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Estimation of Efficiency of Use of Self-Propelled Machines When Developing Caulda Deposits

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KEYWORDS: mine, self-propelled machine, loading truck, underground dump truck, operational performance, coefficient of use of the machine.

I.INTRODUCTION

The Kauldy mine was put into operation on December 27, 1977, the construction of the South Kauldy site began in 1992. The commercial output of the mine is gold fluxing ore.

To deliver ore from the faces, depending on the development system, the following is used:

- scraper winches 17-HP, 30-HP;
- loading and delivery machines of the type LK, TORO, ST.

Rock mass is transported to the surface by underground dump trucks of the MT20-10 type and underground electric locomotives 10K using the UVO-0.8 and VG-1,2 trolleys.

Rock strength according to Protodyakonov XVI-XVIII, bulk density of the rock - 2.6 t / m3, ore - 2.65 t / m3.

The purpose of the work is to establish the influence of technical and technological factors on the level of operational productivity of the complex "bucket loader-underground dump truck", which performs loading and transport operations during underground mining of ore from Kauldy deposits.

Self-propelled equipment has several advantages over other means of loading and delivery. So, the introduction of loading and transporting machines in underground mining since the end of the 60s made it possible to significantly increase productivity in a relatively short period of time, reduce the cost of ore mining by 40-50% and increase the safety of miners [1,2,3].

If at the initial stage machines were used only for certain operations, then over time they began to use complexes of self-propelled machines that provide several technological processes at once, which made it possible to increase the labor productivity of workers in advanced mines by 1.4-2.7 times than in other mines [2].

The largest foreign manufacturers of PTM with a load-carrying bucket are the companies: ARA (Finland), Atlas Copco (Sweden), "EquipmanMinier" (France) and "Fadroma" (Poland), "Gutekhoffnungshütte" (Germany), "Kawasaki" (Japan) and "Jarvis Clark" (Canada).

The requirements for self-propelled transport vehicles, the main of which are:

- small overall dimensions and high reliability;
- the ability to overcome prolonged climbs up to 150 thousandths;
- ensuring work safety;
- the minimum content of harmful components in the exhaust gases and reliably working devices for neutralizing and cleaning them.

Practice shows that the effectiveness of the use of cargo handling and transport vehicles most often depends on the technological scheme of field development.

So, in the mines of Australia, Africa, Canada, USA, Western Europe, about 80% of the ore is mined using self-propelled equipment.

The research results and foreign experience in the operation of self-propelled equipment show that the speed of vehicles and, accordingly, the productivity of transport depend on the condition of underground roads. If underground roads do not have a special coating, then the power consumption of the engine, fuel and air consumption increase [4].

In addition, poor roads cause additional costs for the repair and purchase of tires, which average 18-25% of the total operating costs for the delivery of 1 ton of ore [3,4].

The performance of loading and transporting machines depends not only on the condition of underground roads, the quality of tires and loading methods, but also on the particle size distribution of the blasted rock mass.

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Smaller ore has less resistance to scooping and, therefore, requires less time to fill the bucket, provides a high degree of filling.

For example, the productivity of the PTM during loading and delivery of coarse ore is 100-170 tons / shift, and for fine ore - 140-210 tons / shift, which is 10-20 and 30-40% higher than the productivity of the scraper installation in similar conditions. However, from the factory additional costs for breaking, it is very difficult to achieve the optimal fractional composition of the beaten ore [5].

The optimal value of the coefficient $K_i$of technical use should be not lower than 0.7-0.8. However, often it does not exceed 0.4-0.5 [4.5].

According to many authors, self-propelled equipment has great potential. With an increase in K_i to 0.5-0.6, the productivity of equipment increases by 2 times, and with the appropriate organization of work, increased reliability and quality of machine repair, it can reach 0.7-0.9.

To establish the reasons for the unstable operation of loading machines, timing observations were conducted in the conditions of the Kauldymine.It turned out that loading of ore and rocks and downtime of a bucket loader in anticipation of a dump truck amounted to 214 and 93 minutes, respectively (Table 1).

From table 1.it can be seen that the duration of loading operations is 51.0% of the duration of the work shift, which is significantly lower than at the leading mining enterprises. Frequent malfunctions of the front-end loader lead to a temporary suspension of work, and this, in turn, reduces the shift productivity of the PDM.

The duration of loading varied from 3 to 5 minutes (average value 4.5 min.), And the number of scoops until the bucket was completely filled from 1 to 2. For maximum loading of the dump truck body, the truck driver needed to fill 6-7 buckets. It took 56 minutes to parse the oversize, clear the soil and prepare the bulk for loading.

Table 1
The results of timing observations of the work of the LK-07 wheel loader

№	Operation	Durationmin	%
1	Rock loading	214	51,0
2	Oversizeanalysis, preparation, stripping	56	13,3
3	Waitingforloading	93	22,2
4	Relocation	23	5,4
5	Others (raising the duct, refueling fuels and lubricants, technical inspection and delivery of the shift)	34	8,12
	Total	**420**	**100**

During the shift, the LK-07 wheel loader operator loaded 968 tons of ore.
Based on timing observations and reliable facts, we came to the conclusion that the main reasons for the low productivity of the LK-07 wheel loader are:
- significant downtime caused by insufficient loading of the loader by underground dump trucks and their downtime at the near-barrel receiving hopper, frequent breakdowns of parts and components of loading machines;
- different duration of loading the body of the transport machine, due to the uneven lumpiness of the broken rock mass.
When evaluating the efficiency of bucket loaders, operational (shift) productivity is more indicative, since it takes into account the downtime of self-propelled equipment [6]:

$$Q_э = \frac{3600 * q * T_{СМ} * K_i}{T_Ц}, т/см$$

where q is the load capacity of the bucket PDM, t; $Tсм - shift\ duration, hour$; $Ki - coefficient\ of\ intra-shift\ use; Tц - thedurationofasingleloadingcycle, sec.$
However, this formula also has a significant drawback, since, in our opinion, it does not have a load utilization coefficient (K_q or K_r), because the mass of ore in the bucket often does not coincide with the nominal load capacity.

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This is confirmed by elementary calculations, which were made on the basis of timing observations and a friend of their known data. So, at the Kaulda mine and for loading ore, a LK-07 front-end loader with a lifting capacity of 3.2 tons is used.

The utilization factor K_i was calculated as follows:

$$K_i = \frac{T_{погр}}{T_{СМ}}$$

where T $_{heat}$ - the duration of loading work during the shift, min .;Tсм − shift duration, min.

This approach is explained by the fact that productivity is determined only by the amount (mass) of ore loaded into the vehicle. Therefore, the time spent on other operations (cleaning, preparing the bulk for loading, moving, etc.) and the expectations of the paired unit were not taken into account . The value of Ki did not exceed 0.53 with an average loading cycle of PDM equal to 55.2 sec. As a result of the calculations, the operational productivity was 1532 tons, which is approximately 1.6 times more than the actual indicators.

The reason for the mismatch of this formula with real values, in our opinion, is the lack of load capacity utilization factor (K_q).In this regard, the formula for calculating $Q_{см}$ is transformed into the following form:

$$Q_э = q * K_q * T_{СМ} \frac{3600 * K_i}{T_Ц}, т/см$$

An analysis of scientific research has shown that the mass of ore in the bucket ($G_к$) is determined in two different ways:

$$G_К = q * K_q = V_К * \gamma * K_Н \text{ или } G_К = \frac{V_К * \gamma}{K_р}$$

whereV$_к$ is the geometric capacity of the bucket, m^3;γ is the bulk bulk density of the broken ore, t / m$_3$;K$_н$ - bucket filling ratio; K_p - coefficient of loosening of ore in the bucket PDM.

However, for further calculations, the first option was adopted, since the joint consideration of the bulk bulk density of the beaten ore, the geometric capacity of the loading unit of the PDM and the bucket filling factor completely eliminates the use of the ore loosening coefficient in the bucket.In addition, the change in K_p in the bucket compared to the initial conditions (bulk) in the conditions of the Kaulda mine is very insignificant. For the conditions of the Kaulda mine, Q_e can be calculated from the data in Table 2.

Table 2.
Performance Indicators

Index	$K_Н$	γ, т/м^3	$V_К$, м^3	$T_{СМ}$, час	K_i	$T_Ц$, сек
Values	0,8 - 1,0	2,5 - 2,6	3,7	7	0,53	55,2

As a result of the calculations, the operational productivity amounted to 1054.6 tons, which is 8.94% higher compared to the actual values (968 t / cm).Therefore, the final formula for determining the operational performance of bucket PDM will take the form:

$$Q_э = V_К * \gamma * K_Н * T_{СМ} \frac{3600 * K_i}{T_Ц}, т/см$$

Analysis of the results of timing observations of the operation of the transport machine. Transportation of blasted rock mass in the conditions of the Kaulda mine is carried out by underground MT20-10 dump trucks with a lifting capacity of 20 tons.Interchangeable timing observations (Table 3) established that the main causes of downtime of a transport vehicle are: waiting for the loading and unloading of another vehicle.

The total time of all downtime of self-propelled equipment for ore transportation is 52.5 minutes (Table 3). More than 60% of the indicated time, the driver of the dump truck stood idle waiting for loading, and the utilization rate of the transport vehicle in time was 0.82 (Table 3).

In connection with the elimination of interruptions caused by a violation of the normal course of the production process, it is possible to increase the efficiency of the use of working time:

$$K_1 = \frac{52,5}{420} * 100\% = 12,5\ \%$$

The average speed of the MT20-10 car during the shift reached 20 km / h with an average travel time of 12.7 minutes from the loading point to the unloading point on the surface. The average speed in straight sections with a length of more than 800 m should reach 40 km / h, however, during timing observations, it was 33 km / h.

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Table 3
The results of timing observations of the operation of the MT20-10 dump truck

№	Reason for downtime	Duration min
1	Waiting for the truck to arrive at the place of loading	5
2	Waiting for loading a car that has previously arrived	5
3	Moving to the loading unit and waiting for the start of loading, while the truck was preparing the camera	1 0
4	Stop during the journey, as the roads were irrigated	1,5
5	Waiting for another car to unload	4
6	Waiting for loading while the truck cleans the chamber	8
7	Waiting for loading	3
8	Waiting for loading	8
9	Waiting for loading	2
10	Waiting for another car to unload	3
11	Waiting for refueling	3
	Итого:	**52,5**

With an increase in speed in straight sections by 7 km / h, travel time will be reduced by 23 minutes.And increasing the efficiency of using working time will be:

$$K_2 = \frac{23}{420} * 100\% = 5,4\%$$

A general increase in labor productivity by eliminating worker losses can achieve:

$$\Pi = \frac{12,5 + 5,4}{100 - 17,9} * 100\% = 21.8\ \%$$

The shift worker transported 320 tons of ore (16 flights of 20 tons each). And when eliminating the loss of working time, the removal of the rock mass per shift can be more than 400 tons. The main operations of the dump truck are: loading ore, moving a loaded transport vehicle to a receiving hopper, unloading and moving an empty vehicle to a loading point.

At the same time, the duration of unloading is more constant than the duration of other operations. At the same time, the duration of unloading is more constant than the duration of other operations. The condition of underground roads also has a significant impact on this. According to our observations, when driving along the workings, the MT20-10 dump truck encounters pieces of rock on its way that have fallen from the bodies of previous dump trucks. Their presence to some extent reduces the average speed of vehicles.

For MT20-10 transport vehicles used in the Kauldy mine, breakdowns of the hub, coupler, power take-off (razdatka) were recorded, which necessitates repair work during the change or replacement of self-propelled equipment.

II. CONCLUSION

1 .The main reasons for the low productivity of the LK-07 wheel loader are:

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- significant downtime caused by insufficient loading of the loader by underground dump trucks and their downtime at the near-barrel receiving hopper, frequent breakdowns of parts and components of loading machines;
- different duration of loading the body of the transport machine, due to the uneven lumpiness of the broken rock mass. The utilization rate amounted to 0.43, with an operational productivity of 968 t / cm.

2. The operational (replaceable) productivity of the bucket PDM is determined by the geometrical volume of the bucket, volumetric bulk density of the ore, bucket filling ratio, working shift duration, utilization rate and duration of a single loading loading cycle.

3. As a result of timing observations, it turned out that underground dump trucks often stand idle waiting and loading or unloading, the duration of the journeys to the near-barrel receiving bunker and back (to the camera) varies widely due to the need for clearing and irrigation of roads, refueling and workouts in the way.

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