ABSTRACT

In world practice, mineral processing tasks, such as ore beneficiation, crushed stone production, and similar technologies, are almost universally dealt with by employing jaw and cone crushers whose principle of operation has not undergone any appreciable changes over the last 150 years. As before, these machines are driven by an eccentric shaft that maintains a rigid kinematic connection between interacting crushing bodies - cones or jaws.

With this type of drive, the size to which the material layer can be deformed cannot exceed the discharge setting. The use of eccentric drive is the main reason for a low reduction ratio (within 4-7) in these machines.

Based on the fundamental research into the solid-state physics and vibration theory, a series of jaw and cone crushers have been developed by Mekhanobr that are free from the limitations of conventional eccentric crushers while having quite a number of technological advantages of which the principal one is the possibility of monitoring the reduction ratio from 5 to 30. This in turn makes it possible to completely rearrange the traditional ore preconcentration flowsheets by leaving out rod mills, and sometimes the ball mills. The use of the new machines for crushed stone production in the construction industry results in the proportion of cubical product increasing to 85-92% and the 5-0 mm product overgrinding reduced to 20-28% (in conventional crushers, it amounts to 40%).

Experimental testing of KID range vibrating cone crushers has shown their following advantages compared with the performance of the unbalanced cone crushers:

- the reduction ratio can be adjusted from 5 to 30;
- when the discharge setting becomes wider due to the concaves and mantle wear the product size stays almost the same due to the increased cone throw;
- there is a possibility of bringing overgrinding to a minimum;
- the crusher can be started and stopped under load;

The vibrating cone crushers proved possibility to reduce the grinding section power consumption by some 40 per cent.

INTRODUCTION

The most common and power-intensive processes in industrial and agricultural technologies are those of crushing and grinding. They are known to consume nearly 23 per cent of all the electric power produced worldover.

Such a considerable electric power consumption is due to the fact that modern crushing and grinding machinery employ the disintegration processes that have been known to humanity since time immemorial, viz. compaction, impact, attrition, and cutting. They all break materials indiscriminately, making almost no use of microcracks or other structural defects, thus making the efficiency of crushing and grinding machines unacceptably low. Besides, the use of the abovementioned processes results in irretrievable losses of useful components or else in a substantial deterioration of properties of finished products because of an incomplete liberation of useful components, or, on the contrary, overgrinding, pelletization, and fracture of particles.

In world practice, mineral processing tasks, such as ore beneficiation, crushed stone production, and similar technologies, are almost universally dealt with by employing jaw and cone crushers whose principle of operation has not undergone any appreciable changes over the last 150 years. As before, these machines are driven by an eccentric shaft that maintains a rigid kinematic connection between interacting crushing bodies - cones or jaws.

With this type of drive, the value to which the material layer can be deformed cannot exceed that of the gap between the crushing bodies, i.e. the discharge setting. This is particularly evident in standard cone crushers where plain bearings are used in the drive eccentric assembly, that have considerable radial clearances intended to compensate for manufacture errors in basic machine parts. Under the impact of eccentric drive, the inner crushing cone performs circular pendular oscillations and develops a centrifugal force that presses the cone shaft against one side of the eccentric and takes up radial clearances in bearings. The discharge opening in such crushers is set on idle run, i.e. with no material feed. This arrangement allows the operator to take account of all the factors resisting the setting of a discharge opening that is optimal for the technological performance, i.e.
ellipticity and eccentricity of cone mantles, clearings in the discharge opening adjusting assembly, spinning of the cone on the spherical support, cone and eccentric wear, etc. However, the situation changes perceptibly when the crusher is run under load.

Thus, in standard cone crushers with the cone base diameter of 2200 mm (KMD-2200 type), the discharge opening set on idle run is 5 mm, but increases to 9.5 mm under load when the cone shaft is driven by the crushing force to the opposite side of the eccentric. The crusher product corrected for a realistic oversize factor (2-3) will, at the best, measure 16-0 mm (85%), or 20-0 mm (100%), which is roughly the same. Therefore, the use of eccentric drive is the main reason for a low reduction ratio (within 4-7) in similar machines.1

Another important reason for low reduction ratios in eccentric crushers is a limited frequency of cone oscillations. With the increasing frequency of cone impacts on the material being crushed, the product size becomes finer and the oversize factor decreases respectively. Yet, along with this, an increase in the centrifugal force of the movable cone is registered that is proportional to the number of oscillations squared, which applies to the degree of the crusher unbalance as well. The horizontal dynamic force in the abovementioned crusher KMD-2200 reaches on average 5 t. While the foundation can be protected by means of flexible shock absorbers commonly used at present, the crusher's mechanical components - eccentric and swinging cone resting on their ball socket - will still show a fairly poor performance at an increased oscillations frequency. This is particularly obvious in an idle run mode of operation when the danger arise of the swinging cone shaft being jammed in the eccentric.

Another no less important reason for limited technological performance of eccentric crushers is their high susceptibility to fluctuations in the feed material charging, both in terms of its mass and size distribution. Therefore, it is also important to provide for a uniform distribution of feed material around the periphery of the crushing chamber, which, for example, is impossible to achieve in crushers of the HYDROCONE type.

In the case of segregated feeding, the crusher operates unevenly with peak stresses in some parts and assemblies of the drive, while the concaves wear out in a wavy pattern with large pieces of material filling occasional local hollows. At a number of mining operations this problem is dealt with by periodically machining the concaves (once or twice over their service life), which makes the operation of crushers appreciably costlier.

Yet another factor that prevents the eccentric crusher performance from becoming more efficient is the danger of the mechanism's breakage because of the crushing chamber getting overfilled with a very hard material. This makes starting and stopping of crusher, filled with material to capacity, undesirable.

With the currently employed frequency of the swinging cone oscillations (as an example, for crushers of KMD-2200 type this is 242 mm−1), a piece of ore is squeezed in the crushing chamber on an average seven times, provided the crusher is filled to capacity. However, the lower the throughput, the greater the speed with which the piece passes through the crushing chamber, having sometimes experienced no more than 2-3 squeezes on the way. Such a mode leads not only to a lower reduction ratio, but also to a dramatic reduction of the crusher's resource because of the cone shaft vibrations in the eccentric along with wearing out of oil layer on friction surfaces with the machine forced to operate in a semi-dry friction mode.

Ultimately, the list of main factors, limiting the technological parameters of cone eccentric crushers, includes the following:

- ellipticity and non-concentricity of cone concaves;
- increased radial clearances in the drive eccentric mechanism;
- susceptibility to fluctuations in feed material charging;
- limited frequency of swinging cone oscillations;
- the mechanism is endangered by uncrushable items getting into the crushing chamber, so safety devices are required;
- the crusher cannot be stopped or started under load.

**EXPERIMENTAL AND COMMERCIAL**

Based on the fundamental research into the solid-state physics and vibration theory, a series of jaw and cone crushers have been developed at Mekhanobr that are free from the limitations of conventional eccentric crushers while having quite a number of technological advantages of which the principal one is the possibility of monitoring the reduction ratio from 5 to 30.

This in turn makes it possible to completely rearrange the traditional ore preconcentration flowsheets by leaving out rod mills, and, possibly, ball ones as well (1). The use of the new machines for crushed stone production in the construction industry results in the proportion of cubical product increasing to 85-92% and the 5-0 mm product overgrinding reduced to 20-28% (in conventional crushers, it amounts to 40%) (2).
Shown in Figures 1 and 2 are schematic designs of a conventional jaw crusher and a vibrating jaw unit respectively. The jaw crusher is known to provide a reduction ratio of 4 with all its inherent drawbacks described above, while in the vibrating jaw unit the reduction ratio can be adjusted up to 15 (in terms of weighted average size fraction) and the machine is free from the limitations characteristic of the conventional units.

Figures 3 and 4 show basic designs of conventional unbalanced crushers and the cone inertia crusher (KID).

The principle of operation of the cone inertia crusher is as follows.

The rotating vibration exciter generates a centrifugal force which causes the inner cone to perform gyratory movement on the spherical support. In the process, the inner cone acquires a centrifugal force of its own which is a function of the cone amplitude. The latter depends on the degree of the material layer deformation and the value of the vibrator's centrifugal force.

In its turn, the material layer resistance force is a function C of the degree of its companion. Thus, by varying the crushing force magnitude one can provide for such a degree of the material layer compaction at which the particles of the material, while being subjected to the omnidirectional load, would tend to disintegrate largely along the weak interface zones, leaving the crystal blocks proper intact. This helps to perceptibly bring down the specific power consumption (Revnivtsev et al. 1992).

All the above advantages and peculiarities make the KID crushers applicable for crushing and grinding...
materials of practically any strength, up to hard alloys.

Results and discussion

Plotted on graphs in Fig. 5 are size distributions of products obtained from inertia crushers of various sizes. The graphs show that the same machine can work as a crusher producing crushed stone, as a mill yielding products of predominantly powder-size, or combining these two functions at the same time. The shaded area between the curves shows the range within which the crushing force can be monitored in order to obtain products with size distributions described by any desired curve. The graph for the crusher KID-2200 shows that the minimum size of its product approaches that of a rod mill product obtained in an open-cycle operation, even when processing rather hard materials measuring 20 units on Protodyakonov scale. However, the majority of concentrators use only ball mills fed with the product from fine-crushing eccentric units, which, in the case of hard ores, is finer than 25 mm, while its weighted average size is 10 mm at the best. The weighted average size of KID-2200 product, obtained on the same type of ore, is 2.5 mm. By using an equation relating ball mill capacity increase to decreasing feed size, it is possible to calculate that the increase in question amounts to nearly 41 per cent.

Thus, by using KID-2200 crushers instead of fine-crushing eccentric units of KMDT-2200 type, it is possible to reduce the grinding section’s power consumption by some 40 per cent.

If a KID-2200 is operated with water supplied into its crushing chamber, it is possible to increase its capacity to nearly 1000 tonnes/h, while retaining the product size typical for dry operation. But, if the discharge opening between the crushing cones is reduced to the level of the dry operation capacity, i.e. to 350 tonnes/h, then it becomes possible to obtain a product finer than 4 mm, in which the 0.04-0.250 fraction accounts for nearly 60 per cent. The graph on Fig. 6 shows that this size fraction is, in most cases, amenable to flotation if the ore is of a finely disseminated type. The shaded area of the graph reflects the size distribution of a product comminuted for flotation. It should be noted that the content of a 0.04-0.02 mm fraction (almost non-amenable to flotation) in the product of this crusher is three times less than in a respective ball mill product, while poorly floated, pellet-shaped particles are almost absent from the product.

![Graph showing size distribution of products from KID crushers](image)

**Fig. 5.** Size distribution of products from KID crushers of various sizes for a case of mineral hardness of 18-20 on Protodyakonov scale. Feed size is a function of the crushing chamber geometry and does not affect the product size.

**Fig. 6.** Relationship between the mineral component content in product with its amount lost in tailings and the grinding size (with an aggregate dissemination of fine particles of the recoverable component in gangue):

1 - content of recoverable component in product;
2 - loss of recoverable component in tailings

It follows then that the combination of ore liberation selectivity with the quality of the above product is a means of raising metal recovery by an average of 15 per cent. The use of a crusher KID-2200 in a wet closed cycle with a cyclone will allow the operator to do away with ball mills, which will result in at least 50 per cent saving of electric power consumed in ore preconcentration steps along with a tenfold reduction of grinding media consumption. Whenever there is a potential for expanding ore mining volume, the concentrator’s capacity can be substantially increased at minimum capital cost by making the released grinding sections available for extra flotation banks. Besides, in this variant the belt conveyors and screens of fine crushing sections can
also be dropped. These are replaced by cyclones, sand pumps, and pipelines, which leads to an appreciable reduction of operating costs (Zarogatsky et al. 2000).

CONCLUSION

The experimental testing of the KIDs of all type sizes (for different operating modes, feed materials, variable values of the vibrator static moment, its r.p.m., discharge settings, dry and wet processes) has shown their following advantages compared with the performance of the unbalanced cone crushers:

- depending on the crusher size, the reduction ratio is adjusted in open cycle up to 30 (against 4-5 in eccentric cone crushers);
- as the concaves wear out, the discharge setting becomes wider, but the product size stays almost the same due to the growing cone throw caused by its expanding amplitude, which applies both to dry and wet modes of operation;
- there is a possibility of bringing overgrinding to a minimum for a given size fraction, or, on the contrary, obtaining fairly fine-sized product that is near to a ball mill product;
- the product consists of particles of predominantly fragmented form, which makes further concentration steps more efficient than with pellet-shaped particles produced in ball mills;
- the crusher is started and stopped in a loaded state, which facilitates the automation process;
- the KID crusher does not require batch feeder and the material is fed by gravity directly from a bin;
- uncrushable items, if any, cannot cause the crusher mechanism to fail, so the KID needs no safety devices.

All the above advantages and peculiarities make the KID applicable for crushing and grinding materials of practically any strength, up to hard alloys.

Thus, by using KID-2200 crushers instead of fine-crushing eccentric units of KMDT-2200 type, it is possible to reduce the grinding section’s power consumption by some 40 per cent.

Technological and operating performance of KID crushers allows them to be used for waste materials processing. Since they tolerate uncrushable bodies, they are fit for processing slags of ferrous and non-ferrous metals along with recovering respective metal components, as well as refractories and casting sands. The same machines can effectively be used for processing metal chips, hard alloys, and used-up abrasive tools into powders to be reused (Vaisberg et al., 2000).

The record of commercial operation of cone inertia crushers in mining and metallurgical industries has demonstrated the possibility of substantially simplifying the ore preconcentration steps and even replacing ball mills by KIDs (Zarogatsky et al. 2000). These same crushers are used at present at many of the crushed stone and asphalt-concrete production plants in Japan, where they are manufactured under license, as well as at many similar operations in Russia (Vaisberg et al. 2000).

REFERENCES


