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THE CALCULATION OF AN ARMOR WEAR OF THE DRUM BALL MILL OF BURSHTYN TPP BY THE ANALYTICAL METHOD

Introduction

The power industry is one of the basic components of Ukraine's economy, the effectiveness of which contributes to the state progress. The basis of the power industry is the electric power industry, which uses coal as primary power source. About 30% of the total electric power is produced on coal-fired power plants in Ukraine. Such amount of electric power generation requires efficient combustion of fossil fuel, i.e. coal.

The coal entering a boiler furnace undergoes appropriate preliminary preparation. The fuel is dried and ground in drum ball mills, after which it is fed into the dust hopper, and then in the boiler through the burners.

The efficiency of combustion depends on the quality of the prepared coal dust in drum ball mills, the performance of which deteriorates in the process of operation because of the need to periodically check and adjust the work of the mills.

One of the key operating parameters of a drum ball mill is the drum armor wear and ball charge of a drum, which affect the performance and specific electric power consumption for dust preparation.

During the mill operation, the ball charge is maintained at a constant maximum level by the periodic addition of balls to the drum, which provides the best possible performance with satisfactory quality of the finished dust. According to the characteristic $N_M = f(G_b)$, the operating maximum ball charge corresponds to the mill electric motor loading, which depends on the value of the rotating mass of the drum and balls. In this case, the replacement of the drum armor wear (ΔG_δ) with the value of the ball charge (ΔG_b) increase occurs, which adversely affects the performance of drum ball mills and ultimately the reliability. Therefore, the development of an analytical method for determining the armor wear of the mill drum, taking into account its ball charge, is an urgent task.

Literature review and problem statement

Coal-fired power plants are the basic component of the power industry of Ukraine and many countries of the world and occupy one of the main places in electric power generation [5, 8]. Today, Ukrainian thermal power plants produce about 30% of electric power [9]. In accordance with the development plans of Ukraine's power industry till 2030, TPPs operating on coal of own production will be the basis of flexible power facilities of the united energy system (UES) of Ukraine. It is planned to introduce clean coal technologies, based on the development of new and already known technological processes and to consider the issue of possible coal combustion in a pilot plant [12]. The works [13, 15, 16] highlight the issues of fossil fuel combustion and capture of fuel ash particles in flue gases. In the above publications, the authors consider not efficiency, but actual operation of drum ball mills. Ensuring the reliability of boiler units is a key component of efficient operation of TPP power units, as well as operation of drum ball mills and armor surfaces [4]. In [10, 11], the problem of the power industry regarding the production of synthesis gas from fossil fuels (coal) is investigated. At the same time, the authors pay attention not to fuel preparation, that is, drying and grinding, but only to the process of synthesis gas production.

The papers [14, 17] investigate the processes of solid fuel gasification and describe the design features of circulating fluidized bed (CFB) gasifiers, and do not consider the coal preparation in ball mills, but take estimated values only. Modern research works on drum ball mills, as well as regulatory documents, do not specify the rates and periods of armor wear of drums of different manufacturers, but only expenditures of balls [1, 2, 6]. The paper [2] describes the experimental studies of dust systems, while analytical methods of research have not been given due attention. Accordingly, this does not allow ensuring cost-effective and reliable operation of drum ball mills.

Experimental methods for determining the performance of drum ball mills are also known [3, 7]. However, the rational and maximum efficiency of the mills can be provided by reliable operation of armor surfaces of mills. At the same time, the recommendations contained in them have either a rather general nature, or, conversely, a very narrow application scope.

Therefore, the development of an analytical method that would allow carrying out diagnostic tests and engineering calculations of dust systems without conducting experimental studies is an important scientific and applied problem.

The aim and objectives of the study

The aim of the work was to develop an analytical method and carry out the corresponding calculations of the mill drum armor wear. To achieve this aim, it was necessary to accomplish the following objectives:

- to determine the armor wear of the mills KBM 370/850 (Sh-50A) that grind "G" grade coal;
- to determine the wear rate of the drum armor depending on the manufacturer in Ukraine;
- to determine the ball charge, taking into account the mill drum armor wear and the characteristic $N_m = f\left(G_b\right)$ of the mill electric motor loading.

Results and discussion

The object of the research to develop an analytical method for determining the armor wear rate of the drum ball mill was the boiler TP-100 (TP-100A) of the 200 MW power unit of Burshtyn TPP (Ukraine), equipped with two individual dust-preparation systems with drum ball mills KBM 370/850 (Sh-50A).

The dust system of the boilers TP-100 is designed for grinding "G" grade coal of the Lviv-Volyn coal basin (Ukraine): Q_l^W = 24.41 MJ/kg (5830 kcal/kg), W^P = 7.4%, A^P = 22.4%, V^G = 38.5%, grindability index I_G = 1.2.

Characteristics of ball charge and design armor of the mill drum:

- ultimate ball charge τ = 100 t,
- design ball charge G_b^d = 8 ball 0 t,
- maximum operating ball charge $G_b^{\max}$ = 70 t,
- ball diameter d = 40 mm,
- design weight of the drum armor plates $G_b^{\max}$ = 70 t,
- estimated specified life of the mill drum armor T = 20000 h.

The complete replacement of the drum armor is recommended in case of weight reduction up to 50% of the original design value.

The mills equipped with armor plates, depending on the manufacturer, located in the cities of Donetsk, Bilozersk and Dnipro (Ukraine), have different service life of the drum armor.

According to the method for analytical calculation of the drum armor wear of the mill KBM 370/850 (Sh-50A), the following initial data are required:

- the type of armor coating of the drum (armor plates or sleeper armor) and the place of armor manufacture;

– the grade of coal ground by a mill;
– the value of the duration of the maximum interrepair time of the mill.

Calculation of the armor wear rate of the mill st. No. 8B, the drum of which is equipped with armor plates of Donetsk manufacture, was conducted according to the developed methodology and the initial data.

During the interrepair time, the operating conditions of the mill varied in the following range: coal characteristics: Q_l^W = 17.09-20.18 MJ/kg (4081-4819 kcal/kg), W^P = 9.4-12.5%, A^P = 25.4-35.2%, V^G = 38.4-40.3%, ball charge of the drum G_b = 53-63 t, hardness of balls 534 HB.

The initial data for the calculation were:
– a mill with armored plates of Donetsk manufacture;
– "G" grade coal;
– duration of the maximum interrepair time of the mill τ = 25.194 h.

The results of the calculation of the drum armor wear rates of the mill st. No. 8B of Burshtyn TPP are shown in Table 1.

TABLE 1. *Initial data and results of the calculation of the drum armor wear rates of the mill st. No. 8B of Burshtyn TPP*

Parameter		Calculation	Calculation result
Initial data			
Initial armor weight G_δ^n, t		–	44.00
Operating maximum ball charge $G_b^{\max}$, t		–	70.00
Ball wear rate in case of *GSSh* coal grinding g_{b1}, kg/h		–	15.70
Standard specific expenditure of balls in case of *G* coal grinding	*G* a_{norm}, g/t	–	224.00
	GSSh a_{norm1}, g/t		
Coefficient of proportionality M_p		–	0.07
Conversion factor M_p		–	0.36
Duration of the maximum interrepair time τ, h		–	25.19
Calculation of drum armor wear rates			
Ball wear rate g_b, kg/h		$15.70\cdot\frac{196.00}{224.00}$	13.70
Armor wear rate g_δ, kg/h		0.07·13.70	0.88
Metal loss from drum armor wear ΔG_δ, t		0.88·25.19	22.17
Drum armor wear magnitude b_δ		$\frac{22.17}{44.00}$	0.50
Over-expenditure of balls ΔG_b, t		0.36·22.17	8.00
Drum overcharge with balls G_b^{over}, t		70.00+8.00	78.00
Estimated maximum ball charge G_b^p, t		70.00–8.00	62.00

According to the results of the calculation, the state of armor at the end of the interrepair time of the mill was characterized by:

– the drum armor wear magnitude b_{δ} = 0.50 and the maximum possible metal loss from the drum armor wear ΔG_{δ} = 22.17 t;
– the drum armor wear rate g_{δ} = 0.88 kg/h;
– uncontrolled over-expenditure of balls in the drum ΔG_b = 8.00 t and drum overcharge with balls $G_b^{over} = 78.00$ t.

The dependencies of the drum armor metal loss ΔG_{δ} and over-expenditure of balls ΔG_b on the operation duration τ of the mill st. No. 8B are shown in Figure 1.

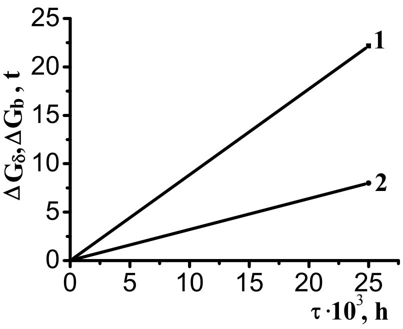

FIGURE 1. *The dependency of the drum armor metal loss and over-expenditure of balls on the operation duration of the mill st. No. 8B: 1 – drum armor metal los, 2 – over-expenditure of balls*

Figure 2 shows the dependency of the estimated maximum drum ball charge on the mill operation duration and the place of armor manufacture provided the maximum allowable drum armor wear (b_{δ} = 0.5) and the same estimated maximum ball charge.

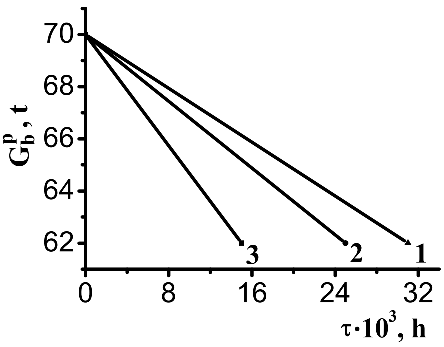

FIGURE 2. *The dependency of the estimated maximum drum ball charge on the mill operation duration and the place of armor manufacture: 1 – Bilozersk, 2 – Donetsk, 3 – Dnipro*

Under operating conditions, ball charge is determined by the characteristic $N_M = f(G_b)$ depending on the mill electric motor loading in the case of discharge of the coal material from the drum.

Based on the estimated ball charge G_b^p = 65 t, the mill electric motor loading N_M = 950 kW, whereby the drum would have the actual operating maximum ball charge $G_b^{\max} = 70$ t (Fig. 3).

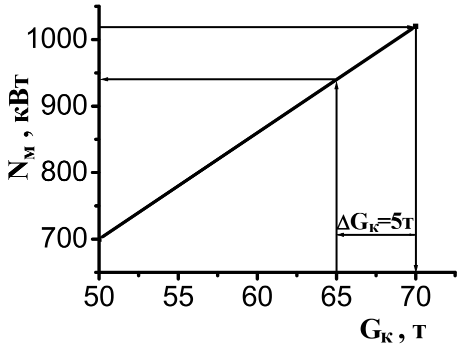

FIGURE 3. *Determination of the electric motor loading of the mill st. No. 8B in case of the actual ball weight of 70 t in the drum*

According to the Operating instructions, the adjustment of ΔG_b to the characteristic $N_M = f(G_b)$ is recommended to be introduced periodically – every 4000-5000 hours of mill operation after the beginning of the interrepair time or the construction of a new characteristic. Note that there is no need for the adjustments of ΔG_b to the characteristics after each regular sorting of balls, which, according to the Operating instructions, are carried out with a frequency of at least 2500-3000 hours of mill operation.

Conclusions

The method of determining the armor wear of the mills KBM 370/850 (Sh-50A) is developed on the example of "G" grade coal grinding, which allows carrying out a partial replacement of armor plates during repair without a complete restoration of armor coating of the cylindrical or end surfaces of the drum.

The comparative analysis of armored plates of the mill ball drum is designed and conducted and the main estimation indicator is obtained – the drum armor wear rate depending on the manufacture quality of plates, which is: Bilozersk armor 0.69 kg/h, Donetsk armor 0.88 kg/h, Dnipro armor 1.37 kg/h.

The mill ball charge and the mill electric motor loading N_M according to the characteristic $N_M = f(G_b)$ as a function of ball charge G_b are determined.

The developed method allows determining the mill drum armor wear magnitude, and, accordingly, and the mill overcharge with grinding balls, which allows increasing ultimately the reliability and efficiency of the drum ball mill.

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