Creating a project for modernizing the feeding balls device to a ball mill using 3D modeling

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Abstract. The work is dedicated to the engineering and 3D modeling of an automated device for feeding balls to the mill in the MMPs mill drum. The new device will reduce labor costs and risks of injury to employees. Also, the new design will increase the productivity of the Copper concentrator (MOF) by increasing the speed of filling the mill drum with grinding balls.

1. Introduction

The modern technologies [1-19] commonly use equipment intended for milling both final product and production waste. Such equipment includes autogenous mills usually used for milling head ore or product of the first stage crusher. Mill feed fineness is limited only by the size of pieces which can be actually transported and loaded to the mill. The mill product should have a fineness suitable for processing or have an intermediate fineness suitable for final milling in the ball mill, gravel mill or vertical mill [20-22].

The ball mill start after routine maintenance or emergency stop is performed in two stages.

The first stage is operation (rotation) of the mill at low speed (at this moment additional grinding bodies and raw material are loaded),

The second stage is the increase of mill speed up to required rpm which depends on operation mode (cascade, waterfall, combined) [23-29].

The ball and rod mills break the material by stroke of falling balls or rods and pulverizing between balls and drum liner while the last rotates consequently.

While filling the drum with the raw material, it is necessary to control that the loaded ore is dry and does not contain any foreign matters. Only the pieces not exceeding the size of the value acceptable for the model should be loaded. The essential parts of the ball and rod mills are: cylindrical drum, loading and unloading devices, crankshaft bearings, and drive. The mill is loaded with balls in three stages. The trial run of the mill with the balls should be performed after each stage in 20 minutes maximum to avoid excessive wear of the liner and the balls. The mill load with feed material is defined by its volume weight. The mill is the most efficient when the volume of loaded material is 10-13% of grinding bodies. In case of wet milling, the mill load is 1/4 to 3/4 of its volume. The mill material in still condition should encase the balls and fill the gaps between them. The mill is loaded through two dish-shaped feeders equipped with inspection glasses. The feed is pulverized by rods which fall during drum rotation and strike feed pieces, breaking and pulverizing them [30].
The procedure implemented at beneficiation plants for additional loading (loading) of balls to the mill is a mechanism consisting of two parts: a container where grinding balls are stored and a launder by which the grinding bodies are fed to the mill [31-35].

The container is equipped with a manually adjusted (open/close) sliding gate (Fig.1). For example, the specific consumption of grinding bodies is 10 kg per milling of 1000 tons of raw material. When 1000 tons of material was loaded to the mill, the gate is opened for certain period of time, while the launder (or pipe) is loaded with 10 kg of grinding balls (about 33 grinding balls). Afterwards, the gate is closed, and loading of mill balls is stopped. The operation is analogous when a person (miller) opens/closes the gate. It is critical to calculate the grinding ball rate correctly to avoid overloading or underloading of the mill with grinding bodies.

Also, the additional loading of the mill should comply with mill’s operation time (for example, additionally load 3 grinding balls in 2 working hours), but this procedure can break the schedule of additional loading in cases related to changes in mill production capacity.

![Figure 1. Mill balls-feeding device.](image)

The storage container for mill balls is securely fastened and located juts outside the mill. It has a continuous free access to provide a proper loading of grinding bodies and visual inspection by plant personnel. The container should be located slightly higher than the mill’s “feed” such that the slope should have an angle of 15 to 25 degrees. The container bottom is designed in such a way that the mill ball goes to the gate itself, driven by the gravity. The slope angle of the container’s bottom should be at least 15 degrees.

Either pipe or channel can be used as a launder. The channel is more preferable as in case of ball mills clogging this problem can be easily solved.

When designing a launder, a number of features should be considered:

- the launder angle should be at least 15 degrees. It is necessary to allow grinding bodies to freely roll from the container to the mill’s “feed”;
- the launder diameter should not exceed the balls diameter by more than 50%. It will allow a free movement of grinding bodies and minimize the risk of obstruction. Thus, for example, if 40mm grinding balls are used, the launder diameter should be 60 mm maximum.
- as few curves as possible should be used during installation of the launder.
There is a number of mill balls-feeding devices comprising a container and a launder (belt feeders in some cases). The container is used for balls receipt and storage, while launder sends them to the mill’s inlet. There, the process of balls movement from the container to the launder has some difficulties related to the design or the defects of the actuating mechanism. Let us review the difficulties in operation of devices by the example of the shown model. The device is used at copper beneficiation plant JSC “Almalyk MMC” (Fig. 1). The use of this device leads to formation of a “clog” during the opening of the hopper gate. Such a problem during balls loading require interference of human element (miller).

2. Main Methods and Results of the Study
After the analysis of existing and known constructions intended for feeding the equipment with material [36-40], a new mill balls-feeding device was designed.

![Figure 2. 3D model of the mill balls-feeding device.](image)

**3D model description:**

The mill balls-feeding device consists of one-piece integral frame and a gate. Carrying capacity of the model is twice higher compared to the previous device model, currently used.

The integral frame combines the functions of the ore hopper and the launder. The transition part from the ore hopper to launder has an elbow shape to transfer the balls consequently and has a grilled surface in the launder area to allow for visibility of balls movement and interference if required. The frame section has a trapezium shape in the launder area. The angle of slope in the launder area is 15°, which allows the balls to move freely. The exit of the body has the size of 300x150 to allow free movement of two balls 120 mm in diameter.

To dose the balls feeding, there is a gate in the shape of teeth arranged in an arc (Fig. 3). Two of the teeth are movable. Due to the trapezoidal shape of frame launder cross-section the outermost teeth are shorter than others. As a result, when the gate goes to full-down position, the teeth do not interfere with side walls of the frame. The central tooth has a triangle shape at the baseline. The aim is to send the balls to the different tooth sides and avoid any blockage.
3. Conclusions
As a result of the work, a new mill balls-feeding device was designed for beneficiation plant JSC “Almalyk MMC”. The device will allow to speed up the process of feeding and starting the mill by decreasing the amount of clogs in the launder and increasing the throughput capacity of the device, as well as will decrease labor costs. In future, we plan to equip the design with an automated system, which can detect the number of the balls passed and actuate (open/close) the gate depending on required balls quantity. The implementation of the suggested device will allow to increase production capacity of the beneficiation plant, while the automated system for the gate actuation will make the process fully autonomous, particularly as related to the required operation mode of the mill.

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Figure 3. 3D model of the gate.
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