Crushing and Screening
Considerations for designing an efficient operation
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Several considerations need to be taken into account in designing an efficient crushing and screening plant, the first being the raw materials to be crushed. The quarry shot material should be analyzed for maximum feed size, gradation, chemical composition, amount of clay, hardness and variations within the deposit or benches. A list of product sizes needs to be determined as well as the percentage of each product in the total production. The quarry’s annual production and operating hours also need to be determined. The entire system should be checked by an experienced crushing and screening expert with a computer flow simulation program to optimize the output and efficiency.

Hopper design
One of the first steps in the process is to select the equipment to load the primary hopper. The truck size and number of trucks or loaders needs to be determined to evaluate the hopper capacity. Typically, the minimum hopper live load capacity is approximately 1.5 times the size of the unit dumping into the hopper. Rock box hoppers are typically used in truck dump operations, while hoppers with sloping sides might be considered for sticky materials.

Types of primary feeders
**Apron feeder** – Apron feeders should be rugged and designed to handle the impact and lump size of the raw feed from the quarry. Many manufacturers use cast manganese pans attached to crawler tractor chain with sealed rollers. Impact rails are also necessary to ensure the lump size does not destroy the feeder pans. The modern apron feeder with tractor chain is known to provide very long life and is trouble-free. The apron feeder can be speed controlled to match the primary crusher capacity. Apron feeders are often followed by a heavy-duty scalping screen to separate products or to remove deleterious materials. The scalping screen allows material that is already sized for the final products to bypass the primary crusher.

**Wobbler feeder** – Wobbler feeders are typically used for the separation of clays in the feed. These machines are self-cleaning and handle sticky clay with a typical separation at 3/4 in or less. These feeders represent a high investment cost but are extremely effective with sticky materials. It is recommended that the feed size is controlled if the wobbler is to be used as the primary feeder. Dumping large rocks directly on a wobbler-type feeder can result in damage to the unit. As with any scalping device, the wobbler-type feeder is most efficient when the material bed depth over the feeder is reasonably consistent. It is common for an apron feeder to be used as the primary feeder transferring material to the wobbler feeder for separation. The wobbler feeder is typically operated at a fixed speed, but can be turned on and off as needed.
Vibrating grizzly feeder – Grizzly feeders typically represent a small investment cost. These feeders perform the dual function of feeding/conveying as well as separating smaller material to bypass the primary crusher. The oversize materials are discharged from the feeder into the primary crusher. This machine has a range of speeds but cannot control the feed rate to the crusher as precisely as an apron feeder. However, grizzly feeders are exceptional when processing free-flowing materials, owing to their multi-function capability and price advantage over the apron feeder. Typically, grizzly feeders offer a G-force ranging between four and five, which is sufficient to stratify the material bed and provide a feathering effect as the material passes over the grizzly section.

Types of primary crushers

Jaw crusher – Jaw crushers are used for extremely hard and abrasive materials, with reduction ratios typically as low as 6:1. However, jaw crushers are very durable, have low maintenance requirements, and are effective with almost any type of friable material. They represent a medium investment cost and, generally, half a horsepower is required per ton per hour of material produced. Jaw crushers are typically long-life machines. New technology has incorporated quicker adjustment times, tramp iron relief and automated product size setting.

Impact crusher – Impact crushers are typically used for hard and moderately abrasive stone. The primary impact crusher, also known as a primary breaker, has a reduction ratio of 20:1. Impact crushers are higher maintenance than a jaw, although are still considered low maintenance with regard to their tonnage rate and overall productivity. Impact crushers typically represent the lowest investment cost compared with other primary crushers with comparable feed size and capacity.

Andreas-style’ impact crushers use three quarters of a horsepower per ton per hour of material produced. While this type of primary impact crusher has become very popular worldwide, due to many time-saving maintenance features, they remain less efficient than the traditional primary impactor or impact breaker. All Andreas-style crushers impact and grind the material past heavy aprons with sizing controlled by speed and the apron’s proximity to the rotor.

In recent years, newer designs of impact crushers have been developed as true ‘impact’ crushers. These units combine the time-saving features of Andreas-style impactors and the traditional primary impactor. They are designed to bounce material off heavy aprons, ricocheting it back into the rotor to produce more crushed material with less horsepower. These true ‘impact’ machines use half a horsepower per ton per hour and produce a higher percentage of finished products than the Andreas-style machines. The impact crusher is one of the most versatile crusher types available and offers the advantages of high reduction ratio with lower horsepower per ton.

Hammermill (primary) – Typically, hammermills are used for soft, non-abrasive and dry materials, although some ‘non-clog’ models can accommodate wet or sticky materials. Hammermills are used where higher reduction ratios are required. Normally, they are used when a product needs to be reduced to a certain size for the next operation in the circuit (e.g. cement plants). Reduction ratios for this machine are typically 20:1. Hammermills are higher maintenance than the impact crushers owing to the higher reduction ratios and the design of the machine. Hammermills require approximately two horsepower per ton per hour of material produced in a primary application. They represent a larger investment than an impact crusher, although less than a jaw or gyratory.

Sizers – These machines are typically used in medium-to-soft non-abrasive material.
Reduction ratios for this machine are approximately 5:1. They are typically lower maintenance than impact crushers and represent a medium investment cost.

Gyratory crushers – Gyratory crushers are used for hard and abrasive materials. Reduction ratios are typically 4:1 and maintenance is minimal. Gyratories represent a high investment cost but are typically long-life machines. They use approximately a quarter of a horsepower per ton per hour of material produced.

With primary crushers, consideration should be made regarding initial cost, reduction ratio, horsepower per ton per hour, hardness, abrasiveness of the material, feed size input and product required. More recently, power consumption per ton produced has become a very important factor in crusher selection.

Tightening the quarry shot pattern should result in less oversize material being fed to the primary crusher hopper. Not having to break or remove oversize rock in the primary hopper can significantly improve efficiency in the system. Rock breaker hammers are a necessity at many primary stations, but at times can encourage operators to put oversize rock in the hopper.

Surge considerations
In a stationary quarry set-up, there is typically a surge pile. The primary crusher is usually oversized in terms of capacity and operated at a lower efficiency than the rest of the plant. It is common for the primary sized material to be stockpiled in such a manner that it can be reclaimed from the bottom of the pile to feed the rest of the plant, thereby overcoming fluctuations in the feed from the primary crusher. The surge pile usually is designed with a live capacity of 2-3h or more.

Scalping and sizing considerations
The scalping screen is typically fed with material after it has passed through the primary crusher, separating out oversize materials that need further crushing. Often, a specific product is pulled from the second or third deck of this screen. Scalping screens normally contain two or three decks, are often inclined, and are not generally used for precise sizing. Oversize materials from the scalping screen are usually conveyed to the secondary or tertiary crusher for further reduction.

Usually, the secondary crusher is followed by a sizing screen which separates the material, with the top deck material being returned, via conveyor, to the secondary crushe for another pass. The materials from the other decks on the sizing screen are sent, via conveyors, for stockpiling. In cases where a tertiary crusher is used, the secondary crushed material may be conveyed to the tertiary crusher and possibly to an additional screen or screens. All reputable screen manufacturers offer formulas for capacity, but a knowledgeable specialist should also be consulted owing to the variable material characteristics.

Secondary crusher considerations
Cone crushers – Cone crushers are a type of compression crusher suitable for crushing hard, abrasive materials. They represent a high initial investment but are low maintenance. Reduction ratios are typically up to 6:1. It is worth noting, however, that the cone crusher is limited to a certain top size of material feed. Cone crushers use approximately one horsepower per ton per hour making a 1in product. Typically, around 15-20% of oversized product is recirculated for re-crushing to size.

Roll crushers – Roll crushers are another form of compression crusher that can be used to crush hard and abrasive materials. They represent a medium-to-high initial investment and maintenance requirements are average. Reduction ratios are up to 3:1. This machine requires one-and-a-quarter horsepower per ton per hour of material crushed to make a 1in product. The product from the roll crusher has almost no oversize. The triple roll crusher is the same as above except that it has a reduction ratio of up to 5:1. Roll crushers typically have lower tonnages than their counterparts and are most noted for their low production of fines and controlled output gradation.

Horizontal-shaft impactors – Horizontal-shaft impactors are typically used in soft or moderately abrasive materials. This type of impact will crush abrasive materials, although the wear cost may be prohibitive depending on the metallurgy of the wear parts selected. Horizontal-shaft impactors have a reduction ratio of up to 12:1 in secondary applications. They are low-cost machines with a minimum investment value and are capable of high tonnages. Typically, about 15% of the horizontal shaft impactor product will need to be re-screened, with oversize material being recirculated for re-crushing. Impact crushers require approximately one horsepower per ton of material crushed when making a 1in product.

Vertical-shaft impactors – Vertical-shaft impactors are typically used in moderately abrasive materials. These machines are usually installed as a tertiary unit. They are very effective at fine crushing down to 1/8in size, and providing a cubical product.

Hammermills – Hammermills are primarily used in soft and non-abrasive applications. They are usually installed to make finer-graded finished products and require high horsepower per ton per hour produced, typically around two horsepower per ton of material crushed to make a 1in product. They represent a low investment cost and are small in size. Hammermills have sizing grates through which the material must pass, yielding little oversize. The finer the desired product, the more horsepower required.

Conclusion
There are many considerations to be taken into account when designing an efficient crushing and screening system. Carrying out a complete analysis of the equipment should include considerations for improving efficiency, minimizing the number of pieces of equipment, analysing power consumption based on the volume of material produced, maintenance schedules, labour hours required to maintain equipment, capital costs, and personnel requirements.

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