CHAPTER 3.5

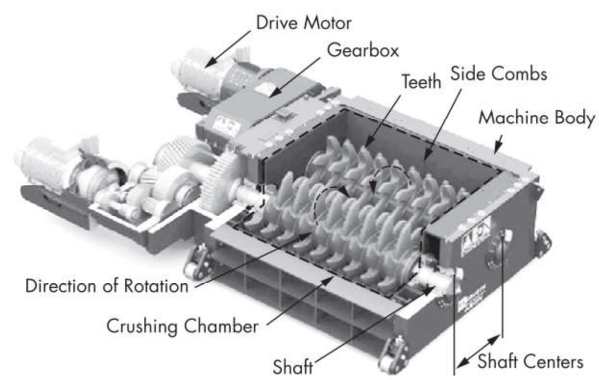
Sizers and Roll Crushers

David J. Bowman

Sizers and roll crushers represent an old family of crushing machines, with roll crushers often described as some of the earliest crushing machines. Roll crushers, as known today, have been in use since the 1920s (Cohen and Porter 1986). Sizers, or low-speed mineral sizers, are a newer introduction, with the Mining Machinery Developments (MMD) company having designed the first modern sizer in 1978. The first sizers were developed for underground crushing of coal in the United Kingdom, where low physical profile and high throughput were required. The terminology is important: *Sizers* are so named because the machine creates a series of sized voids for undersize rock to pass through before presenting oversize to the teeth to be broken in tension to minimize energy used (Flynn 1988). This comminution action specifically *sizes* the rocks, rather than simply crushing them.

The first sizers were installed to combat problems of blockages in more traditional equipment, which is an application that continues today. The other features of both sizers and roll crushers that make them attractive to designers are the efficient application of crushing power (through low speed and high torque) and the smaller footprint compared to an equivalent gyratory or jaw crusher installation. The supporting structure can also be lighter than for a gyratory crusher, as the crushing forces have no eccentric component and are contained within the machine frame. Another feature of sizers that can differentiate them from other coarse comminution devices is that the action tends to produce less fines than a comparative compression-based crusher.

Both sizers and roll crushers consist of two counter-rotating crushing members that grab or *nip* the rocks between the rolls (in the case of inward turning) or between the rolls and fixed combs (in the case of outward turning). The key components and their terminology are illustrated in Figure 1.



Courtesy of FLSmidth ABON

Figure 1 Key terminology for sizers

Roll crushers are available as a single-roll unit, with the material crushed between the rotating roll and a fixed plate; however, they are most commonly manufactured in a double-roll configuration. In the case of sizers (Figure 2), the breakage is between opposing teeth, with the large, aggressive tooth profile and low rotation speed working to nip the rock. Undersize material falls through the gaps between the rolls and teeth. With roll crushers (Figure 3) breakage is between two sets of much smaller teeth (or smooth drums), with the large roll diameter and high roll speed acting to nip and drag rocks into the crushing chamber. Once material has entered the crushing chamber, the crushing action is more of a traditional compressive crush than in a sizer.

In addition to the primary breakage mechanism between the rolls, some sizers rely on secondary breakage with the use of a breaker bar, as shown in Figure 4. The application of the breaker bar allows fewer teeth to be used in the crushing chamber, creating larger gaps between teeth, thus giving greater opportunity to nip larger rocks, and enabling a greater reduction ratio. The breaker bar can also be adjusted upward toward the rolls as teeth wear, giving the ability to control product top size. The downside to the application of the breaker bar is that it introduces an interruption into the flow, creating a further wear area caused by constant washing by fine material flowing past. In applications with wet and sticky material, the breaker bar can collect this material and force the teeth to be dragged through the fine material, accelerating tooth wear. No equivalent to the breaker bar is employed in roll crushers.

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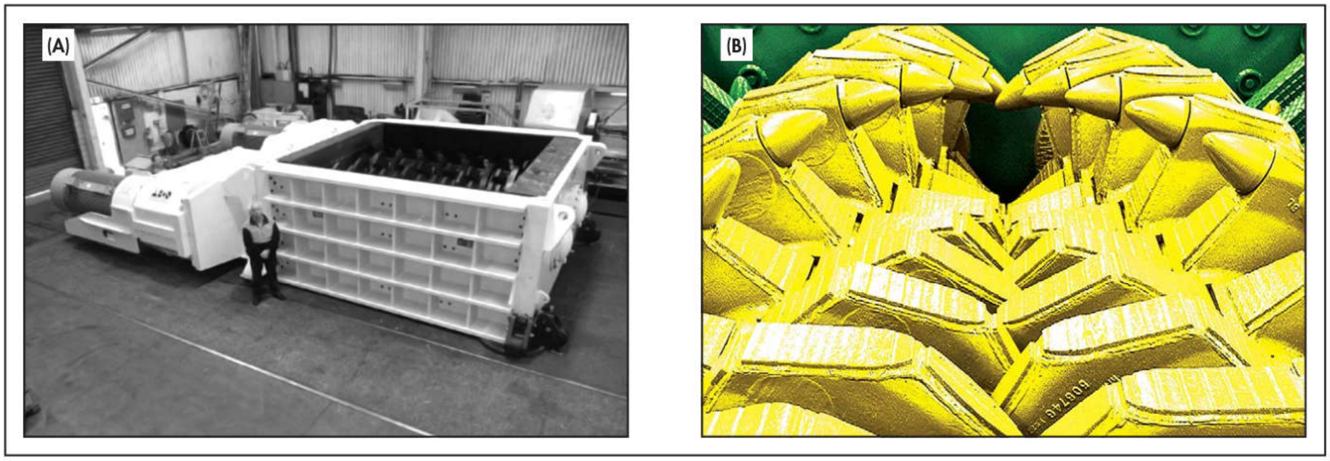

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Figure 2 (A) Primary sizer and (B) primary sizer teeth

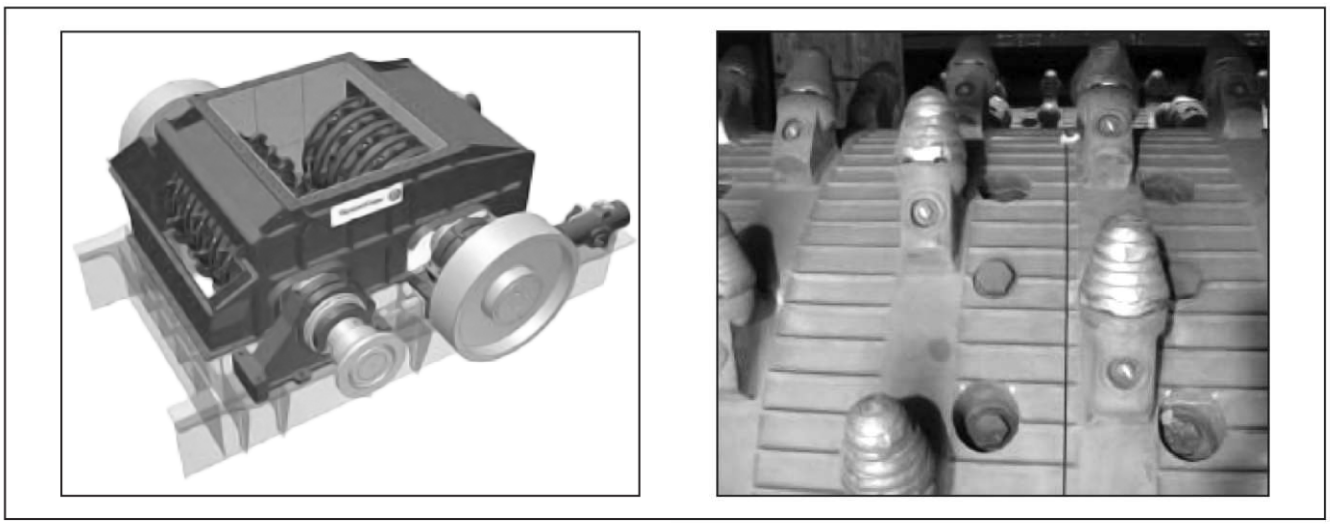

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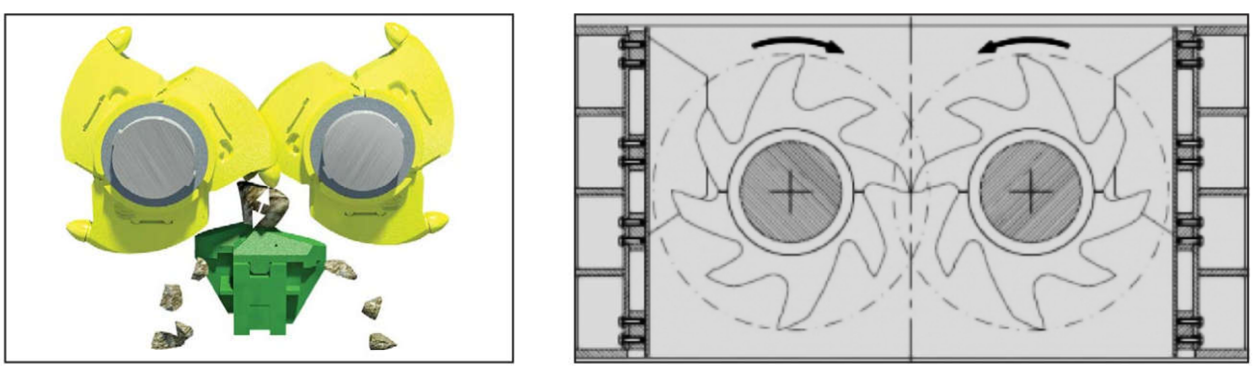
Figure 3 Double-roll crusher showing tooth profile



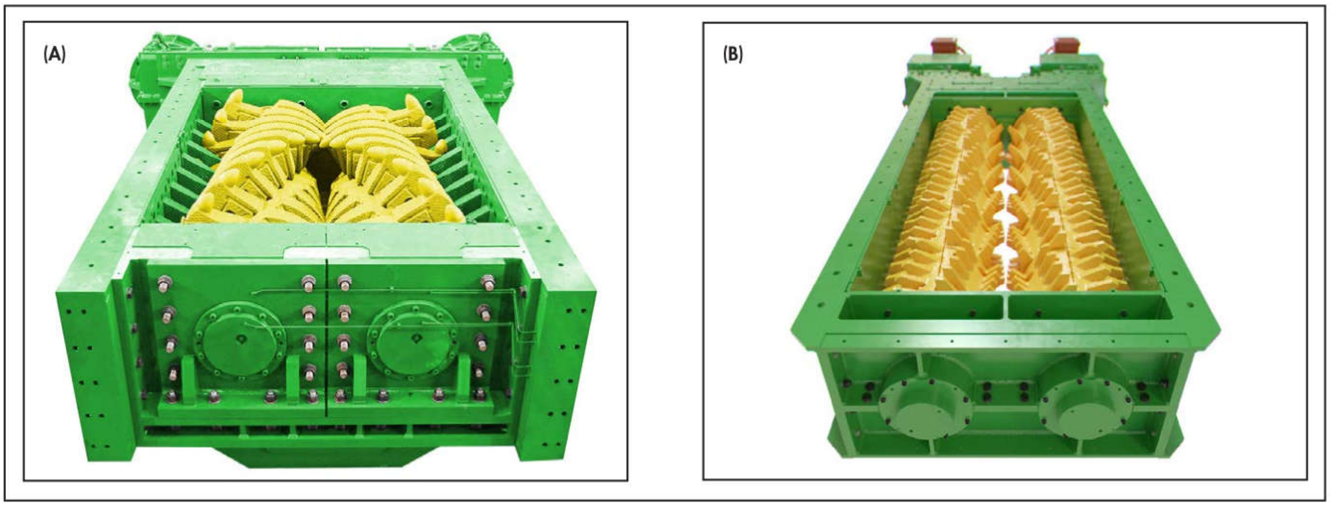
A. Sizer with breaker bar

B. Sizer without breaker bar

Courtesy of MMD

Courtesy of FLSmidth ABON

Figure 4 Sizer arrangements



Courtesy of MMD

Figure 5 (A) Primary and (B) secondary/tertiary sizers

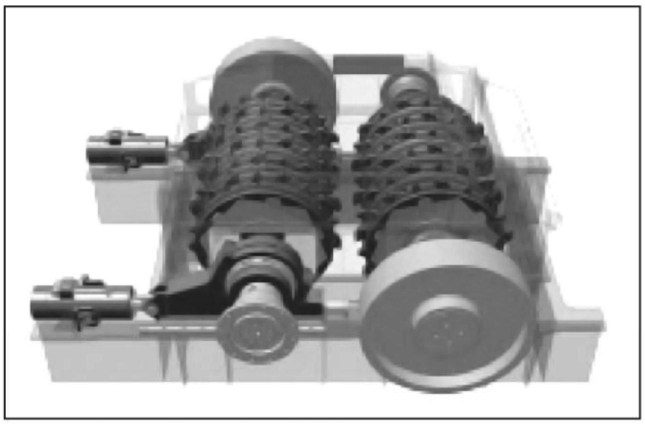


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Figure 6 Double-roll crusher showing shaft adjustment

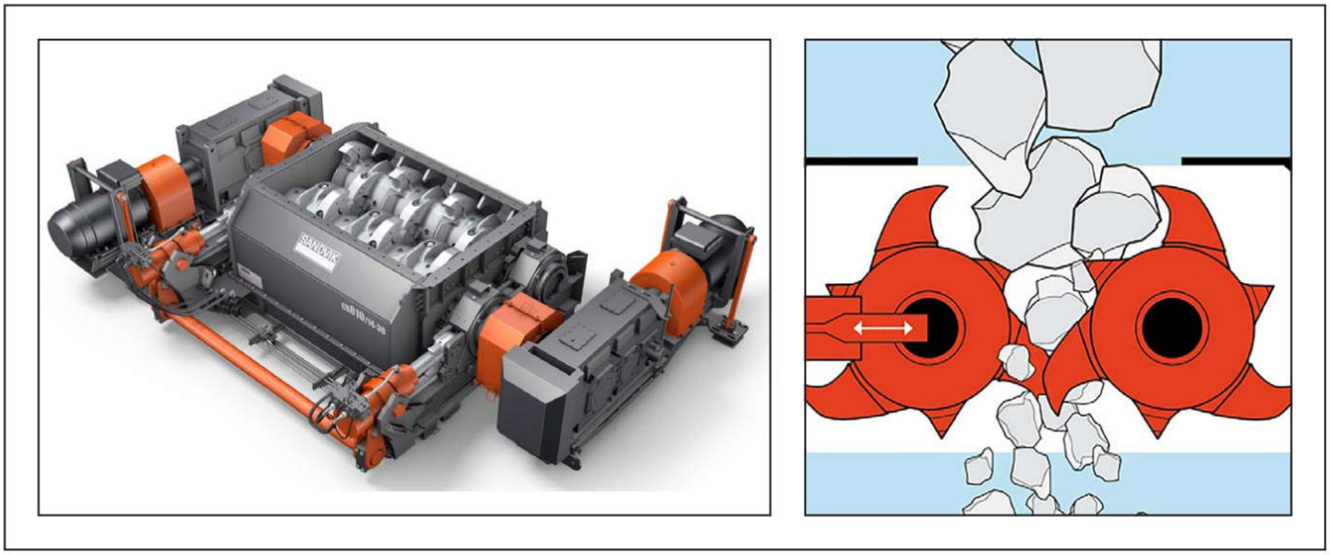
Sizers and roll crushers are used at all stages of comminution, from primary to quaternary duties. Machines specified for the different duties have different tooth profiles and shaft centers, in line with the feed and required product size distribution. Sizers are generally specified in terms of the gap between the shaft centers, with the largest primary sizers employing 1,500-mm (59-in.) shaft centers and the smaller sizers using 200-mm (~8-in.) centers (Figure 5). Roll crushers are specified in terms of the diameter and width of the rolls. The smallest machines usually measure about 400 (diameter) × 750 mm (width) (16 × 30 in.). The largest roll crusher currently on the market measures 2,400 × 3,600 mm (94 × 142 in.).

The shafts in sizers are traditionally fixed in place, giving no option for the machine to have the rolls adjusted inward as the teeth wear (to maintain product top size) or to relieve outward to allow tramp metal such as ground-engaging tools to pass. Although sizers have safety devices such as underspeed sensors to protect the machine in this event, tramp metal in the chamber is difficult to remove because it requires either the chamber to be manually dug out or the sizer retracted to the maintenance position with a full chamber (where possible). Both of these activities can create greater hazards to personnel than allowing the tramp metal to pass and collecting from a receiving conveyor. As shown in Figure 6, roll crushers do allow this horizontal adjustment, reducing the potential damage from ground-engaging tools and giving the operation greater control over product top size. The shaft adjustment can be mechanical, including a spring for passing tramp material, or more commonly, a hydraulic arrangement is used.

There are some machines currently on the market that incorporate the adjustable shaft centers on a low-speed sizer, such as the Sandvik hybrid crusher (Figure 7).

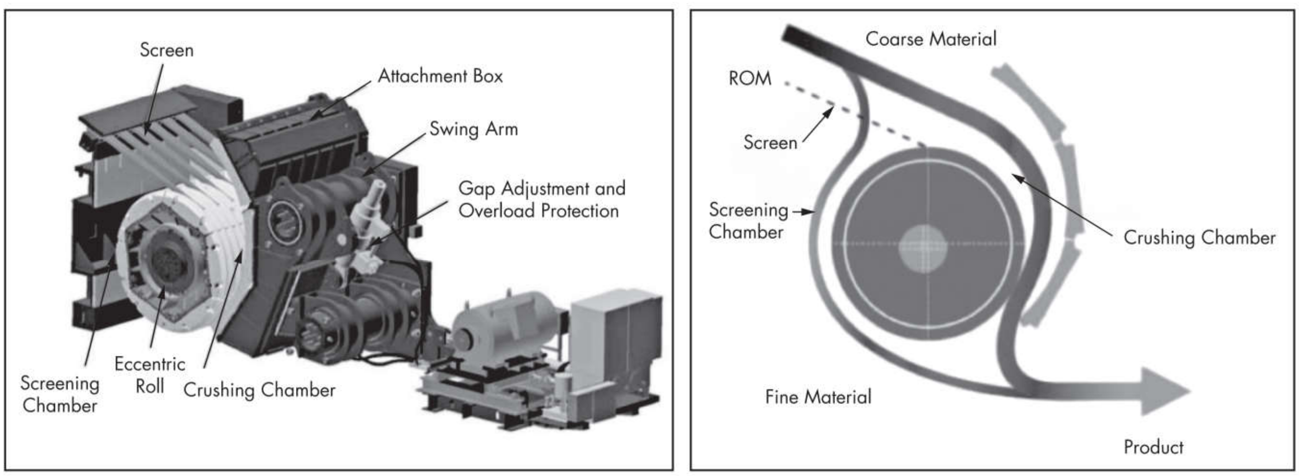
Feed to primary sizers or roll crushers is traditionally an *all-in* feed, as with primary gyratories, with the full run-of-mine (ROM) feed distribution going to the machine. The material that is smaller than the desired product size will fall through the machine, although it is important to note that the volume taken up by this fine material will contribute to the volumetric capacity. It is possible to have a primary sizer or roll crusher fully volumetrically utilized, yet drawing very little power when crushing fine feed. Material too large to fall through the gaps between the teeth and rolls will be grabbed by the teeth and broken. There are two mechanisms of breakage at work in the crushing chamber, exploiting compressive and tensile failure. Compressive failure occurs when material is forced into the gap between a tooth and the opposite roll, a space that will reduce in size as the rolls rotate. Tensile failure occurs when rocks are grabbed between opposing teeth, creating sufficient tensile force to cause fracture. Subsequent crushing of the progeny particles can be in either mode, but more commonly compressive as the particles become smaller. The smaller teeth and larger-diameter rolls of a roll crusher (relative to a sizer) lead to the crushing action being primarily driven by the compressive force between the rolls. The teeth in this instance are more for grabbing material than crushing or sizing it.

There is another variant of the roll crusher concept, which is the eccentric roll crusher (ERC). The ERC25-25 has a 2,500-mm (98-in.) feed opening width and a 2,500-mm (98-in.) diameter roll (Szczelina et al. 2017). In the design, the roll is mounted horizontally and moves with an eccentric motion that is consistent across the full width of the roll. Material is fed horizontally to an integral screen arrangement,



Courtesy of Sandvik

Figure 7 Sandvik hybrid crusher



A. General arrangement of the ERC25-25 crusher

B. Material flow through the ERC25-25

Courtesy of ThyssenKrupp Industrial Solutions

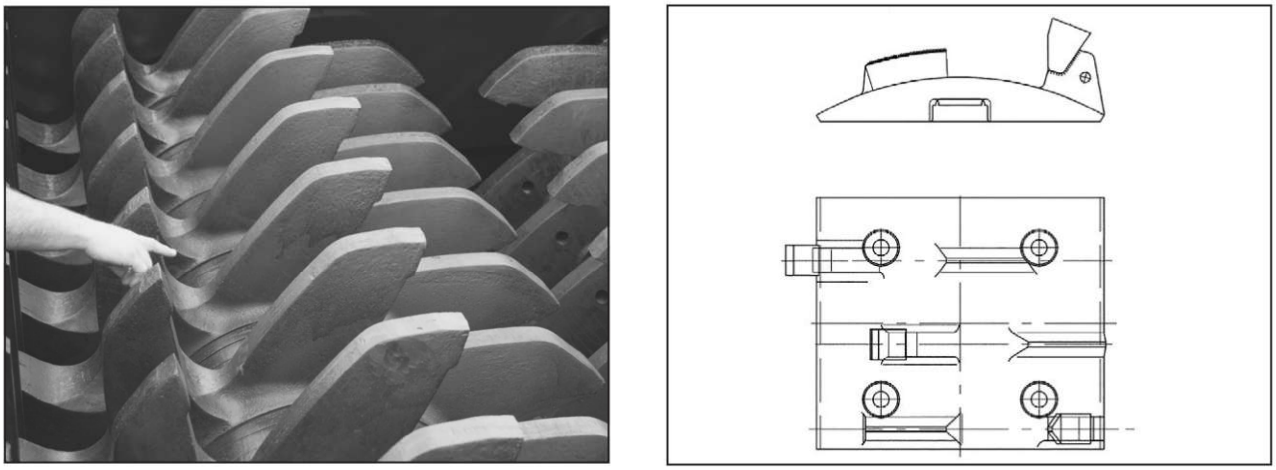
Figure 8 Eccentric roll crusher

where undersize is removed down the front of the crusher, therefore bypassing the crushing chamber. Oversize from the screen falls into the gap between the roll and a stationary curved crushing surface. The flow and general arrangement of the crusher are shown in Figure 8. The machine has a range of features, including a low-height requirement, high throughput (up to 3,000 t/h), integrated gap adjustment and overload protection, low residual forces, and a reduction in the generation of elongated product. As the machine is new to market at the time of writing, it is not possible to gauge the potential for the machine, but it is claimed that it specifically offers advantages for deployment in underground caverns and in mobile applications.

The power required for sizers and roll crushers is generally less than that for other forms of crushers, such as gyratory machines. Primary sizers are typically fitted with twin 350–400-kW (470–540-hp) drives, one for each shaft for a total installed power of 700–800 kW (940–1,070 hp). The most powerful sizers are fitted with 2 × 750-kW (1,005-hp) drives. As a comparison, some 60–89 primary gyratory crushers are now fitted with 1,000-kW (1,340-hp) drives.

PRINCIPLES AND TERMINOLOGY

Both sizers and roll crushers rely on the principle of grabbing rock using rotating elements mounted on a horizontal shaft. For sizers, these shafts generally rotate slowly (<1 m/s [1.3 ft/s] tip speed) to minimize the amount of material movement (boiling) on top of the shafts. Roll crushers operate at higher shaft speeds (typically 130–300 rpm), although in tougher applications this can be as low as 80 rpm (~3 m/s



A. Single-piece tooth segments for sizers

B. Tooth segments for roll crushers

Courtesy of FLSmidth ABON

Courtesy of ThyssenKrupp Industrial Solutions

Figure 9 Tooth segments for sizers and roll crushers

[~10 ft/s] at the tips) with the circumferential speed being used to grab rock in the chamber and to match the velocity of the falling material, thus reducing wear. Roll crushers operate with inward-turning shafts, that is, reducing distance between the surfaces of the rolls, moving down the machine to create the compressive crushing force. Sizers are generally inward rotating for primary and secondary crushing, often moving to outward turning for tertiary and quaternary applications. The outward-turning arrangement subjects the machine to higher wear, but crushing between the teeth and fixed side combs gives a fine product size that is difficult to achieve with inward-turning shafts.

The rock-engaging wear materials used in sizers and roll crushers fall into two broad groups: single-piece segments (Figure 9) and replaceable picks (Figure 3). The roll crusher plates can have the teeth replaced if tooth wear has far outstripped the rate of baseplate wear. These picks can be welded in place or mechanically fastened, with mechanical fastening claimed to reduce downtime from tens of hours to a few hours (Good and Zimmerman 2014). One-piece sizer tooth segments are either cast or flame cut, and are often hard faced. The inherent risk of hard facing is that once the weld layers have been worn away, the underlying parent metal suffers accelerated wear because of heat-induced softening from the hard-facing process. The hard-faced layer can either be reapplied in situ or after removal of the shafts for maintenance. Side combs and breaker bar components are also subject to hard facing and suitable hardening treatment to extend operational life.

The transfer of energy in sizers and roll crushers is through a simple drive train (Figure 10). Machines are fitted with a single drive for soft rock applications, such as coal, or multiple drives for harder rock applications. Most hard rock primary sizers are fitted with a single motor for each shaft, driving through a fluid coupling (for machine protection) and reduction gearbox to the main shafts. Some manufacturers also employ a synchronizing gear set to ensure that the two shafts turn with the teeth meeting at the optimum angle for rock nip and ingestion.

This drive arrangement has been optimized for use on mobile machines underground by Joy Global. The Joy Global DRC1200 was designed specifically to achieve the ability to move the sizer through an underground mine on a tracked chassis to enable semimobile operation (Good and Zimmerman 2014).

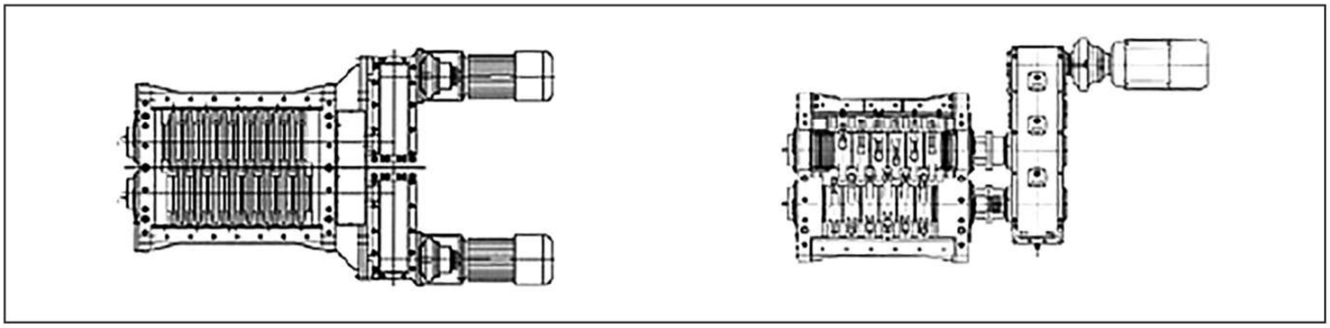
Sizers for further reduction are frequently designed in a quad-drive arrangement, as this works better with the dimensions of the machine itself. These sizers are generally flatter and longer than a primary machine (driven by the roll diameter), so quad drive allows the drive motors and gearboxes to be smaller and limits the torque loading on the main shafts.

Roll crushers and the hybrid crusher are generally driven through a set of belts following the gear reducer (see Figure 7). The belt drive provides further speed reduction, effective flywheel energy storage in the large pulley, and mechanically isolates the other drive components from impact forces seen by the rolls.

Feed rate to sizers and roll crushers is generally controlled with an apron feeder, separated from the truck tipping forces by a ROM ore bin. The shafts and bearings in some machines are not designed to accept the impact forces imparted by rock rolling directly down from a truck body, only feed from the apron feeder, the crushing forces, and those applied through the use of hydraulic rockbreakers.

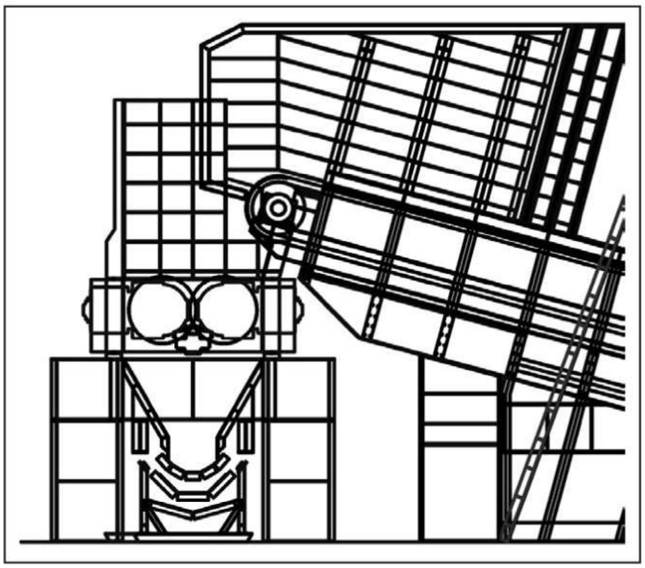
Roll crushers are fed with the *ribbon* of feed material falling directly into the crushing chamber, with the apron feeder shafts in the same orientation as the rolls. Sizers can be fed either parallel to the machine shafts, as shown in Figure 11, or perpendicular to the shafts with the machine turned through 90°. Both of these alternatives have positive points, depending on the machine style used. Most scrolling machines are fed perpendicular to the apron feed discharge to allow the scrolling motion to remove uncrushed material from the ore stream. Nonscrolling machines and roll crushers are parallel fed, with the sizer shafts arranged parallel with the apron feeder discharge axis. In general, machines fed this way use a larger *snag tooth* (as seen in Figure 4B).

The sizer discharges to either a receiving conveyor belt or another sizer (known as a *stacked arrangement*). Feed rate is dictated and controlled by many factors including sizer power draw and load on the receiving conveyor.



Courtesy of ThyssenKrupp Industrial Solutions

Figure 10 Dual- and single-drive arrangements



Courtesy of MMD

Figure 11 Parallel sizer feed arrangement

CONSTRUCTION AND DESIGN

As with most mineral processing equipment, sizers and roll crushers have been increasing in load and power as the scope of application grows. The structure of the machines is simple, with a twin-roll secondary sizer shown in Figure 12. The overall construction principles for roll crushers are very similar. The main frames are fabricated from heavy welded plate, not cast elements such as used in gyratory crusher mainframes. Frames are designed with removable end plates that allow the removal of the shafts for refurbishment, reducing the duration of production interruption. The machines are mounted on either fixed or retractable wheels, which are jacked down, thus lifting the machine, for removal along steel rails from under the feed point. This makes machine maintenance safer (less risk of falling material, with clear space overhead for crane lifts) and quicker.

Replacement of teeth, being the main wear component on both sizers and roll crushers, can be done either in the machine or with the shaft removed to a maintenance stand. Access to sizer teeth for in situ work is from the top, with roll crushers generally accessible via maintenance access doors on the sides of the machine (Figure 13).

The teeth in a sizer or roll crusher act to engage or nip the rock, apply force to the point of breakage, and also screen the passing material. Tooth design must work within these design parameters while also ensuring that product top size is controlled as the teeth wear, with an acceptable wear life. Generally, teeth are fashioned in a pick arrangement with an aggressive point to engage the rock (see Figure 9A). The width and profile of the tooth will provide the effective open area for screening, so these areas must be built to handle both flow wear and wear under high normal force. Manufacturers offer various tooth materials on machines to provide the best balance between wear rate and tooth strength.

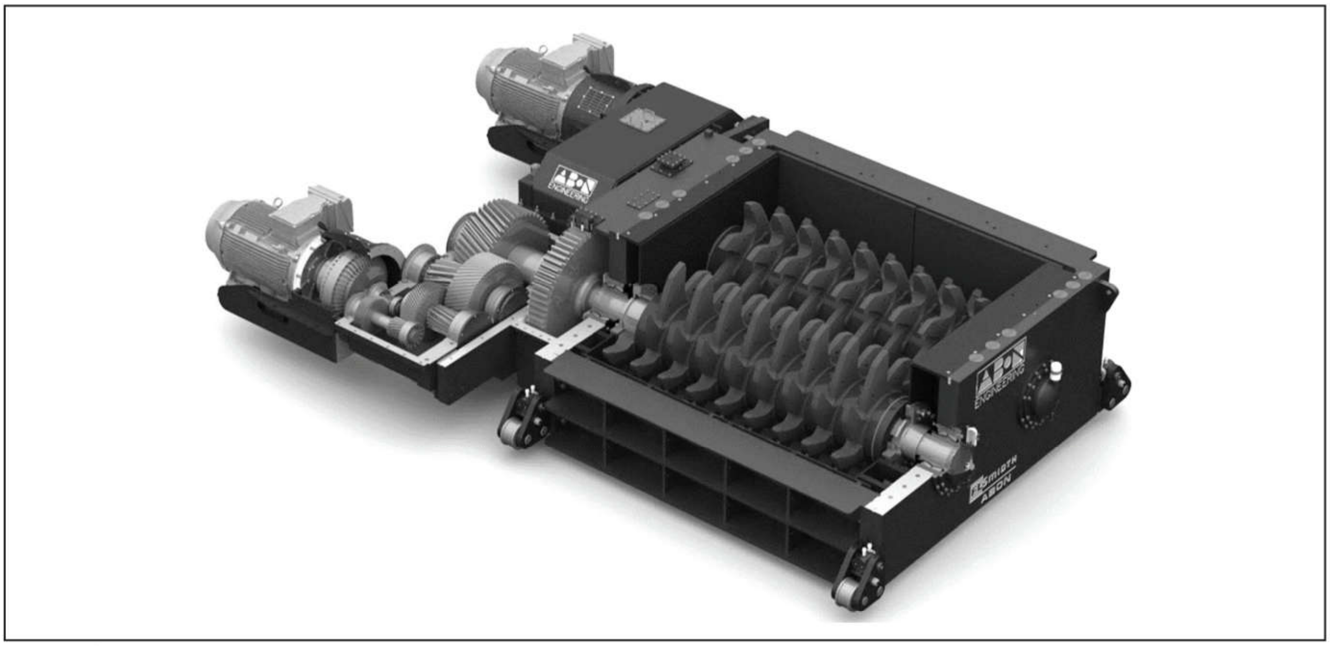
The shaft removal approach offers the advantages of reducing risk of injury to maintenance personnel by taking the activity to a level surface as well as reducing the time the machine is out of productive service. Many sizers and roll crushers are now sold with rotatable spare shafts as part of the package; worn shafts are taken offsite for repair and refurbishment in a workshop environment.

All sizer manufacturers have different methods to handle clay, excessively hard rock, or other uncrushable material. The scrolling action of some machines removes unnipped material from the main flow area, with other machines being able to stop and reverse to clear blockages. Some, such as the FLSmidth ABON secondary sizer, are fitted with hydraulically actuated side panels that open while the machine reverses to eject uncrushable material.

APPLICATION AND OPERATION

As with any installation, information should be sought from manufacturers regarding the feed size, product size, required power, and throughput. All manufacturers have this information available for stated feed properties, along with reference lists of global installations. A guide to the type of information generally available is shown in Table 1.

As a general rule, the specification of sizers and roll crushers is dictated by the feed size and strength. In a typical primary application, ROM feed will be presented with an F_{80} in the order of 1,000–1,500 mm (39–59 in.). Such feed forces the designer to specify a machine with sufficiently large shaft centers to guarantee that this size material will be nipped and broken. This size of machine may well exceed the necessary throughput requirements of the process plant because of the large volumetric capacity. For example, a large (1,300-mm [51-in.] centers) primary sizer operating in moderate rock will comfortably process up to 5,000 t/h, regardless of the plant requirement. This gives further justification for feeding these



Courtesy of FLSmidth ABON
Figure 12 Cutaway view of a twin-drive secondary sizer

Courtesy of ThyssenKrupp Industrial Solutions
Figure 13 Maintenance access to primary double-roll crusher

machines through a controlled means, such as an apron feeder, to avoid flooding downstream equipment.

The limitation to the application of sizers and roll crushers is usually the strength of the feed rock and/or the abrasivity. The strength and abrasivity must be considered for each area of the material to be mined, not as an ore-body average. There are many examples of crushing plants (of all types) around the world that have failed to perform on plant start-up because of the highly competent cap rock that can be a feature of certain deposit types. Although the average rock strength may be within the necessary limits, small parcels of extreme material can stop production through the inability to nip and break the rock, or through machine damage and accelerated wear.

The measure of rock strength and abrasivity is discussed at length in Chapter 3.6, "Crusher Selection and Performance Optimization." Typically sizers and roll crushers are used in material with an uniaxial compressive strength below approximately 180 MPa, or fracture toughness below ~2 $MN/m^{1.5}$.

Because the machines are fed with an all-in whole of feed stream (including all fines), both sizers and roll crushers are highly vulnerable to wear. They are susceptible to both flow and gouging abrasion, depending on the application. In soft rock applications, wear on the machines is governed by flow abrasion of material running between the teeth and rolls. This can present itself with the back and side surfaces of the teeth wearing away, leaving a slender tooth of almost original length. In harder rock applications, gouging abrasion becomes an issue, with the large force on the teeth acting to wear away the points, leaving a much shorter tooth with almost the original width and depth. As a general rule, feed to sizers and roll crushers should have a Bond abrasion index (i.e., flow measure) less than 0.4 and a CERCHAR (Laboratoire du Center d'Études et Recherches des Charbonnages de France) abrasivity index (i.e., gouging measure) no greater than 3.0, or alternatively, a gouging abrasion index of less than 15. The duty and likely type of wear should be considered in all applications and an economic trade-off applied.

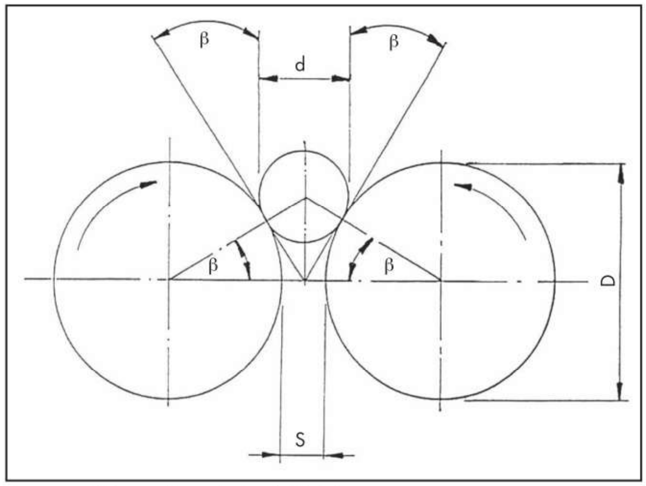
Sizers and roll crushers are fed from a ROM bin (single or dual tip) via an apron feeder. The exception to this is underground, where the ROM bin is replaced by a feed hopper to accept discharge from load-haul-dump machines. There is no requirement for the installation to include a large bin beneath the machine (as with a gyratory) as the surge decoupling is taken up by the ROM bin, and the production of crushed rock is at a controlled rate.

Table 1 Typical sizer manufacturer information

Sizer Shaft Centers, mm (in.)	Maximum Feed Size,* mm (in.)	Throughput Rate, t/h	Total Installed Power, kW (hp)	Machine Mass† (approx.), t
500 (20)	480–650 (18–26)	Up to 1,500	55–220 (75–300)	5
660 (26)	650–850 (26–33)	Up to 2,500	160–500 (215–670)	20
800 (31)	750–1,050 (30–41)	Up to 3,500	200–630 (270–845)	32
1,000 (39)	950–1,300 (37–51)	Up to 5,000	250–700 (335–940)	42
1,250 (50)	1,200–1,600 (47–63)	Up to 7,500	450–800 (600–1,070)	80
1,500 (59)	1,400–2,000 (55–79)	Up to 10,000	750–1,200 (1,000–1,600)	125

Courtesy of ThyssenKrupp Industrial Solutions
* Maximum feed size depends on tooth arrangement.
† Mass of machine without drive.

Courtesy of MMD
Figure 14 Fixed, semimobile, and mobile primary sizer stations



Courtesy of ThyssenKrupp Industrial Solutions
Figure 15 Calculation of maximum feed size in double-roll crushers

A key consideration with the application of sizers and roll crushers is the ability of the machines to be used in fixed, mobile, or semimobile applications. The machines are small, light, and simple when compared with other crushing equipment. There is no requirement for stand-alone hydraulic and oil lubrication systems, further increasing the mobility.

This small size of machine, coupled with the containment of all crushing forces within the machine frame, make sizers and roll crushers ideal for mobile applications. The smaller mass and reduced head height allow machine stability, even when track mounted. The use of a ROM bin and inclined apron feeder to feed the machine also allows a lower ROM pad wall, reducing the cost of installation for fixed or semimobile installations. This reduction in site capital costs for machine installation can make a strong economic case for relocatable units, with the corresponding reduction in both the capital and operating costs of supporting long truck hauls. The trade-off is the additional cost of conveying infrastructure, which is largely driven by site layout and topography. Typical sizer installations are shown in Figure 14.

Mobile applications have been successfully deployed in coal and oil sands, fed directly by shovel, truck tip, or as a dozer trap (Morrison and Lourel 2009). Further considerations for the degree of mobility for in-pit and mobile crushing are contained in Chapter 3.4, "Gyratory and Cone Crushers," and in Boyd and Utley (2002).

Process performance of sizers and roll crushers are not well documented, compared to many other types of crushers, with the general level of detail usually limited to the type of data seen in Table 1. In terms of throughput and maximum feed size, some estimates are possible.

For smooth-surfaced roll crushers, Figure 15 shows the geometry for the calculation of maximum feed size:

$$d = 2\left(\left(\frac{\left(\frac{D}{2}+\frac{S}{2}\right)}{\cos\beta}\right)-\frac{D}{2}\right)$$

where

d = maximum particle diameter, m
D = roll diameter, m
S = gap between rolls, m
β = half of total included nip angle, degrees

In reality, the calculated feed size is quite conservative, and in the case of toothed rolls, the maximum feed particle size can be significantly larger.

For the theoretical calculation of throughput for a roll crusher, the following equation can be used:

$$Q = 3{,}600\ WDvfs\gamma$$

where

Q = throughput, t/h
W = roll width, m
D = roll diameter, m
v = peripheral speed, m/s
f = void factor
s = gap between rolls, m
γ = bulk density, t/m^3

In terms of product size distribution from roll crushers and sizers, a majority of data is experiential, and as such, the manufacturers should be contacted for further information.

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