport cycle in the SONICHAR Mine (Tchirozerine, North Niger). The transport cycle consists of several unit operations: Loader waiting for, Loading truck, Go in charge of the truck, Truck maneuver, Emptying bucket and Empty Returning truck. Variable time activities (Go in charge, Empty Returning, Loader waiting for) were identified. The optimization of the transport cycle consisted in reducing the duration of the variable time activities. Optimal speeds (25 km/h for the loaded trip and 45 km/h for the unloaded return trip) were proposed to reduce truck travel times. These speeds make it possible to considerably reduce the waiting time for the loader from 3mn 42s to 2mn 40s for the D24 truck and from 3mn 41s to 2mn 46s for the D28 truck. However, regular maintenance of the driving lanes is necessary.

KEYWORDS: Coal mine, SONICHAR, Transport cycle, Cycle optimization, Optimal speed.

I. INTRODUCTION

The Anou-Araren's Nigerien Coal Company (SONICHAR) is mining coal in an open pit at Tchirozérine (northern Niger). The coal is used on site in a thermal power plant for the production of electricity. However, in recent years, the mine has experienced difficulties in supplying the power plant with coal. Among the causes of these shortages, there is a decrease in production efficiency. However, the transport is an essential part of the production of the ore. The objective of this work is to optimize the transport cycle of coal ore in the SONICHAR Mine. This cycle consists of several unit operations: loading, transport, storage. The improvement of the transport cycle consists in reducing as well as possible its duration by limiting the execution times of the unitary operations. Thus, the follow-up and the timing of these operations made it possible to study them and determine their duration of execution. This diagnosis carried out on production machines (loader, dump truck) allowed us to propose ways of improvement.

II. GENERAL CONTEXT OF SONICHAR

II.1. Location of SONICHAR

The Anou-Araren coal mine (SONICHAR) is located 45 km as the crow flies northwest of the Agadez city in Niger (Fig. 1). SONICHAR's main activities are coal mining through an Open Pit Mine (OPM) and electricity generation through a coal-fired power plant.

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Fig. 1: Geographic location of SONICHAR [1]

II.2. Description of the SONICHAR mine

The SONICHAR mine is an open pit coal mine (Fig. 2) where the coal deposit is mined at an average depth of about 50 m [2]. In this mine, two (2) steps must be crossed to reach the mining slice (the coal bed).

➢ First step

The first step is 18 to 20 m thick and is located between 520 m and 500 m above sea level. It's constituted from the base to the top of the sandstone and consolidated alluvium. Between these two layers, there is a thin layer of gypsum of 1 to 2 cm thick. From the tectonic point of view, this step is stable, except for some fractures [3].

➢ Second step

It is a step that is 22 to 24m thick and rests directly on the coal roof. It starts from the altitude 476 m above sea level. The lithological description of the second step shows from the base to the top a sandstone-clay overburden that must be stripped to reach the coal, a belt of carbonaceous shale, very fine sandstones, medium sandstones, oxidized very fine sandstones and medium sandstones [3].

➢ Coal bearing horizon

The coal levels (Fig. 3) are located at the base of the Carboniferous formations [4]. The average thickness of the coal seam varies from 3 to 4 m [5]. The wall of the coal-bearing horizons has a silt-bearing facies with whitish spots. The contact of these silts with the coal is generally quite clear. The roof of the coal horizons is much richer in coal with a higher calorific value of about 2000 Cal/g [3]. The Anou Araren coal is subdivided into two (2) layers: layer A (upper part) of approximately 1 to 3 m thickness and layer B (lower part) of 1 to 2 m thickness. These two layers are separated by an intercalation of argillites of about 50 cm, pyrite nodules and often a belt of carbonaceous shale. From the point of view of coal quality, the B layer is richer than the A layer.

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Fig. 2: View of SONICHAR's open pit mine

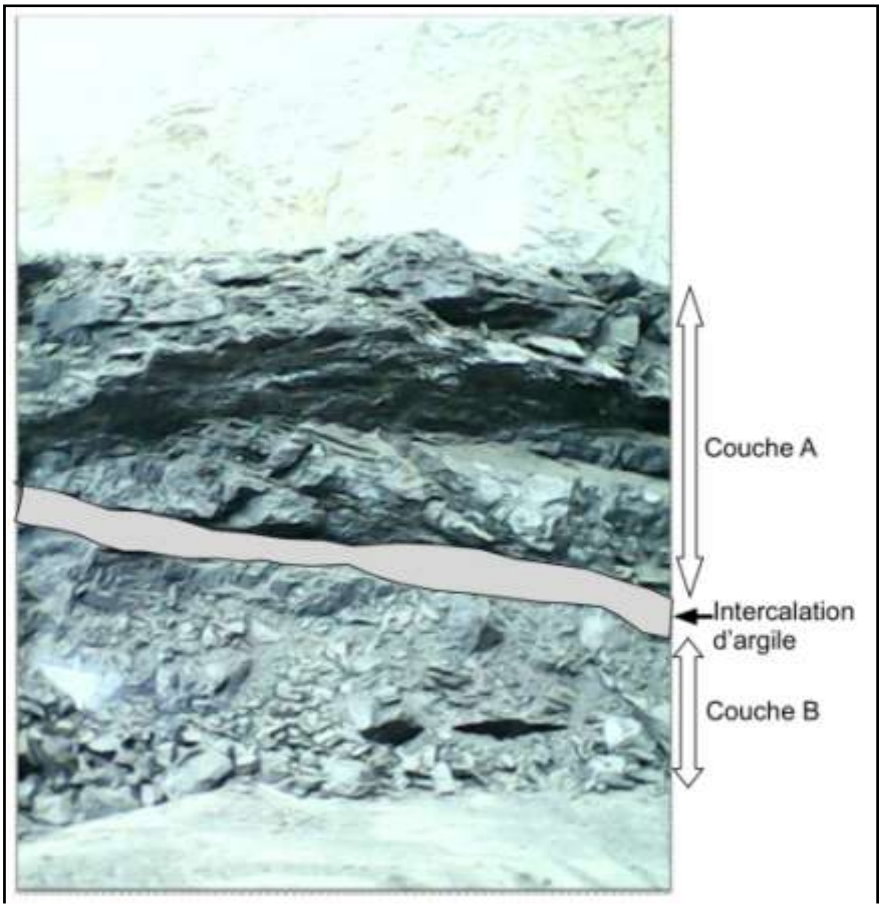

Fig. 3: Main coal layer

III. MATERIAL AND METHODS

III.1. Material

The equipment used in this study was the loading and transport equipment (loader, trucks). The operations of these machines during the transport cycle were monitored and timed for one week.

III.1.1. Bulldozer

The bulldozer (Fig. 6) is the machine eventually used for mechanical mining of low hardness coal.

III.1.2. C15 Loader

The loader used in this study is a CATERPILLAR type machine (Fig. 4), on wheels with a useful bucket capacity (CU) of 6.3 m^3. It is composed of a specially robust frame, used to support the equipment. It has a power-shift transmission with torque converter and hydraulic controls.

Fig. 4: C15 Loader

III.1.3. Dumpers truck D24 and D28

These are CATERPILLAR trucks (Fig. 5) with a useful capacity of 30 tons. They are composed of a short frame, very reinforced with three (3) axles. They have a diesel engine of 1000 hp and a multiple combination gearbox with torque converter giving up to 9 forward speeds.

Fig. 5: Dumper Truck D24

III.2. Coal or sterile transport cycle

The coal haulage cycle is the set of unit operations involved in transporting coal ore or waste rock from the coal face to the coal yard or to the pour. When the ore is hard (requiring blasting), the transportation cycle consists of two (2) main activities: loading and rolling. For soft ore, the transport cycle consists of blasting, loading and rolling. The assessment of the transport efficiency or yield is done by determining the transport cycle time.

III.2.1. Mechanical felling

This operation consists of breaking down the coal layer with a machine (Fig. 6). Bulldozing is used when the traditional method of blasting is not suitable due to the low hardness of the coal.

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Fig. 6: Mechanical coal removal by bulldozer

III.2.2. Loading of coal or sterile

This operation consists of loading coal or sterile material (Fig. 7) with a loading machine (wheel loader) onto a transport machine (Dumper truck). The loader production cycle includes:

- Maneuvering the loader;
- Filling the bucket;
- Bucket emptying.

Fig. 7: Loading operation

III.2.3. Transport of coal or sterile material

The haulage operation consists of transporting coal (Fig. 8) or waste rock on a haulage vehicle (Dumper truck) from the loading point (bottom of the mine) to the hopper in the coal yard. Dumper truck hauling includes the following unit operations:

- Go in charge of the truck;
- Truck maneuvering;
- Dumpster Emptying;
- Return of the truck empty.

Fig. 8: Coal Transportation in SONICHAR mine

III.2.4. Storage of coal or sterile material

This is the operation that consists in dumping the coal by the stockpiler in two (2) piles in a storage area commonly called coal yard (Fig. 9). In the coal yard, the piles are made up according to the ash content set by the power plant.

Fig. 9: Coal storage yard

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IV. RESULTS AND INTERPRETATION

During this study, two (2) trucks (D28 and D24) are assigned to the loader (C15).

IV.1. Truck cycle time

The distance from the coal face to the coal dumping hopper is 1500m (1.5 Km). The truck transport cycle times were recorded for one week (7 days). These times are made up of:

- waiting time for the loader,
- loading time (bucket filling, loader maneuvers, bucket emptying)
- go in charge of the truck time,
- truck maneuvering time,
- emptying the skip time,
- truck empty return time.

IV.1.1. Truck transport cycle time D24

The average times of the different activities constituting the transport cycle of truck D24 are recorded in Table I.

Table I: Time of the different activities of the transport cycle of the D24 truck

Operations	Times	Time percentages
Loader waiting for	03mn 42s	23,77%
Loading	04mn 00s	25,70%
Go in charge	04mn 22s	28,05%
Truck maneuver	50s	5,35%
emptying the skip	25s	2,68%
empty return	02mn 15s	14,45%
Total	15mn 34s	100%

NB: **mn**: minute; **s**: second

The average percentage durations of the different activities of the transport cycle of truck D24 are represented by the graph in Fig. 10.

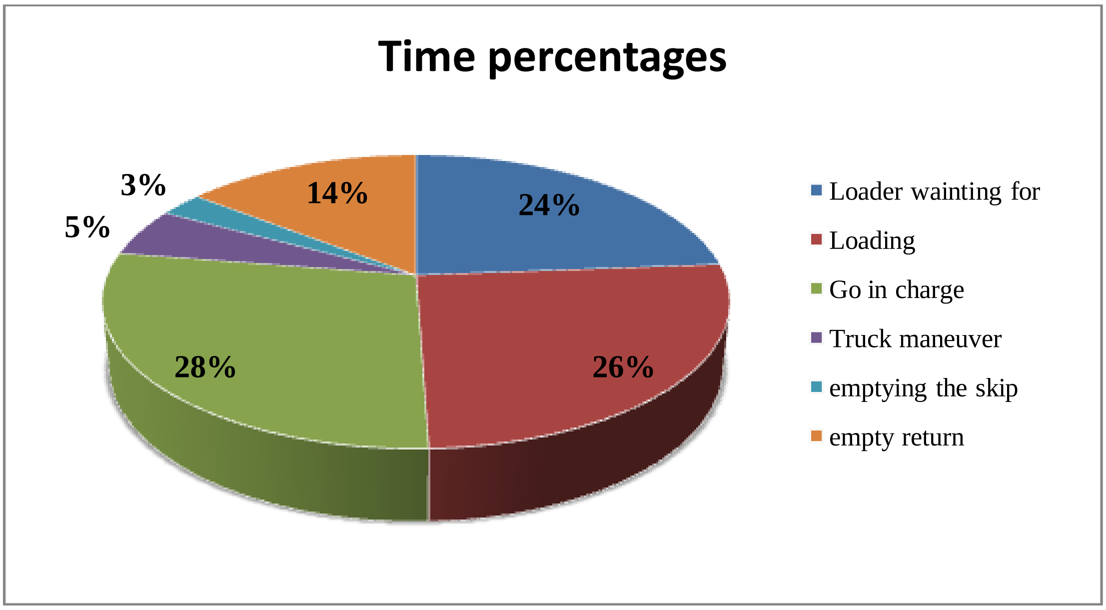

Fig. 10: Transport cycle time of truck D24

Figure 10 shows that the times for the Loading and Go in charge are the longest (> 4 minutes) of the D24 truck cycle (26% and 28%). The average times (> 2 to 3 minutes) are for the D24 Truck Empty return and Loader Waiting for (14% and 24%). The shortest activities (< 1 minute) are Maneuvering the D24 truck and Emptying the bucket (5% and 3%).

Table II: Time distribution of loader and D24 truck operations.

Operations	Times	Time percentages
Loader related	07mn 42s	49,46%
Truck related	07mn 52s	50,54%
Total	15mn 34s	100%

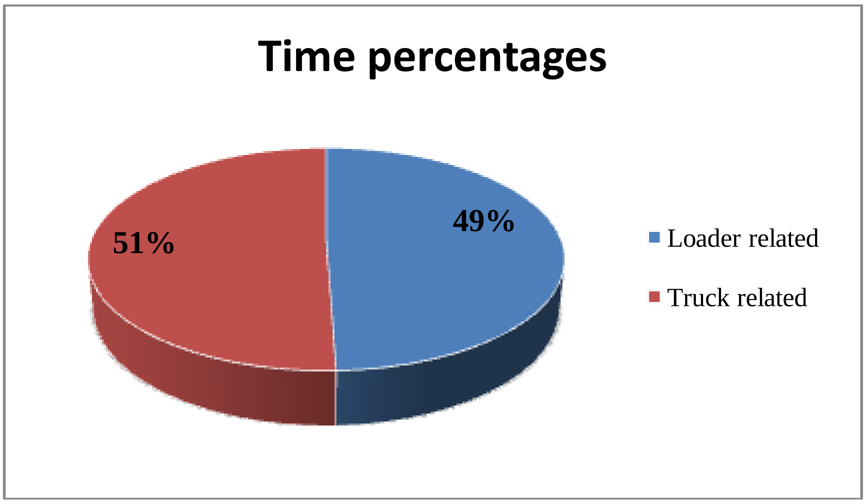

Fig. 11: Time distribution of loader and D24 truck operations

Figure 11 shows that the activities related to the D24 truck (51%) take up slightly more time than those related to the loader (49%).

IV.1.2. Truck transport cycle time D28

The different average times of the operations constituting the cycle of transport of the Truck D28, during one week, are consigned in the table III.

Table III: Time of the different activities of the transport cycle of truck D28

Operations	Times	Time percentages
Loader waiting for	03mn 41s	23,71%
Loading	04mn 10s	26,82%
Go in charge	04mn 20s	27,90%
Truck maneuver	49s	5,25%
emptying the skip	22s	2,36%
empty return	02mn 10s	13,95%
Total	15mn 32s	100%

The average percentage durations of the different activities of the transport cycle of truck D28 are represented by the graph in Figure 12.

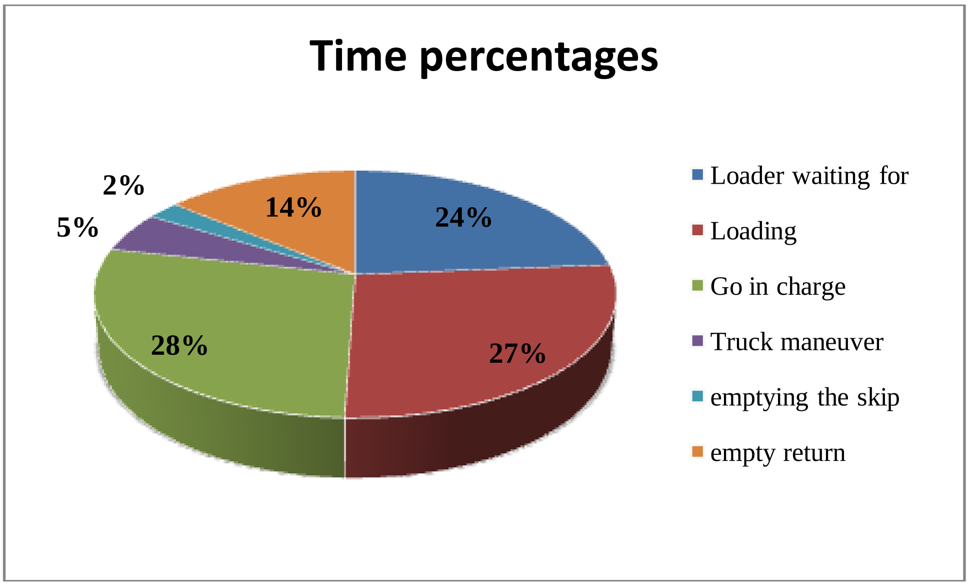

Fig. 12: Transport cycle time for truck D28

Figure 12 shows that the times for the Loading and Go in charge are the longest (> 4 minutes) in the D28 truck cycle (27% and 28%). The average times (> 2 to 3 minutes) are for the D28 Truck Empty return and Loader waiting for (14% to 24%). The shortest activities (< 1 minute) are Maneuvering the D28 truck and Emptying the bucket (5% and 2%).

Table IV: Time distribution of loader and truck operations D28

Operations	Times	Time percentages
Loader related	07mn 51s	50,54%
Truck related	07mn 41s	49,46%
Total	15mn 32s	100%

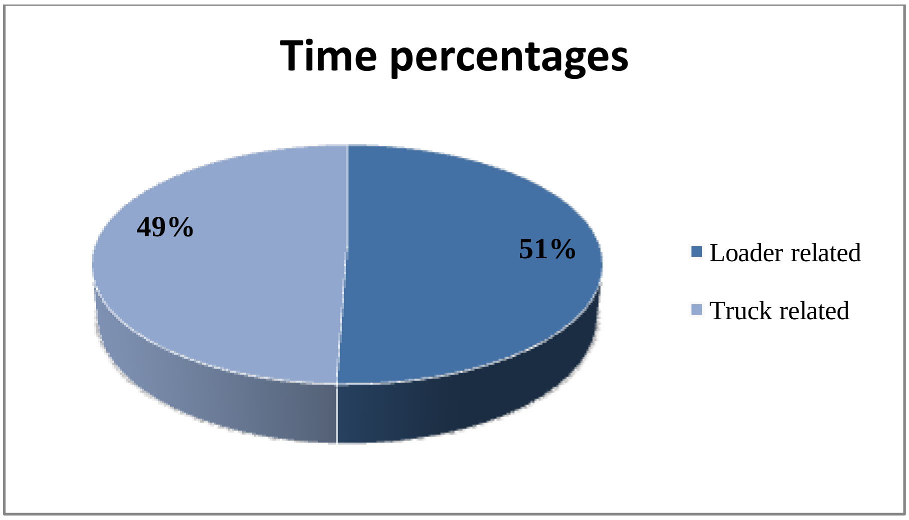

Fig. 13: Time distribution of loader and truck operations D28

Figure 13 shows that loader-related activities (51%) take up slightly more time than truck- related activities (49%).

IV.2. Interpretation

IV.2.1. Analysis and interpretation of results

The monitoring of the production cycle made it possible to identify the different average times taken by each of the activities in the transport cycle (Figs 10, 11, 12 and 13). This analysis shows that in order to optimize the coal transport cycle, it is necessary to act on the variable times (the times of Go in charge and Empty return of truck) to reduce the waiting times of the loader. Thus for trucks D24 and D28, the waiting times for the loader are respectively 3mn 42s and 3mn 41s. These waiting times occupy about 24% of the total duration of the transport cycle for each of the trucks. These waiting times are too long relative to the total cycle time. To reduce this loader's waiting time, the solution that offers more leeway is the one that consists of acting on the variable times (Go in charge, Empty return, Loader waiting for), as opposed to the one that consists of acting on the fixed times (loading, maneuvering of the truck, emptying of the bucket).

Knowing that the distance between the coal face and the coal dumping hopper is 1500m (1.5Km) we have:

Average driving speeds of the D24 truck:

- Go in charge : $V = \frac{d}{t} = \frac{1500\ m}{4\ mn\ 22s} = 5{,}76\ m/s \Rightarrow V = 20{,}74\ km/h$ (1)
- Empty return : $V = \frac{d}{t} = \frac{1500\ m}{2\ mn\ 15s} = 11{,}11\ m/s \Rightarrow V = 40\ km/h$ (2)

The average driving speeds of the D28 truck are as follows:

- Go in charge: $V = \frac{d}{t} = \frac{1500\ m}{4\ mn\ 20s} = 5{,}77\ m/s \Rightarrow V = 20{,}77\ km/h$ (3)
- Empty return: $V = \frac{d}{t} = \frac{1500\ m}{2\ mn\ 10s} = 11{,}54\ m/s \Rightarrow V = 41{,}54\ km/h$ (4)

Truck speeds are about 20 km/h for the going in charge trip and about 40 km/h for the empty return trip. These speeds can be improved. In coal mines with good stability of the stacks, average speeds of 25 km/h loaded and 45 km/h unloaded are allowed [6]. As the SONICHAR has stacks with dimensions and characteristics that give them good stability, these speeds can be used to reduce the waiting time of the loader and thus improve the efficiency of the transport cycle.

IV.2.2. Calculation of the optimal values of the variable cycle times

The improvement of the transport cycle will allow the shortest possible waiting time for the loader. Thus, with a speed of 25 km/h for the loaded trip and a speed of 45 km/h for the unloaded return trip, we obtain the following values for the two (2) trucks (D24 and D28):

- Calculation of the time of Going under load at 25 km/h:

$$t = \frac{d}{V} = \frac{1{,}5\ km}{25\ km/h} = 0{,}06\ hours \Rightarrow t = 3mn\ 36s \quad (5)$$

- Calculation of the time of the Empty return at 45 km/h:

$$t = \frac{d}{V} = \frac{1{,}5\ km}{45\ km/h} = 0{,}033\ hours \Rightarrow t = 1mn\ 59s \quad (6)$$

- Calculation of the waiting time of the Loader waiting for the truck D24:

$T_{waiting\ D24} = (T_{Go\ in\ charge} + T_{maneuvring\ D24} + T_{Emptying\ the\ skip} + T_{Empty\ return}) - T_{D28\ truck\ loading}$

$T_{waiting\ D24}$ = (3mn 36s + 50s + 25s + 1mn 59s) – 4mn 10s = 2mn 40s (7)

- Calculation of the waiting time of the Loader waiting for the truck D28:

$T_{waiting\ D28} = (T_{Go\ in\ charge} + T_{maneuvring\ D28} + T_{Emptying\ the\ skip} + T_{Empty\ return}) - T_{D24\ truck\ loading}$

$T_{waiting\ D28}$= (3mn 36s + 49s + 22s + 1mn 59s) – 4mn 00s = 2mn 46s (8)

CONCLUSION

The study of the coal transport cycle at SONICHAR first allowed determining the durations of the unit operations that make up the cycle. Then, the variable time activities (Go in charge, Empty return, Loader waiting for) were identified. The optimization of the transport cycle consists in considerably reducing its duration by acting on the activities with variable duration, which are the trips. Thus, optimal speeds have been proposed to reduce the driving time of the trucks. Following the optimization calculations, the waiting time for the loader was reduced from 3mn 42s to 2mn 40s for the D24 truck and from 3mn 41s to 2mn 46s for the D28 truck. However, regular maintenance of the driving lanes is necessary.

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