METHOD OF SELECTING THE RATIONAL STRUCTURE OF THE INTRA-MILL DEVICE WHILE DESIGNING A BALL MILL

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Abstract. The article describes the technique for selecting the intra-mill design of a ball mill device, the first stage of which involves the removal of deliberately unsuitable variants of intra-mill devices according to specified criteria. At the second stage, the final choice of mills for technical and economic indicators is made using the hierarchy analysis method. The paper presents a description of the subject area, identifies the criteria and defines the relationships between them, and multicriterial estimation of the designs of vane elliptical energy-exchange devices is made. As a result, recommendations were formulated on the choice of the optimal intermittent device in the design of the ball mill design.

Keywords: ball mill, vane energy exchange device, multicriteria approach, decision making, hierarchy analysis method, vane energy exchanger.

1 Introduction

The production of many materials is associated with the need for fine grinding of the raw materials. This is the production of cement and fertilizers, the production of ceramic and glass products, grinding of coal, ore, etc. Milling materials is one of the most energy- and labor-intensive processes in various industries [1]. The main technological processes are mainly carried out with materials in the crushed state. The fineness of grinding has a significant effect on the quality of the finished product. In the production of various building materials and products thereof (sheet building glass, cement, products made of fine ceramics, etc.), a sufficiently high dispersion of the components used is required.

Thus, about 85% of the electricity spent on cement production is spent on crushing and grinding, of which 75% is for grinding only. When producing cement grade 400 for grinding, 35-40 kW h / t are consumed, and for the 700 mark - from 70 to 80 kW h / t, while the mill productivity decreases by 1.5-2 times. Despite the low efficiency, large dimensions and energy intensity, ball mills (BM) are still the most common aggregates for milling various materials due to high productivity, simplicity and reliability of the structure [2-3].

From the fineness of grinding of the products of processing, the granulometric distribution, the quality characteristics of the output are largely dependent on the homogeneity of the distribution of properties, strength characteristics, and others.

2 Methods

The choice of BEM is a complex and ambiguous task, which is connected both with a large number of proposed design devices, and the possibility of combining them. In this case, the process of selecting the device must be carried out both for a number of formal characteristics and with the help of experts with professional knowledge and having relevant experience of their application in specific situations.

When deciding on the choice of the most appropriate authors according to the criteria of the BEM, a two-stage procedure is proposed:

1. Choice of the type of vane energy-exchange device based on the design parameters of the mill and the conditions for the grinding process.

2. Selection of the design of a rational BEM taking into account the costs, qualitative and quantitative parameters of the mill operation.

The variety of properties of various materials subjected to grinding in a ball mill, the various volumes of industrial production, the requirements for fineness of grinding have contributed to the formation of mills of various sizes, both periodic and continuous, operated in wet or dry grinding, open or closed cycle, coarse or fine grinding . The desire to increase the efficiency of the BM operation and their marked structural and operational features predetermined the formation of intermittent devices of various designs. These include inter-chamber partitions, output gratings, gratings, bladed energy-exchange machine (BEM), and a number of others [2].

By means of the equipping of mills with bladed energy exchangers, the internal recycling of the material to be ground is ensured in the chambers; intensification of movement of grinding media (GM) in transverse and longitudinal directions; including in the area of the stagnant zone. The effects of devices on the GM are cyclical, intensity, and direction. Strong abrasive wear protects adjacent partitions and grids. When the housing is rotated, the BEMs are provided, in the areas of zones of pronounced influence, by changing the GM driving modes [3]. A more intensive mode of movement of the GM contributes to a decrease in their weighted average size. Modes of movement of the GM changing during the rotation of the body help to more efficiently grind the particles of material of various sizes, the components of which, as a rule, have different grindability.

Schemes of various designs of Bladed long radius energy-exchanged machine (BLEM) are shown in Figures 1 and 2. Their main characteristics are the angle of inclination to the longitudinal axis α and the value of the minor axis α equal to the inner diameter of the chamber. To ensure the necessary nature and intensity of the impact on GM constructions, devices are limited to both rectilinear and curvilinear generatrices.

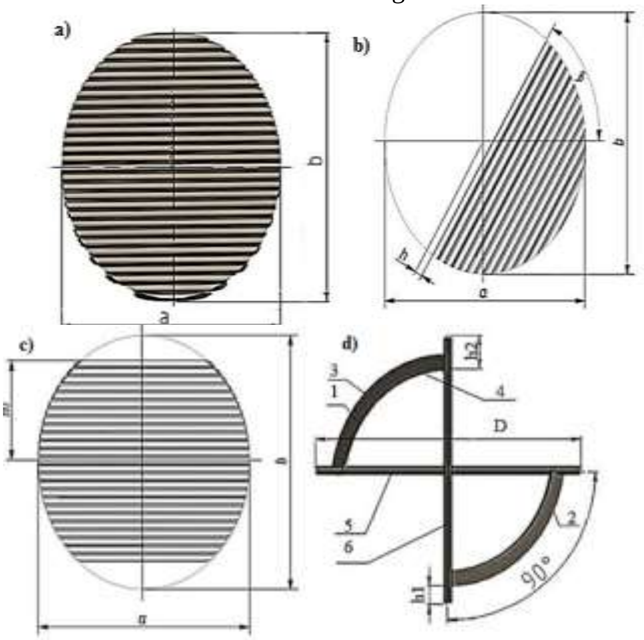

Figure 1. Schemes of various designs of blade elliptic energy-exchange machines: a) - IIP, b) - BLS, c) - BDB, d) - BLQM

Thus, in order to intensify the MT movement process both in the transverse and longitudinal directions, the construction of Single-threaded helical blades (SHB) is proposed in [4]. The helical blades are installed in the loading part and the end of the mill chamber. The direction of the screw of their helical surfaces is opposite to each other. The initial generators of the first SHB installed in the loading part are rotated, in the plane of the cross section of the body, relative to the initial generatrices of the second SHB installed in the unloading part by an angle of 180 ° [4]. During the first half-turn of the body, the first SHB, immersed in the grinding load, acts on the GM towards the second SHB. During the second half-turn of the body, the second DHB exerts a similar effect on the GM in the direction of the first SHB.

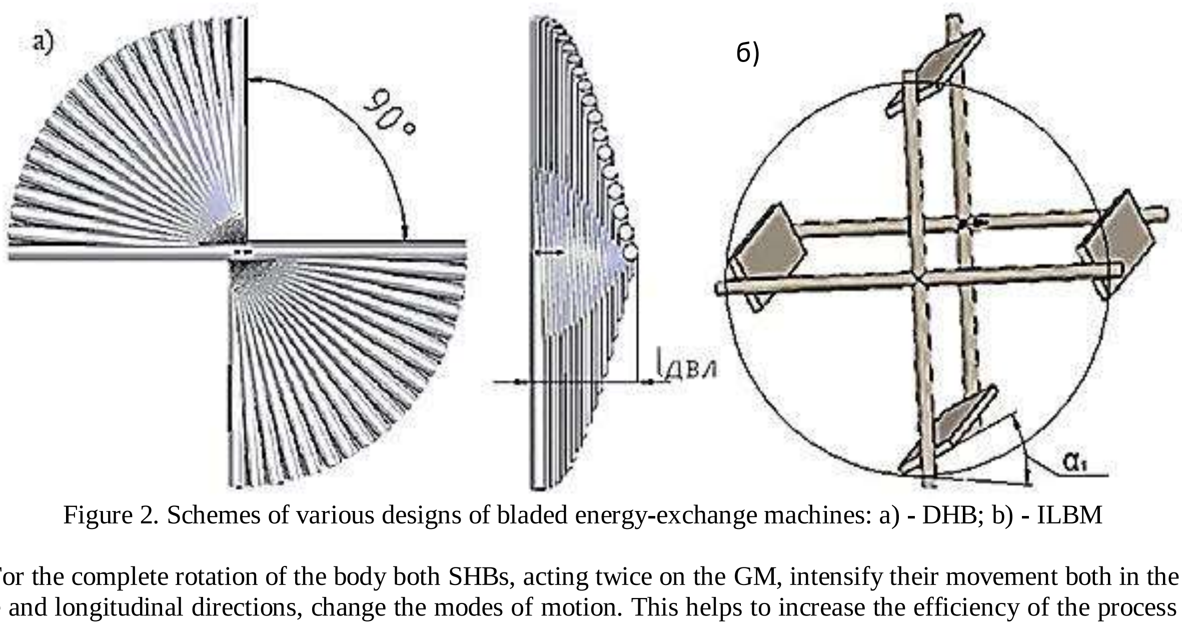

Figure 2. Schemes of various designs of bladed energy-exchange machines: a) - DHB; b) - ILBM

For the complete rotation of the body both SHBs, acting twice on the GM, intensify their movement both in the transverse and longitudinal directions, change the modes of motion. This helps to increase the efficiency of the process of grinding the material. The considered design and layout of the SHB installation is rational to use on BM with a shell diameter exceeding 1.5 times its length with coarse grinding of one-component materials with medium and lower grindability or multicomponent charges or slurries, the components of which are characterized by grinding. When using the considered design of SHB and the scheme of their installation in BM fine grinding, a camera of the house should be provided. The use of these devices is not advisable in BM batch.

To intensify the process of GM motion in the transverse direction, the construction of a centrifugal longitudinal blade machine (CLBM) is proposed in [5]. The blades of the device are located radially and parallel to the longitudinal axis of the housing. With respect to each other, the planes of the blades are rotated through an angle of 90 °. When the body rotates, the blades raise the load placed in the chamber to a sufficiently high altitude; the material partially breaks off from their surfaces, falls onto the lining and collapses, and partially rolls, being destroyed by abrasion. CLBM provides an intensive dynamic impact on the material. Devices are advisable to use in mills wet or dry self-milling materials of medium and low grinding.

The considered designs are combined into a group of bladed energy exchanging machines for technological purposes - the transfer of energy to the GM and the organization of their movement. Based on the design features, the devices are combined in accordance with the classification (Figure 3).

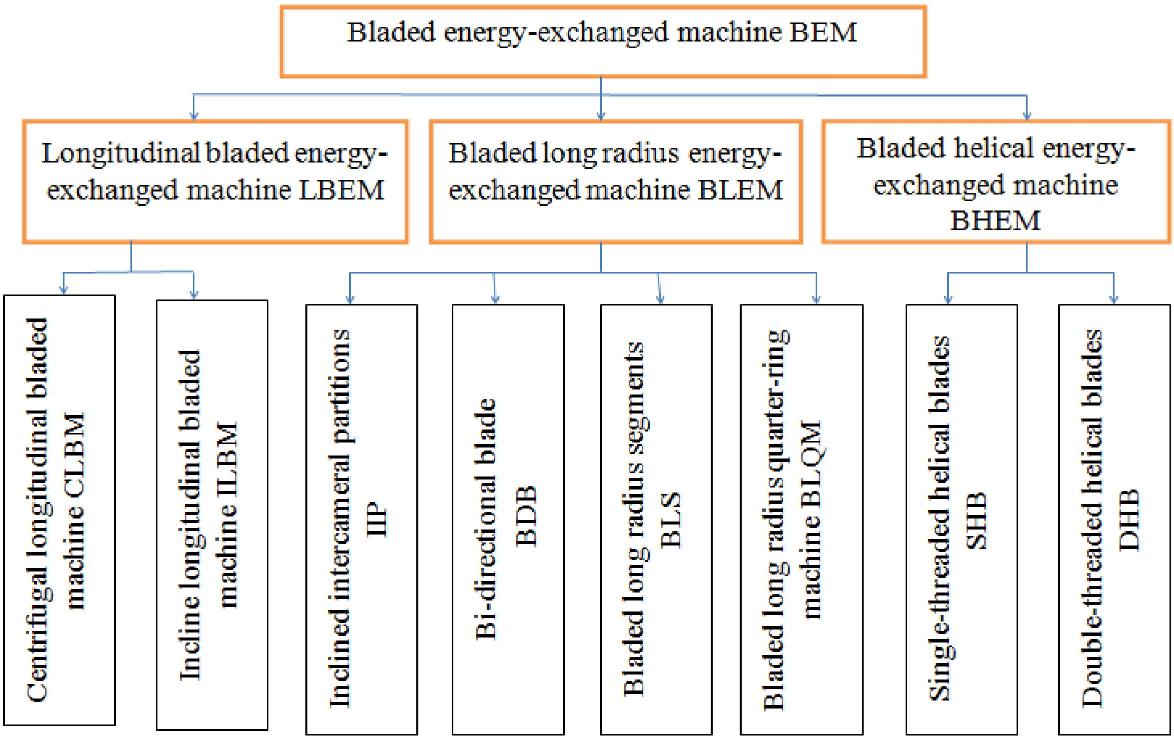

Figure 3. Classification of intra-mill bladed energy-exchanged machines

3 Results

Step 1. Select the type of vane energy exchanger. This stage is carried out with the purpose of discarding obviously inappropriate types of BEM.

When constructing the design of a ball mill, depending on the initial properties of materials and the requirements for the fineness of grinding, we will select the type of blade energy exchanger.

The main criteria for selection will be the following parameters: production method, type of material to be crushed, size and mode of operation.

When selecting the equipment for processing rocks, it is necessary to take into account their basic physical and mechanical properties. First of all, this refers to the grindability of materials. It is generally accepted to divide them into materials of high, medium and low grinding.

Machine-building companies that manufacture mills produce several sizes of mills of different capacities. Ball mills are characterized by the size, determined by the diameter of the shell D and its length L. So, the mills of the sizes D × L = 2 × 10.5 m are widely used; D × L = 3.2 × 15 m; D × L = 4 × 13.5 m; D × L = 7 × 2.3 m and a number of others.

Table 1 Summary table of BEM characteristics primary data

Type of machine	Way of grinding		Diameter ratio and the length of the mill chamber			Grindability			The initial size of the material		Mode	
	Wet	Dry	$D_1/L_1<1$	$1<D_1/L_1<2$	$2<D_1/L_1<3$	Increased	Medium	Reduced	Regulated	Increased	Continuously	Periodically
BLS												
BLS and BDB												
BLS and IIP												
BLQM												
DHb												
SHB												
ILBM												
CLBM												

On the basis of the analysis in Table 1, we construct a decision tree that rejects the obviously unsuitable variants of the BEM based on the previously identified criteria (Figure 4).

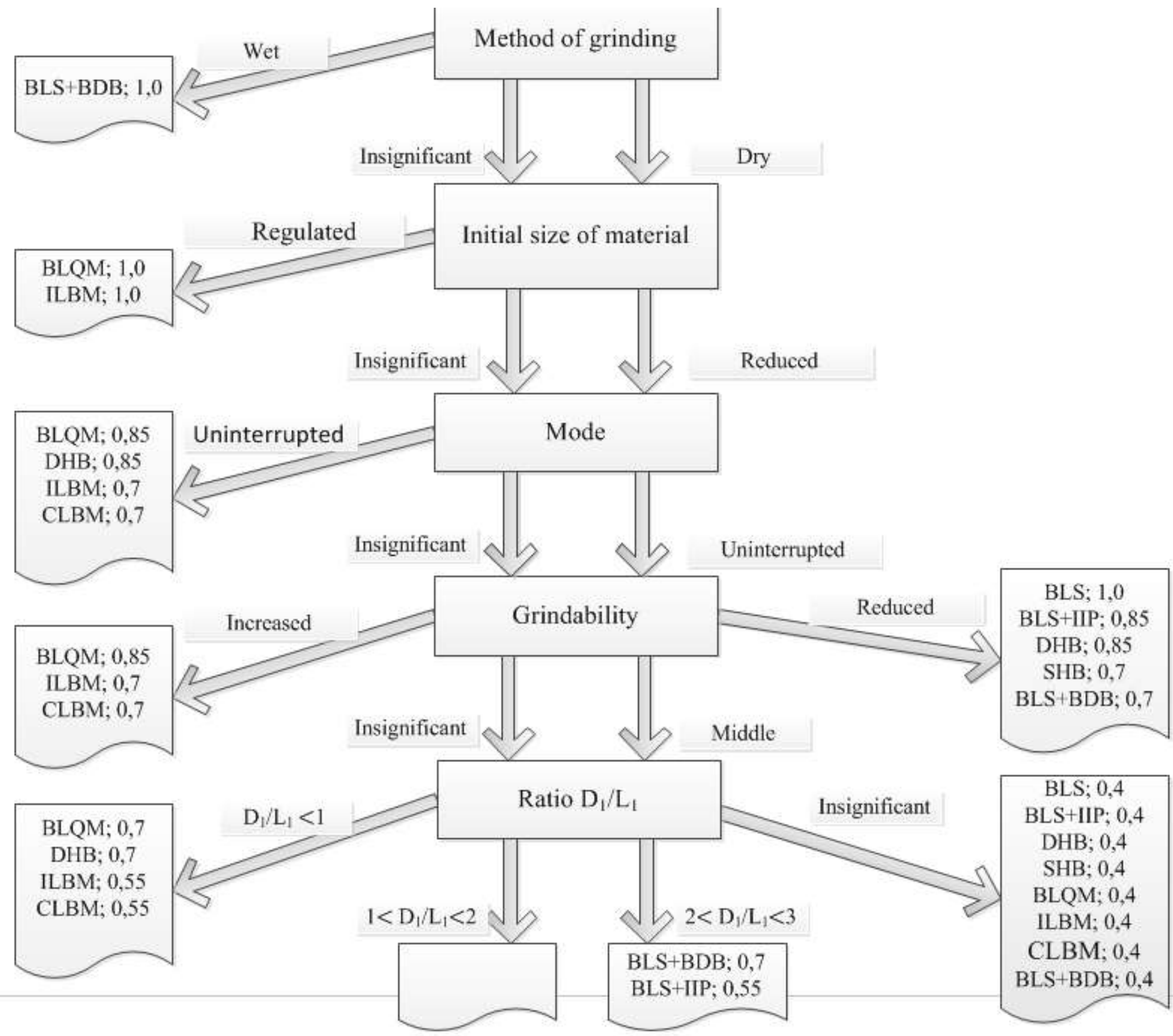

Figure 4. Solution tree

As a result, a set of BEM sets is obtained that satisfies given initial conditions. In this case, in each set, for any of the BEMs, the degree of correspondence in the form of a decimal fraction from the range [0; 1] is indicated.

Stage 2. Selection of the design of a rational BEM taking into account the costs, qualitative and quantitative parameters of the mill operation.

This stage of choosing the rational design of the bladed energy-exchange machine of the mill is carried out taking into account a number of criteria based on the hierarchy analysis method [6]. This method is designed to order the finite set of real variants A1, ..., Am, estimated by many quantitative and qualitative criteria K1, ..., Kn, and choosing the best variant for the greatest total value. The task of choosing the type of a ball mill's BEM is represented as a hierarchy, which in the simplest case consists of 3 levels: the goal (dominant), criteria, alternatives (options).

Alternatives are ball mills with selected designs of intra-mill devices[7-12].

The criteria are the technical and economic indicators that characterize the operation of the mill with different designs of bladed long radius energy-exchanged machine (Figure 5).

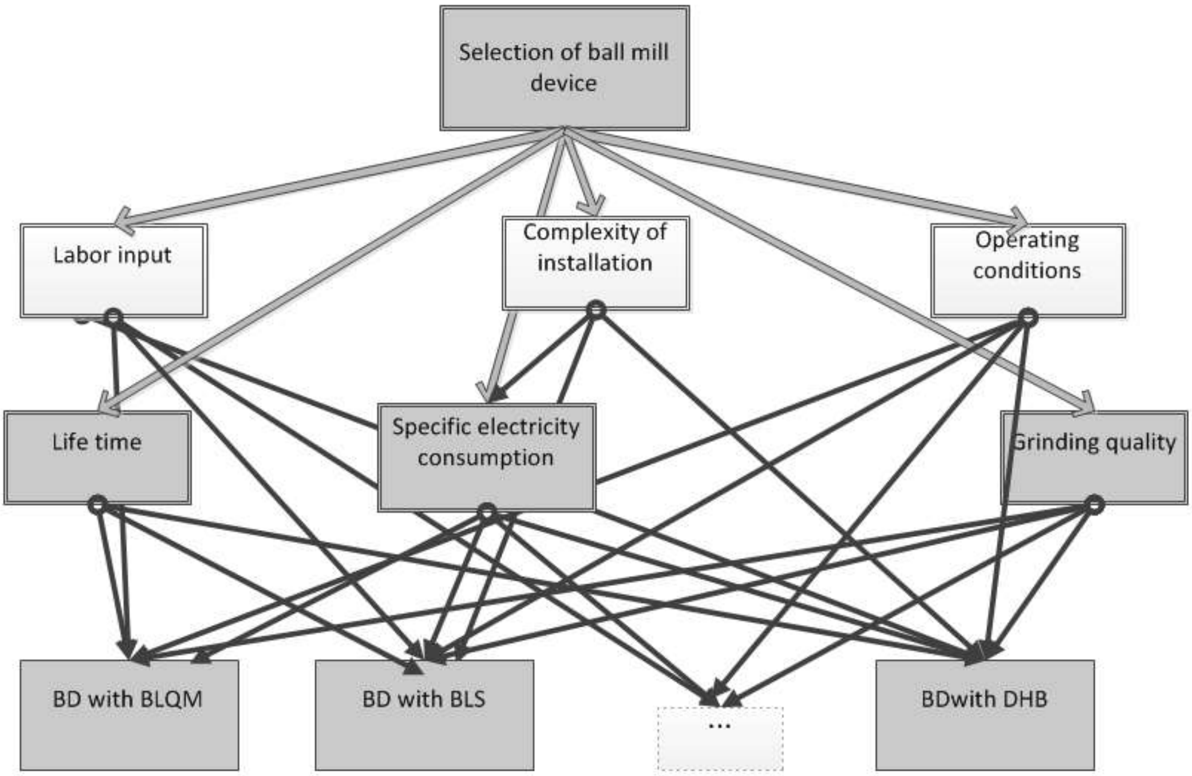

Figure 5. Hierarchy of selection of a ball mill device

4 Conclusion

The proposed methodology is used to select the BEM ball mill according to the declared requirements of the enterprise. The considered approach allowed narrowing the number of considered variants from 8 to 5 at the first stage. At the 2nd stage, the decision maker chose the kind that is most beneficial to the enterprise on the basis of technical and economic indicators.

1. The analysis of the use of ball mills in various industries: construction materials, chemical, mining, etc. The features of the conditions of their operation are given.

2. For ball mills, different designs of blade energy exchangers and their installation schemes in the housing are considered, as well as the advantages of their use, which allow grinding of the required quality from various materials.

3. A two-stage technique is suggested that allows choosing the most rational design of blade energy-exchange devices for a ball mill, proceeding from its design and features of technological production.

4. Approbation of the proposed method for application at the machine-building enterprise was carried out.

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