Study of structural features of draglines for their possible adaptability to changing mining and geological conditions

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ABSTRACT: Draglines (walking excavators) are widely used in opencast mining. However, the area of their effective use is relatively small and is reduced to the excavating of horizontal and flat coal seams, which makes it possible to use draglines on a transportless (non-transport) scheme of mining with a dumping of the internal spoil (rock dump). In this case, the cost of extracted coal is significantly reduced due to the fact that the costs of rock transportation are completely eliminated.

Currently, more than 100 walking draglines of various sizes are operating in the Russian Federation open pits. Almost all of them are machines of domestic production. The main Russian manufacturer of draglines is the Uralmash plant which produces draglines of a wide range of standard sizes: bucket capacity up to 65 cu.m, boom length up to 130 m.

In addition to domestic draglines, the market presents walking excavators manufacturers «NKMZ», «Komatsu Mining», «Caterpillar», etc. Analysis of their parameters shows that their main characteristics are quite comparable with each other, but excavators are significantly different in terms of boom and A-frame design. The difference in design leads to limitation of possible use of draglines as modular units due to peculiarities of the above mentioned nodes.

1 INTRODUCTION

Domestic and import walking draglines currently used in opencast mining are characterized (Bereznyak et al, 1970; Demirel, 2011; Huddart and Runge, 1979; Nazarov, 2011; Palamarchuk et al, 2019; Sadri and Lee, 1982; Scott et al, 2010; Seib and Carr, 1990) by the following main parameters (Table 1).

As we can see from table above, the main parameters of draglines are bucket capacity and boom length. The purpose of this work is to define those parameters that can be changed without making significant changes to the design of the dragline as a whole, in other words - modular parameters.

Since the area of application of draglines are horizontal and flat beds, it is necessary to say a few words about the geology of developed and prospective coal deposits of Siberia.

The Siberian platform as a whole is characterized by horizontal, flat and slightly inclined bedding (up to 15 degrees) on a highly dislocated crystalline shield represented by deeply metamorphosed gneiss and granitoids (Allison and Palmer, 1980; Markov et al, 2019;

Table 1. Dragline parameters.

Manufacturer, model	Working weight, t	Boom length, m	Bucket capacity, cu.m	Tub diameter, m
Caterpillar				
CAT 8000	1770 – 1988	75 – 101	24 – 34	15.24, 15.6
CAT 8200	3836 – 4123	100	46 – 61	19.5
CAT 8750	5800 – 7500	110 – 133	76 – 116	22.9
NKMZ				
ESH 11/70	No data	70	11	9.7
ESH 10/100	No data	100	10	12.3
ESH 15/80	No data	80	15	12.3
ESH 20/65	No data	65	20	12.3
Uralmash				
ESH 11.75	840	75	11	10.8
ESH 20.90	1690	90	20	14.5
ESH 25.90	1900	91	25	15.3
ESH 15.100	1710	100	15	14.5
ESH 24.95	1960	95	24	15.3
ESH 40.100	3310	100	40	18.0
Komatsu Mining (P&H draglines)				
P&H 2355	No data	42.7 – 61	15.3	No data
P&H 736	No data	53.3 – 79.2	22.2	No data
P&H 752	No data	73.2 – 97.5	35	No data
P&H 757	No data	83.8 – 106.7	57.3	No data
P&H 9020	No data	88.4 – 123.4	91.8	No data
P&H 9160	No data	99.1 – 129.5	122.3	No data
P&H 9010C	4056	84 – 107	42 – 60	18.7
P&H 9020C	5940	90 – 125	55 – 93	22.30
P&H 9020XPC	8002	100 – 130	85 – 122	26.8
P&H 9030 C	7539	117	99.1	No data
Bucyrus International (was acquired by Caterpillar at 2011)				
680 W	1043	58 – 90	12 – 24	No data
7820	1996	69 – 99	27 – 38	No data
8050	3357	76 – 107	47 – 67	No data
1260 W	1678	59 – 92	18 – 31	No data
1300 W	2132	79 – 99	22 – 36	No data
1370 W	2989	87 – 99	44 – 48	No data
1570 W	3630	94 – 105	48 – 61	No data
2570 W	6000	104 – 122	69 – 89	No data
2570 WS	7271	110 – 128	85 – 120	No data
8200	4492	84 – 122	53 – 84	No data
8750	6580	102 – 131	84 – 114	No data
8750 B	7620	109.7	81 – 116	No data
8750 D3	5534	109.7	90	No data
8750 R	5851	124.9	79 – 99	No data
W 2000	1780	75 – 101	24 – 34	No data
BEML				
W2000	1701 – 1980	74.6 – 100.85	23 – 34	No data
HEC Draglines				
HEC		74.6 – 95.6	24 – 34	No data

Katsubin and Fedotov, 2019). Typical cross-sections on some promising deposits from the point of view of draglines application are shown in Figures 1-a, 1-b.

2 MATERIALS AND METHODS

In our opinion, the effective use of draglines has no comprehensively substantiated scientific basis. Among the priority problems we can refer to:

- complexity of mining and geological conditions: variability of coal seams' occurrence parameters, their disturbance and variability of physical and mechanical properties of the overburden rocks;
- terrain and orography features, and other topography conditions that hinder the creating of stable dumps;
- remoteness and poor development of deposits with favorable mining and geological conditions (Figure 1-a, 1-b);
- insufficient adaptability of the application of a particular dragline model to the degree of variability of the mining and geological conditions within the developed area (deposit).

Consideration of these problems makes it possible to formulate a number of priority scientific tasks:

- 1) Determining the degree of variability of the mining and geological conditions as a factor affecting the adaptation of the dragline to the current conditions of its effective work.
- 2) Upgrading the design of the dragline in order to make it more adaptable to changes in working conditions.

Figure 1. a. Geological scheme of the South Yakut basin: 1 – Lower Cretaceous sediments, 2 – Middle Upper Jurassic sediments, 3 – Lower Jurassic sediments, 4 – Jurassic undifferentiated sediments, 5 – Archean foundation, 6 – faults; a – general scheme; b – geological cross-section of the Chulmakan field; c – geological cross-section of the Nerungri field; Г5, Г7, Г9, Д7, Д15, Д19 – coal seams.

Figure 1. b. Scheme of Tungus coal basin (a), cross-sections of Kayerkan (b) and Kokuisky (c) deposits: I – Norilsk region: 1 – Schmidt and Nadezhda mountains (Norilsk-1), 2 – Kayerkan, 3 – Imangdinskoye; II – Arctic region: 4 – Kureiskoe, 5 – Kayakskoe; III – Western District; IV – Central district; V – Eastern district; VI – Southern district: 6 – Kokuiskoe, 7 – Boguchanskoe.

- 3) Identification of the most important dragline parameters that can be modified within the same model for specific mining and geological conditions.
- 4) Determination of the range of changes in the parameters of modular equipment.

3 RESULTS

Variability of the mining and geological conditions, in fact, is reduced to changes in the angle of incidence and thickness of the developed coal seams. Besides, it is necessary to take into account the number of coal beds (bed series) and parameters and structure of the series. If parameters of the bed series have been studied to a certain extent by domestic and foreign scientists (Demirel and Frimpong, 2009; Elliott, 1989; Lee, 1988; Michaud and Calder, 1988; Runge, 1983; Ramani and Bandopadhyay, 1985; Soloviev and Kuziev, 2017; Tanaino and Cheskidov, 1999; Vukotic et al, 2013; Sengstock, 1992; Townson et al, 2003), the series structure is still poorly studied, especially for prospective areas. Meanwhile, it significantly affects both the structure of dumps (number of tiers, etc.) and the required characteristics of the equipment used. For example, an increase in the dip angle entails an increase in the number of tiers, a decrease in the general angle of the internal dump slope and the need to increase linear parameters of the dragline. This problem does not occur, for example, with backhoes using (Dubinkin et al, 2019; Strelnikov, 2019a; Strelnikov, 2019b).

This raises the question of applicability to the development of the area (deposit): a) stand-ard dragline models; b) modular draglines; c) a combination of standard models and modular draglines.

As part of the second task, we would like to focus on the following. Since dragline is a complex multinode machine, there is a problem of identifying those nodes (modular or dynamic nodes), the parameters of which can be changed without affecting the design as a whole. In our opinion, such nodes can include a boom, a bucket, and counterbalances. At the same time, some basic (or static) elements of the structure (tub, revolving frame, winches, rope drums, etc.) should be designed to use modular nodes with maximum parameters. For example, the rope drum as a base element must provide the maximum length of the rope winding used with the maximum length of the boom.

Figure 2. Dragline ESH 20.90 by “Uralmash”; modular (dynamic) elements are highlighted in red; basic (static) elements are highlighted in blue.

Figure 3. Dragline ESH 15/90 by NKMZ; the modular (dynamic) elements are highlighted in red, the basic (static) elements are highlighted in blue, the elements that can be referred to both modular and basic elements are highlighted in green.

However, changes in some parameters of modular equipment may be limited by design features. For example, an A-frame of ESH draglines made by Uralmash can be used only with a certain boom (Figure 2), i.e. the parameters of the modular element (boom) cannot be changed without changing the basic element – A-frame.

Thus, the design features of modular elements can limit the consideration of a particular dragline model in the concept of “dragline as a modular system”.

At the same time draglines made by “NKMZ” have a boom design that does not depend on the A-frame and allows to change its parameters in a wide range (Figure 3).

Thus, the possibility of changing certain parameters of modular (dynamic) elements within one dragline model is determined by their design features.

4 CONCLUSIONS

Hence the necessity to study the significance of changing the parameters of individual modular elements of the dragline’s design to its maximum performance in specific mining and geological conditions. On the other hand, it is necessary to define degree of influence of change of mining and geological conditions on necessity of change of parameters of modular elements from the point of view of expediency of such change. For example, along the length of the front of the work there is a change in the angle of formation fall by a certain value. In this case it is necessary to define productivity decrease of base model of a dragline at passage of the complicated site, decrease in productivity of a dragline at change of parameters of its modular equipment and economic expenses connected with such replacement, to compare the received results and to choose the optimum decision.

Whether in this case there is a need to change the parameters of modular equipment or it makes sense to go for a temporary change in the performance of the base model – this question requires a comprehensive solution, taking into account specific geological, mining and technological conditions, as well as technical and economic calculations.

Closer contact with coal mining companies and open pit design institutes could be offered as a recommendation for dragline manufacturers to find a specific dragline model that meets all or almost all the requirements of the mining and geological conditions of a given deposit. In other words, the optimization (adaptability) of dragline parameters should start at the pre-project development stage.

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