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USE OF ARTICULATED TRANSPORT SYSTEMS IN THE MINING INDUSTRY

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Abstract. The work is devoted to the possibility and prospects of the use of all-wheels drive articulated transport systems in the mining complex. A comparative analysis of the traditional methods of exporting minerals in open pit mining and the method of using active trailed elements are given. The trailer has a load factor several times higher than the same rate for mining dump trucks. The use of an active trailer makes it possible to reduce the mass of the tractor and trailer by almost 40 tons and increase the specific power of the road train.

1. Introduction

The use of all-wheel drive transport systems based on the activation of the trailer and the use of articulated transport and technological machines is one of the promising directions in solving many problems arising from the operation of transport and technological complexes in winter roads, dirt roads during the muddy season and in other specific conditions [3]

The concept of “articulated transport system” (ATS) is very broad and includes a whole range of machines that have at least two sections connected by a hinge with one or more degrees of freedom. As a special, but rather widespread, case of ATS, road trains with active trailers or active ATS (AATS) should be considered.

The use of AATS and ATS in the sectors of the mining complex, agriculture, as well as in the sectors of the forest, oil and gas complexes and other raw material sectors of the economy makes it possible to create a wide range of technological and transport systems.

The problem of improving the operational properties of transport systems is one of the main in mechanical engineering, the solution of which should be carried out in various directions: increasing productivity, improving economic and environmental indicators, increasing operational reliability, improving and automating transport control systems, and a whole range of other theoretical and experimental focus [1,2]

2. Theoretical part

Let us analyze traditional transport systems operating in open pit mining. As a rule, BelAZ family dump trucks are used as a transport unit. As the main comparative characteristics, we take the following:

- Q_v – carrying capacity, kN;
- G_v – own weight of the vehicle, kN;
- N – engine power, кВт;
- k – factor carrying capacity.

$$k = \frac{Q_v}{G_v} \tag{1}$$

Table 1. Comparative characteristics of dump trucks

Car model and make	Q_v, kN	G_v, kN	N, kW	k
BelAZ - 548A	400	288	367,7	1,4
BelAZ – 549	750	669,8	772	1,2
BelAZ - 75214	1800	1570	1 691	1,15
MAZ- 5335	80	67,25	132,4	1,19
KamAZ – 55102	70	90,75	154	0,77
MAZ - 75165	245	223,5	346	1,1

An analysis of the technical characteristics in table 1 shows that BelAZ dump trucks are no exception among other trucks in terms of load capacity.

AATS means at least two sections, one of which carries a technological function. The trailer link in the composition of the road train is a section that carries a technological function [4,5,6]

Consider the characteristics of heavy-duty trailers manufactured by the industry. Options for comparison:

- make and model of the base tractor;
- Q_{Tr} – carrying capacity trailer, kN;
- G_{Tr} – own weight trailer, kN;
- k_{Tr} – factor carrying capacity trailer;
- N – base tractor engine power, kW;
- Q_T – carrying capacity tractor, kN;
- G_T – total base tractor weight, kN;
- k_{at} – ratio of full load trailer weight to full tractor weight.

The coefficient of the load capacity of the trailer is determined similarly to the coefficient of the load capacity of dump trucks. To compare the ratio of the total weight of the trailer and the tractor, we introduce the concept of the coefficient of the total mass of the road train k_{at}. The coefficient of the total mass of the road train will be determined as the ratio of the total weight of the trailer to the full weight of the tractor:

$$k_{at} = \frac{G_{Tr} + Q_{Tr}}{G_T + Q_T} \quad (2)$$

The results of the analysis are shown in table 2.

Table 2. Comparative characteristics of the trailer

Trailer brand	Q_{Tr}, kN	G_{Tr}, kN	k_{Tr}	Base tractor	N, kW	G_T, kN	k_{at}
MAZ – 8378	145	55	2,64	MAZ – 5335	132,4	147,3	1,36
CMZAP-5523	250	67,5	3,7	KrAZ - 258	176,5	192	1,65
CMZAP -5208	400	109	3,67	MAZ – 537P	525	440	1,16
CMZAP -5212	600	139	4,32	MAZ – 537P	525	440	1,68

An increase in the carrying capacity of a trailer increases its carrying capacity. This is due to an increase in the number of wheels.

As can be seen from the data presented, regardless of the carrying capacity of the trailer, the coefficient of its carrying capacity and the type of tractor, the value of the coefficient of the total mass of road trains is in the range 1.3 - 1.7. The reason is that universal vehicles are used as tractors, designed both for transporting goods on a loading platform (cargo weight is considered in G_T), and for towing trailers.

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3. Experimental part

If you determine the necessary weight of the traction link for the trailer CMZAP-5212 according to the conditions of adhesion of the wheels to the ground, then it turns out to be 23.4 kN, which corresponds to its own weight MAZ - 537P.

Let us consider the possibility of creating an articulated transport system with a heavy-duty trailer link and a traction link corresponding to it in terms of coupling capabilities [9,10]

As an analogue of the load capacity, we take a dump truck BelAZ - 75214 from table 1 and a load coefficient of a heavy trailer k_{Tr} = 4 from table 2.

Determination of the total weight of the trailer.

Carrying capacity trailer:

Q_{Tr} = 1 800 kN.

Own weight trailer:

$$G_{Tr} = \frac{Q_{Tr}}{k_{Tr}} = \frac{1800}{4} = 450 \text{ kN} \quad (3)$$

Total trailer weight:

$$G_{Ttw} = Q_{Tr} + G_{Tr} = 1\,800 + 450 = 2\,250 \text{ kN} \quad (4)$$

Determination of the force required to tow a loaded trailer.

Road conditions in open pit mining:

- rolling resistance coefficient, f = 0,02;
- steering bias, i = 7 – 10 % (corresponds to the angle of rise $\alpha \approx 6^0$);
- operating speed of the transport system, v = 10 km/h = 2,78 m/s.

The strength of the total resistance to the movement of the trailer:

$$P_{\psi Ttw} = G_{Ttw}(f \cdot \cos\alpha + \sin\alpha) \quad (5)$$

$$P_{\psi Ttw} = 2250 \cdot (0{,}02 \cdot 0{,}99 = 0{,}174) = 436{,}05 \text{ kN} \quad (6)$$

For uniform rectilinear movement, a force must be applied to the towing device of the trailer (P_{kr}), equal to the strength of the total resistance to movement:

$$P_{kr} = P_{\psi Ttw} \quad (7)$$

Determination of the power spent on towing a trailer:

$$N_{Ttw} = P_{Ttw} \cdot v \quad (8)$$

where N_{Ttw} – trailer towing power, kW.

$$N_{Ttw} = 436{,}05 \cdot 2{,}78 \approx 1212{,}3 \text{ kW} \quad (9)$$

Determination of tractor engine power:

$$N_e = \frac{N_{Ttw}}{\eta_t} \quad (10)$$

where N_e – tractor engine power, kW;

$\eta_t \approx 0{,}8$ – transmission efficiency.

$$N_e = \frac{1212{,}2}{0{,}8} = 1515{,}25 \text{ kW} \quad (11)$$

Taking into account the power reserve for overcoming unforeseen resistances, the effective engine power should be taken 8 - 10% higher than the calculated:

$$N_{ef} = N_e + 10\,\% = 1668 \text{ kW} \quad (12)$$

The calculated power corresponds to the engine power of the dump truck BelAZ - 75214.

Choose the weight of the tractor from the condition of lack of slipping of the drive wheels.

The condition of the movement of the transport system in the absence of slipping of the wheels:

$$P_t \leq P_\varphi \quad (13)$$

where P_t – tangential traction on tractor wheels, kN;

P_φ – traction force of wheels with soil (traction force on coupling), kN.

$$P_\varphi = G_\varphi \cdot \varphi \quad (14)$$

where G_φ – coupling load of the tractor (weight per drive wheel), kN;

φ = 0,6 - 0,7 – coefficient of coupling for open cast mining.

For full drive systems:

$$G_\varphi = G_T \quad (15)$$

Accept the boundary condition for coupling:

$$P_t = P_\varphi \quad (16)$$

To be able to tow a trailer, it is necessary that the tangential traction force P_t be not less than the total force of resistance to the movement of the trailer:

$$P_t = P_{\psi Ttw} = P_{kr} \quad (17)$$

where P_{kr} – traction force on the hook of the tractor.

Then, in view of the above:

$$G_T = \frac{P_{\psi Ttw}}{\varphi} = \frac{436{,}05}{0{,}6} \cong 727 \text{ kN} \quad (18)$$

4. Results of the experiment and their analysis

Compare the existing dump truck with a carrying capacity of 1800 kN with the projected weight indicators:

BelAZ – 75214:
own weight, kN - 1570;
factor carrying capacity - 1,15.
Projected:
trailer weight, kN – 450;
tractor weight, kN – 727;
total weight, kN - 1177;
factor carrying capacity – 3,09.
Weight difference, kN – 393.

That is, the movement of cargo is carried out by a transport system having its own weight 25% less than the base.

5. Conclusion

As indicated earlier, the weight of the tractor is selected for reasons of lack of slipping of the drive wheels. Having reduced the traction force realized on the drive wheels, transferring part of the power to the trailer wheels (i.e., making them drive - AATS), the total traction force required for the movement of the ATS does not change. This allows you to reduce the weight of the tractor by an amount proportional to the power given to the trailer [7,8]

Thus, based on the above calculations, it can be concluded that it is advisable to develop a set of machines for opencast mining on the basis of ATS and AATS.

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