ANALYSIS OF THE PRODUCTIVITY AND ENERGY EFFICIENCY OF IMPACT CRUSHERS WHEN CRUSHING LIMESTONE

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Abstract. The article discusses the technological process of limestone crushing at crushing and sorting complexes and analyses the effectiveness of using the Metso NP1313 impact crusher to ensure a design capacity of 800 thousand tonnes per year. It provides a description of the raw material, characteristics of the primary and secondary crushing stages, and a comparative assessment of the technical parameters of the crushing equipment. The required power and productivity have been calculated, and the operating indicators and cost of crushing have been determined. A comparison of the Metso NP1313 crusher with the alternative PF1315 model is made in terms of key technical and economic parameters. Based on the analysis, it was established that the NP1313 provides the necessary power reserve, a high degree of crushing, economic efficiency and reliability in the processing of limestone on an industrial scale.

Keywords: limestone; crushing; impact crusher; Metso NP1313; PF1315; productivity; cost price; fractionation; mineral processing; DSK; secondary crushing; comparative analysis.

INTRODUCTION

The mining industry plays a key role in the economies of many countries. An important task in the mineral processing technology chain is the effective crushing of limestone, which is used as a raw material in various industries, including metallurgy, construction and chemistry. To ensure high productivity and energy efficiency, it is necessary to choose the right equipment and justify technological solutions.

Limestone is a sedimentary rock formed by the accumulation and compaction of predominantly calcite components (calcium carbonate), which gives it a characteristic porous structure that varies in density and colour. Limestone also contains other minerals, which reduce its porosity while increasing the mechanical strength of the material.

DISCUSSION OF THE PROBLEM

Limestone deposits are represented by layers of rock of various colours — from grey and grey-white to beige and even grey-pink shades. For extraction, these layers are turned over and fragmented using bulldozers and crawler excavators. The stone material is then loaded into large dump trucks, which deliver it to a crushing and sorting complex. It should be noted that limestone in its original state, straight from the quarry, is not suitable for sale and requires further processing.

Fig. 1. The process of open-pit limestone mining (quarrying)

Uneven limestone layers are not suitable for direct sale. Therefore, before delivering the extracted raw material to the customer, it must be crushed and classified by fraction. To do this, the stone from the quarry is sent for preliminary crushing and sorting.

MATERIALS AND METHODS

The limestone crushing process consists of two stages:

- primary crushing;
- secondary crushing.

During these operations, large pieces of rock, reaching 1.5 metres in diameter, are reduced to sizes of 25 mm and less. However, in some cases this is not enough — limestone powder is also a sought-after product on the industrial market.

The powder is widely used in the manufacture of ceramics, glass, and a range of construction and finishing materials. To obtain the powder fraction, natural limestone, in addition to primary and secondary crushing, is further subjected to ultra-fine grinding.

All stages of crushing and processing require specialised equipment capable of giving the product a marketable appearance and separating it into the required fractions.

As noted earlier, limestone extracted from the quarry is sent to a crushing and sorting complex for further processing. Jaw, cone or hammer crushers are used in the crushing stages.

The crusher is usually operated by a single operator, which facilitates operation.

RESULTS AND DISCUSSION

During the commissioning phase, the annual capacity of the enterprise is 400,000 tonnes/year. According to the design parameters, the annual production volume is expected to reach 800,000 tonnes/year of fractionated limestone.

The estimated service life of the technological equipment and production complex is assumed to be 10 years. The standard annual working time fund is determined based on 220 working days with a shift duration of 8 hours, which is 1,760 hours/year.

Calculation of the required crusher capacity

$$P = \frac{Q}{t}$$

- Q=800,000 tonnes/year
- t=1760 hours

$$P = \frac{800{,}000}{1760} \approx 454{,}5\text{т/ч}$$

Required crusher capacity — ~455 t/h

Based on the required crusher capacity, a **Metso NP1313** crusher can be selected**.**

The main technical characteristics of the Metso NP1313 impact crusher include the following. This machine belongs to the category of horizontal shaft impact crushers (HSI). The NP1313 model is manufactured by Metso Minerals and is designed for the efficient crushing of medium-strength and strong materials, ensuring a high degree of grinding and stable operating parameters.

Fig. 2. NP1313 Horizontal Shaft Impact (HSI) crusher

The technical parameters of the Metso NP1313 crusher are characterised by the following values. The rotor diameter is 1300 mm, with a length of 1300 mm. The feed opening size is 1320 × 1200 mm, which allows for the feeding of large pieces. The installed drive power reaches 200 kW.

The equipment's productivity can reach up to 600 t/h, depending on the physical and mechanical properties of the material being processed and the selected settings. The unit weighs approximately 16,500 kg (excluding the electric drive and support frame). The rotor speed is in the range of 500–800 rpm, which is determined by the working configuration and the required crushing mode.

Verification of the compliance of the Metso NP1313 crusher's operating parameters shows that its main operating characteristics meet the requirements for secondary crushing. The maximum capacity of the unit is 450–500 t/h, which is determined by the type and properties of the material being processed. The maximum permissible size of the feed pieces is approximately 900 mm, which allows for the effective processing of large-sized raw materials after primary crushing.

The output fraction is adjustable within a wide range and can be approximately 0–100 mm, depending on the settings of the deflector plates and the operating mode. Medium-strength materials such as limestone, dolomite and various types of concrete waste are optimal for processing. In terms of its purpose and operating principle, the crusher belongs to the class of secondary crushing equipment.

The Metso NP1313 impact crusher has a number of operational advantages that ensure its effective use in the secondary and tertiary crushing stages. One of its key advantages is the high degree of crushing, which allows for a high-quality finished product with a minimum amount of large fractions.

Structural reliability is ensured by a reinforced frame and the use of wear-resistant elements, which increases the durability of the unit when working with abrasive materials. A significant advantage is ease of maintenance: the design provides quick and safe access to the impact plates, rotor and other internal components, reducing downtime.

Particular attention has been paid to safety issues — the crusher body is equipped with a hydraulic opening system that facilitates routine maintenance and provides safe access to the crushing chamber. Additional technological flexibility is provided by the ability to adjust the angle of the deflector plates and change the rotor speed, which allows the particle size of the finished product to be optimised for specific production requirements.

Calculation of annual energy consumption

$$W = N \cdot t = 200\text{кВт} \cdot 1760\text{ч} = 352{,}000\ \text{кВт}/\text{ч}/\text{год}$$

If the price per 1 kW·h is $0.10:\

$$\text{С}_{\text{эл}} = 352{,}000 \cdot 0{,}10 = \$35{,}200\ \text{в год}$$

Calculation of specific power per 1 tonne of product

$$U = \frac{N}{P} = \frac{200}{455} \approx 0{,}44\ \text{кВт}/\text{ч}/\text{т}$$

For limestone — **within the norm** (typically 0.3–0.5 kW·h/t)

Consumables and maintenance

Beaters (impact elements): replacement ~1–2 times per year
Reflector plates: once every 1–2 years
Approximate annual consumables costs: ~$20,000
Scheduled maintenance (oil, servicing): ~$5,000/year

Calculation of crushing cost (crushers only)

$$C_{\text{тонна}} = \frac{C_{\text{эл}} + C_{\text{обслуж}} + C_{\text{ЗИП}}}{Q}$$

$$C_{\text{тонна}} = \frac{35{,}200 + 5{,}000 + 20{,}000}{800{,}000} = \frac{60{,}200}{800{,}000} \approx 0{,}075\$/\text{т}$$

Economic efficiency and power reserve

Indicator	Value
Required capacity	455 t/h
Maximum NP1313	~500 t/h
Power reserve	~10%
Cost of crushing	$0.075/ton
Annual engine power	352,000 kWh

After calculations were made to determine the most cost-effective equipment option, the Metso NP1313 impact crusher was compared with alternative crusher models.

Alternative model: PF1315 impact crusher from Liming Heavy Industry

Fig. 3. PF1315 impact crusher

The technical characteristics of the equipment include the following parameters. The installed drive power is 200 kW (or 272 hp), which ensures stable operation of the crushing unit in various load modes. The rotor has dimensions of 1300 × 1500 mm, which determines its high inertia and ability to efficiently process the feed material.

The size of the feed opening is 860 × 1520 mm, allowing it to accept medium-sized raw materials. The maximum permissible feed size is 350 mm. The equipment's productivity ranges from 120 to 260 t/h, depending on the properties of the material, the settings of the deflector plates and the speed of the rotor.

The unit's own weight is 3100 kg, and its overall dimensions are 2930 × 2760 × 3050 mm, which makes it easy to install in standard process layouts. The equipment complies with international industrial safety and quality requirements, as confirmed by CE, ISO and SZUTEST certificates.

Comparison table: NP1313 vs PF1315

Parameter	**Metso NP1313**	**Liming PF1315**
Drive power	200 kW	200 kW
Rotor diameter	1300 mm	1300 mm
Loading opening size	1320 × 1200 mm	860 × 1520 mm
Max. feed size	900 mm	350 mm
Capacity	200–540 t/h	120–260 t/h
Weight	22,300 kg	3,100 kg
Dimensions	4000 × 3000 × 4000 mm	2930 × 2760 × 3050 mm
Certificates	ISO, CE	CE, ISO, SZUTEST

An assessment of the acquisition cost of impact crushers shows a significant difference in capital expenditure between the PF1315 and Metso NP1313 models. The cost of the PF1315 crusher ranges from $7,500 to $21,600, depending on the configuration and supplier. The cost of the Metso NP1313 industrial crusher is significantly higher, ranging from $50,000 to $100,000 , due to its higher technical level, increased productivity and structural reliability.

The following are among the key advantages of the PF1315 compared to the NP1313. First of all, its low cost, which significantly reduces the initial capital investment and makes this model more affordable for businesses with limited budgets. In addition, the unit is compact and lighter, which simplifies transportation, installation and integration into the production line. International certificates of conformity confirm compliance with basic quality and safety requirements.

However, the PF1315 model has a number of technical limitations. In particular, its maximum capacity is lower than that of the Metso NP1313, which can

be a critical factor when processing large volumes of raw materials. It also has a reduced maximum feed size, which limits the use of the unit for crushing large-sized material and requires preliminary reduction of the fraction.

CONCLUSION

The Metso NP1313 impact crusher is a technically sound and rational choice for our calculation for limestone processing with a design capacity of 800 thousand tonnes per year (including 400 thousand at the start-up stage). The crusher provides sufficient capacity, has an adequate feed opening size, and meets the power requirements. **The Metso NP1313** is a sufficiently powerful and suitable option for:

- crushing limestone at volumes of up to 800,000 tonnes per year
- low crushing cost ($0.075/tonne)
- operation as part of a 2-3 stage crushing plant

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