



# MINERAL PROCESSING MILLING

## Introduction

Milling, sometimes also known as fine grinding, pulverising or comminution, is the process of reducing materials to a powder of fine or very fine size. It is distinct from crushing or granulation, which involves size reduction to a rock, pebble or grain size. Milling is used to produce a variety of materials which either have end uses themselves or are raw materials or additives used in the manufacture of other products.

A wide range of mills has been developed for particular applications. Some types of mills can be used to grind a large variety of materials whereas others are used for certain specific grinding requirements. This brief aims to present the factors to consider when choosing particular grinding applications and to give an overview of the equipment which is available.

Material grinding is quite often an integral part of an industrial process, whether carried out on a large or small scale and in some cases the grinding mill may be the single most costly item for the production operation. Installing a grinding mill which is suitable for the purpose would be one of the main requirements for cost-effective and trouble-free material processing if a grinding stage is involved.



Figure 1: Swing hammer mill being used for lime milling in Malawi. ©Practical Action.

<ul style="list-style-type: none"> <li>Abrasives</li> <li>Animal products</li> <li>Brewing industry</li> <li>Chemical</li> <li>Confectionery</li> <li>Food processing</li> <li>Fuel preparation</li> <li>Metal powder</li> <li>Mineral preparation</li> <li>Paint preparation</li> <li>Paper</li> <li>Pigments for colour industry</li> <li>Abrasives for grinding</li> <li>Cement and Limestone</li> </ul>	<ul style="list-style-type: none"> <li>Petroleum products</li> <li>Pharmaceuticals</li> <li>Plastics</li> <li>Printing ink</li> <li>Rubber</li> <li>Textiles</li> <li>Sintering</li> <li>Refractory materials for investment casting</li> <li>Tungsten powder and dry lubricants</li> <li>Dry powder opacifiers for ceramics industry</li> <li>Carbon black for rubber</li> <li>Powders for the detergent industry</li> <li>Colour coating of polymers for the plastics industry</li> </ul>
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**technical brief**

Grain milling Laboratory milling Pulverised coal for power generation Glass, sand, lead oxide, potash and arsenic for glass making	Aggregates for the construction industry Fertilisers Salt Charcoal for briquetting
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Table 1: Some applications of the milling process

In this brief we will concentrate on mineral grinding, rather than the grinding of grain and other foodstuffs, because a comprehensive publication already exists in the area of grain milling (see final section on resources).

**Material Characteristics**

When a material is to be milled there are certain characteristics which have to be taken into account. These include the following

- Hardness
- Brittleness
- Toughness
- Abrasiveness
- Stickiness
- Softening and melting temperature
- Structure (e.g. close grained or cellular)
- Specific gravity
- Free moisture content
- Chemical stability
- Homogeneity
- Purity

The *hardness* of a material is probably the most important characteristic to consider when deciding on what type of mill to choose. Trying to grind a material which is too hard, such as sand in most types of beater mill, will result, either in costly damage to the mill or an expensive maintenance requirement. Most types of readily available hammer mills for agricultural grinding are not suitable for grinding most types of minerals.

Hardness of minerals is expressed on Mohs scale - a numerical index ranging from 1 for talc (the softest mineral) to 10 for diamond (the hardest known material). Table 2 below shows Mohs' scale of hardness.

Hardness No.	Mineral (example)	Common practical test
1	Talc or graphite	Marks paper - like a pencil
2	Rock salt or gypsum	-
3	Calcite	Can be marked with fingernail
4	Fluorspar	Can mark a copper coin
5	Apatite	-
6	Felspar	Can mark window glass
7	Quartz	Can mark a knife blade
8	Topaz	-
9	Sapphire	-
10	Diamond	-

Table 2: Mohs' scale of hardness

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In general, the harder the material, the more specialised and expensive the type of mill used has to be. In addition if a particular mill can be used over a range of hardness scales, the harder the material the lower the throughput for a given size requirement. Another characteristic of a material to be aware of is *brittleness*, which is the degree to which a material will easily break. Most minerals are brittle, as opposed to metals which are ductile, although some to a greater degree than others. Brittleness does not equate with hardness as brittle materials can be hard or not particularly hard. Materials which are not brittle to some degree, metals or soft plastics for example, cannot easily be milled.

*Free moisture content* of a material should be as low as possible for dry milling. In practice this can be a problem, especially in humid regions where the moisture can cause the material to stick to the grinding media. Different mills behave in different ways with moist materials and in some cases drying of the raw materials is required.

Also important is the final *size of the material* in question. Table 3 below gives details of some materials which are milled and the degree of fineness required. Specifiers may stipulate that a proportion of the material is finer than a particular size. Usually this proportion is 90% or 95% but may be 99% for particularly demanding applications. In certain applications a particular range of particle sizes may be required.

Material and Application	Particle Size in mm
Feldspar - (flux in ceramics)	0.075
Talc - (paper making and cosmetics)	0.01
Limestone - (agricultural lime)	1.2
Ordinary Portland Cement	< 0.10
Chalk	0.05
Powdered charcoal or coal for fuel briquettes	<0.10
Pigments for Paints (various materials)	~ 0.005
Silica quartz (glass making)	0.01
Phosphate (fertiliser)	0.075
Iron Ore	0.20
Lime (industrial applications such as detergents)	0.10
China clay	0.002
Alumina	0.005

Table 3: Material Particle Size

### Characteristics of Mills

#### Types of mills

In this brief we categorise mills in 3 groups:

1. Low-speed tumbling mills
2. Roller mills
3. Very fine grinding mills, which include the following types of mill:
  - High speed pulveriser or hammer mill
  - The vibrating mill
  - Pin mill
  - Turbo mill

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- Fluid energy mill
- Stirred media mill

There is also a section which looks at traditional mills used in developing countries and other forms of size reduction other than milling:

- Attrition mills e.g. stone milling
- Cutting machines
- Cryogenic comminution

### Glossary for the milling process

*Milling circuit - open and closed.* The milling circuit is the complete mill system from beginning to end, including feed mechanism, mill, classifier, separator, product collector, etc. In a closed mill circuit the oversize particles are returned from the post milling processes for milling again (see figure below) whereas with an open circuit the process has no feedback loop.

*Air classification.* Classification or sizing of particles using a mechanical air separator.

*Batch mills.* Mills which receive a discrete quantity of charge which is milled and then discharged. The process is then repeated.

*Continuous mills.* A mill which can accept a continuous flow of feedstock and hence can operate on a continuous basis. Both batch and continuous mills have their relative merits.

*Peripheral and trunnion discharge.* For cylindrical mills which are continuously fed, the discharge of the final product can be either through the periphery of the mill (peripheral discharge) or through the far end of the mill (trunnion discharge).

In this section we will now look in more detail at the mill types mentioned above.

## Tumbling Mills

### Autogenous mills

Description:

This type of mill consists of a large diameter, short length cylinder fitted with lifting bars. The cylinder is fed with a coarse feedstock of up to 250mm in size and in rotating the feedstock is lifted and then allowed to drop through a significant height. Three significant mechanisms cause the breakdown of the mineral; impact due to the fall of the mineral onto the charge below causes a reduction in the size of the feedstock; attrition of smaller particles between larger grinding bodies; abrasion or rubbing off of particles from the larger bodies. Steel or ceramic balls are often added to aid with the reduction process (the mill is then referred to as a semi-autogenous mill). The process can be carried out wet or dry. Removal of the final product can be carried out using air (where the process is dry) removing only the fines. Rotational speed is usually fairly low, about 80% of critical speed (critical speed is the speed at which the charge will be pinned to the rotating drum and does not drop) and the typical drum diameter ranges from 2 to 10 metres. This type of mill is often used as a single stage process, providing sufficient size reduction in a single process. Alternatively, it can be part of a two stage process where further size reduction is required.

Characteristics:

This type of mill is only suited to certain kinds of mineral - one which has a fairly coarse nature but once it is broken will disintegrate readily into a small size. In certain circumstances this type of mill can deliver a product with a fineness of less than 0.1mm. Testing is required beforehand to determine the suitability of a mineral for processing in an autogenous mill.

Suitable minerals such as copper or iron ore are listed in table 4. This type of mill has the distinct advantage of accepting coarse feedstock and supplying a relatively fine finished product, often sufficient as an end product. This can provide a reduction in plant costs if a single mill is used as a substitute for two or more stages. There is little wear as the grinding is often carried out by the mineral itself. Autogenous mills are most suited to large installations i.e. more than 50 tonnes per hour and have a power requirement ranging from 40 kW up to

hundreds of kW.

Iron ore	Phosphate
Limestone	Bauxite
Copper ore	Slags
Uranium	Niobium ores

Table 4: Material Suitable for Autogenous Mills

**Rod Mills**

**Description:**

The rod mill is another tumbling mill but having a large percentage of its volume (30 - 40%) loaded with steel rods. The rods are placed axially in the mill and are loose and free to move within the mill. The internal lining of the drum has a series of lifters which raise the rods and drop them at a predetermined point. The mineral is fed in at one end with a maximum size of about 25mm. The rods crush the rock and as the charge passes through the mill it is reduced in size to between 2mm and 0.1mm. The mill can be fed from one end with the product removed from the other end or, alternatively, the mill can be fed from both ends with the discharge at the centre. The process can be wet or dry but is more commonly carried out wet. Maximum rod length is about 6 to 7 metres, otherwise there is a risk of the rods bowing. The drum diameter is limited to 0.6 or 0.7 times the length of the mill.

**Characteristics:**

Rod mills are used for grinding hard minerals. This type of mill is usually used as the first stage of a milling process to provide a reduced size feedstock for a further milling process.

Coke	Products for the glass industry
Cement clinker (needs to be dry)	

Table 5: Material Suitability for Rod Mills

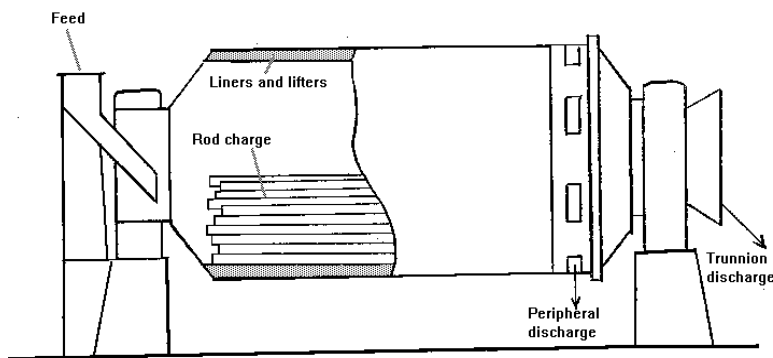


Figure 2: Rod Mill

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**Ball Mills**

**Description:**

Ball mills are similar in concept to the rod mill but are charged with steel balls in place of the rods. The mill consists of a cylindrical drum, sometimes tapered at one end, and usually has a charge of steel balls (up to 40% by volume) ranging in size up to 125mm for larger mills. Product size can be as small as 0.005mm, but product size is dependant upon the time the charge spends in the grinding zone and therefore the reduction rate is a function of the throughput. The lining material is of great importance as there is a significant amount of wear taking place due to the action of the steel balls. The speed of rotation is optimum at about 75% of critical speed. Some mills are compartmentalised with each subsequent section having a smaller ball size. The mineral can pass through to the proceeding section, but the balls cannot. This ensures that the smaller particles are attacked by the smaller grinding media.

**Characteristics:**

It is a versatile grinding mill and has a wide range of applications. The mill can vary in size from small batch mills up to mills with outputs of hundreds of tonnes per hour. They are the most widely used of all mills. Small hand operated ball mills are used in Bolivia for preparation of ore, sand and gravel.

Iron ore	Coal for combustion
Limestone and lime	Talc
Cement	Sand
Gold ore	

Table 6: Material Suitability for Ball Mills



Figure 3: A ball mill being used as part of a gold mining operation in Arequipa, Peru ©Practical Action

**Roller Mills**

**Description:**

There are two distinct types of roller mill. The first is a series of rollers which rotate around a central axis within a drum. The reduction takes place between the rollers and the drum. The second is where there are a series of fixed rollers and a rotating table. The milling takes place between the rollers and the table. This type of mill is used for dry grinding only and accepts

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only relatively soft minerals. Small machines can have a throughput of only a few tens of kg per hour whereas larger machines are capable of handling up to 40 or 50 tons per hour and occasionally more. Feed size varies according to the machine. The machines are often fitted with screens for closed-circuit grinding. Product size can be controlled by changing screens.

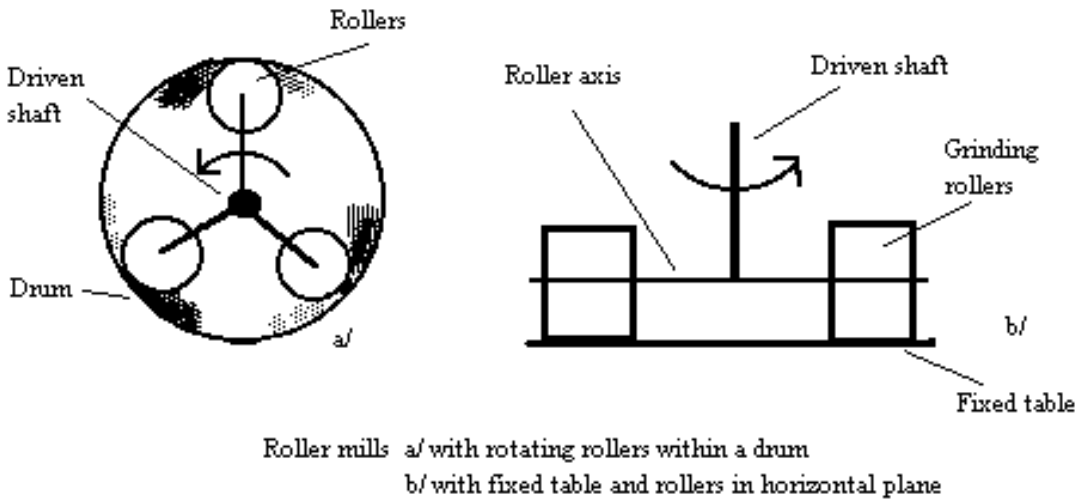


Figure 4: Types of roller mills

Barite	Phosphate
Limestone	Coal
Slate	Miscellaneous chemicals

Table 7: Material Suitability for Roller Mills

### Very fine grinding mills

#### Hammer mills

##### Description:

These are high-speed mills operating at speeds of between 2000 and 6000 rpm. A set of 'hammers' rotate about a central axis in a vertical or horizontal plane. The hammers can either be fixed or can swing freely, in which case the mill is termed a swing-hammer mill (see figure below). The whole system is enclosed in housing and the outlet for the product is usually via a screen which sieves the product and allows only the required size of particle to pass.

##### Characteristics:

The product size can be extremely fine - talc can be reduced to a size of 0.0025mm (40%), although an air classifier is required when such product size is required. Maximum capacity is in the order of 10 tons per hour and power consumption is relatively high. Rotating hammer mills are suited to the milling of softer materials and this type of mill is often used to mill grain and other food stuffs.

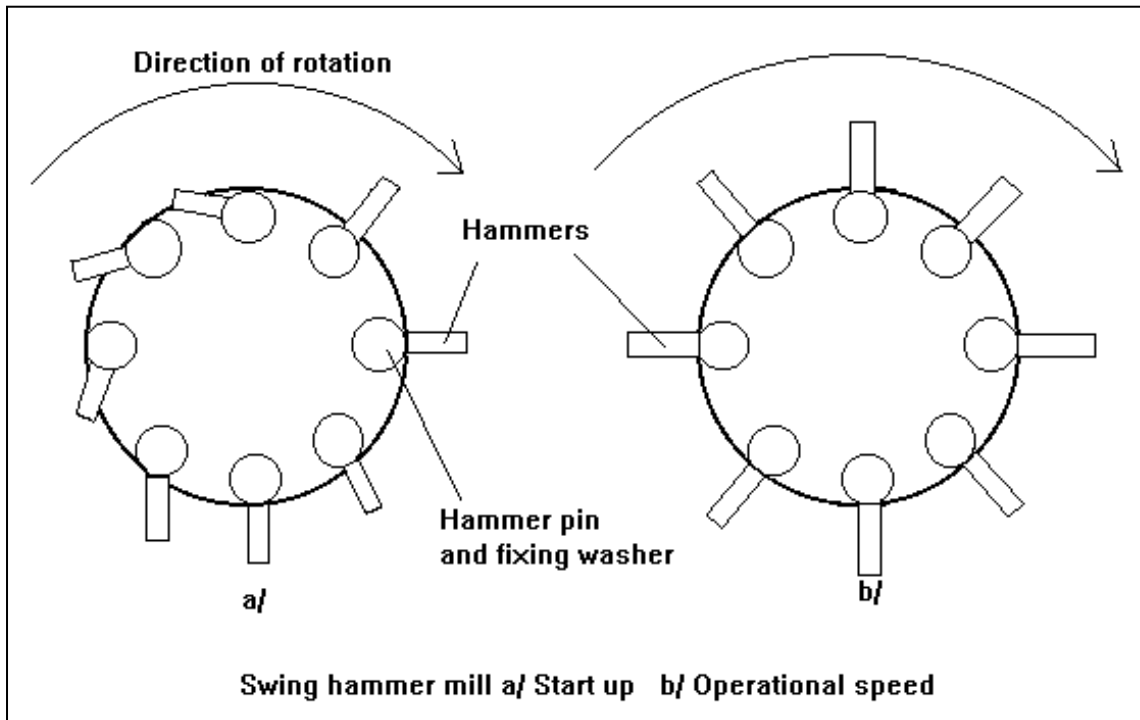


Figure 5: Types of hammer mills

Calcite	Talc
Barite	Grain and other food stuffs

Table 8: Material suitability for hammer mills

**Pin, air classifying and turbo mills**

**Description:**

A pin mill comprises two discs, one rotating and one stationary which are fitted with intermeshing pins set in a concentric pattern. The charge is fed into the centre of the discs and is broken down as it moves outwards through the pins which are moving at very high speed - up to 20,000 rpm. The air classifying mill is similar in construction to the pin mill but incorporates a built-in classifier. This type of mill produces a significant airflow through the machine to aid with keeping temperature as low as possible. Oversize grains which pass through the mill have to be recycled. Turbo mills use a similar concept but the rotating disc is fitted with paddles or bars rather than pins. This rotating disc sits within a cage which is fitted with grids, screens or breaker plates. The mill is configured in such a way as to produce the desired particle size.

**Characteristics:**

Pin mills are capable of very fine grinding without the need for screens and provide a uniform product size. Air classifying mills are used where the product is temperature sensitive. They are widely used in the pharmaceutical and fine chemical industries. They are suitable for relatively soft materials (below Moh 3) and for small quantities of material. Wear on the pins is significant if used continuously.

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Carbon	Pharmaceuticals
Chalk	Spices
Talc	Sugar
Pigments	Resins
Dyestuffs	

Table 9: Material suitability for pin, air classifying and turbo mills

**Vibratory mills**

Description:

This is the first mill we will consider which does not rely on rotation for the main grinding action. The vibrating mill is a grinding chamber which is filled to about 65 - 80% of its capacity with grinding media such as balls or rods. The chamber is vibrated at a frequency of between 1000 and 1500 times per minute (can be variable speed) by cams or imbalanced weights.

The grinding action is efficient and thorough. Grinding media material and chamber lining can vary depending on application.

Characteristics:

Vibrating mills can grind hard or soft materials. Maximum throughput is in the order of 20 t.p.h. but feed size should be kept fairly small. Although final product size can be as low as 0.005mm this type of mill is often used for less fine applications. Product size and shape is a function of the time spent in the mill, media type and size, and frequency of vibration. Commonly the mill is used as a batch process.

Lime	Calcium carbide	Alumina
Gypsum	Bauxite	Chromite
Limestone	Sillimanite	Fluorite
Pigments	Dolomite	Magnesite

Table 10: Material suitability for vibratory mills

**Stirred media mills**

Description:

Stirred media mills are usually constructed in the form of a cylindrical drum inside which there are a series of rods, arms or perforated discs which are rotated on a central shaft. The drum is loaded with grinding media, such as metal balls or glass sand. The media and the charge is 'stirred' together and thus the grinding takes place.

Characteristics:

The mill is suited primarily to the very fine grinding of soft materials. Usually used with wet grinding but can be used for dry grinding also. Product size is as small as 0.005mm.

Pigments	Kaolin
Colorants	

Table 11: Material suitability for stirred media mills

**Fluid energy mills**

Description:

The general principle of operation in a fluid energy mill is that the mineral to be ground is fed into a grinding chamber in a high speed, high pressure and, often, high temperature jet of air (or other gas). The particles collide violently and this causes comminution to take place.

Various designs of fluid energy mill exist, the most common being the microniser. This mill has a shallow circular grinding chamber and a series of peripheral jets set tangentially to a common circle. The turbulence causes bombardment which effects a rapid reduction in particle size. A centrifugal classification system keeps larger particles within the chamber while allowing fine particles to leave. In a well designed fluid energy mill there will be almost no contact between the charge and the mill lining.

**Characteristics:**

Suitable for hard or soft materials to be reduced to 0.02mm, or less, this method of milling tends to be energy intensive and slow but is suitable where the product is highly sensitive to heat or contamination from grinding media.

Mineral	Product size	Production (Kg / hr)	Fluid use
Alumina	100% - 0.0075mm 50% - 0.003mm	5500	2850 kg/hr steam at 7000 kPa and 400°C
Feldspar	90% - 0.0075mm	3600	85 m <sup>3</sup> /min air at 7000 kPa and 20°C
Graphite	90% - 0.01mm	25	2m <sup>3</sup> / min air at 7000kPa and 20°C
Mica	95% - 0.075mm	725	20m <sup>3</sup> / min air at 7000kPa and 425°C

Table 12: Typical jet mill performance

**Other mills and reduction processes**

**Attrition mills**

Attrition mills are the most common type of mill found in developing countries. The traditional grain mills of many regions of the world are based on attrition grinding between two circular stones, one rotating and the other stationary. Plate mills use a similar principle but are constructed of steel or ceramic plates and used more commonly in the vertical plane. Output from such a mill is low and only of practical use for small scale milling.

**Cutting machines**

Many ductile or fibrous materials such as plastics, rubbers and miscellaneous chemicals cannot be milled using conventional milling equipment. Instead they are often cut or shredded. High speed rotating knife blades set in cutting mills will reduce such materials to a usable size. In certain cases reduction can be down to 0.25mm.

**Cryogenic comminution**

Ductile materials such as steel, plastics and rubber, which cannot be milled easily, can be embrittled by lowering the temperature of the material. Once embrittled the material will lend itself more easily to comminution by conventional methods, usually with the use of a hammer mill. Liquid nitrogen is a gas used for this purpose. The process is expensive due to the cost of the gas but is used for some specialised applications.

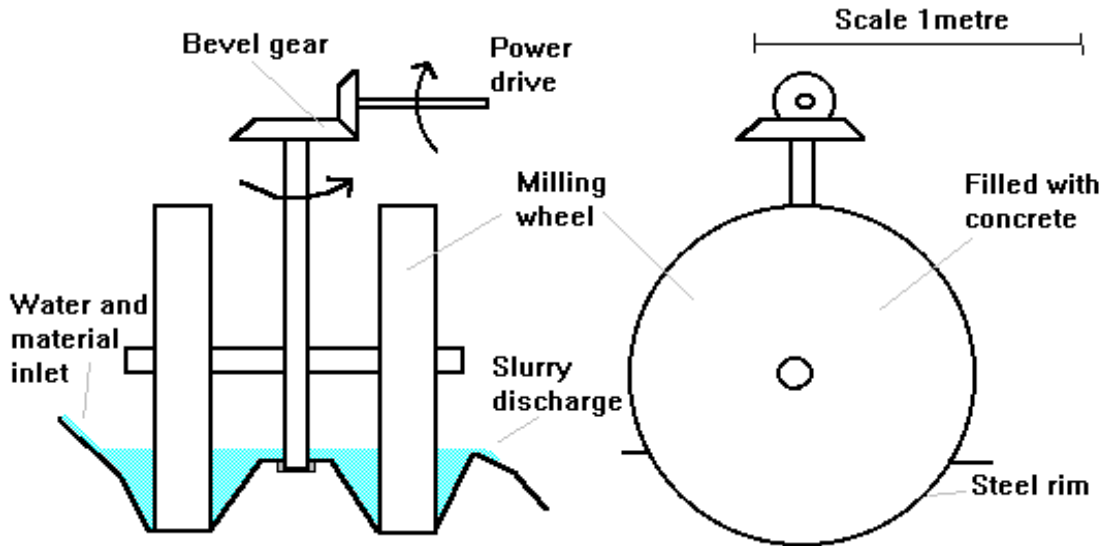
**Traditional mills in developing countries**

As mentioned in the previous section there are a number of traditional mills in use throughout the world. Some of these mills date back thousands of years and have changed little in design. Many are precursors to modern mills. They are usually constructed from materials found locally by indigenous craftsmen. Often the quality of the product varies considerably and the throughput for such a mill is low, but in many circumstances, where the fineness is not critical and the quantity to be milled is low, choosing a traditional mill can be the best option. They are often simple and cheap to construct and can be powered by one of a wide variety of power sources. Some examples are given below.

- *The Chilean Edge Mill.* Used commonly in Chilean gold ore processing, the edge mill has two large steel rimmed concrete wheels (these would have been stone in previous

centuries) which roll around a circular concrete track and grind the gold ore beneath them.

Figure 6: Chilean edge mill



Final product size can be very small and the final size is a function of the time in the crusher. Grinding is usually carried out wet, the ore being washed in and out of the circular track by the water.

- *The See-Saw Crusher.* Very heavy stone or steel ‘see-saw’ crushers are rolled over the material which is to be crushed with the aid of a lever arm. The material is placed on a flat stone or steel surface and the product is similar to that from a roller crusher

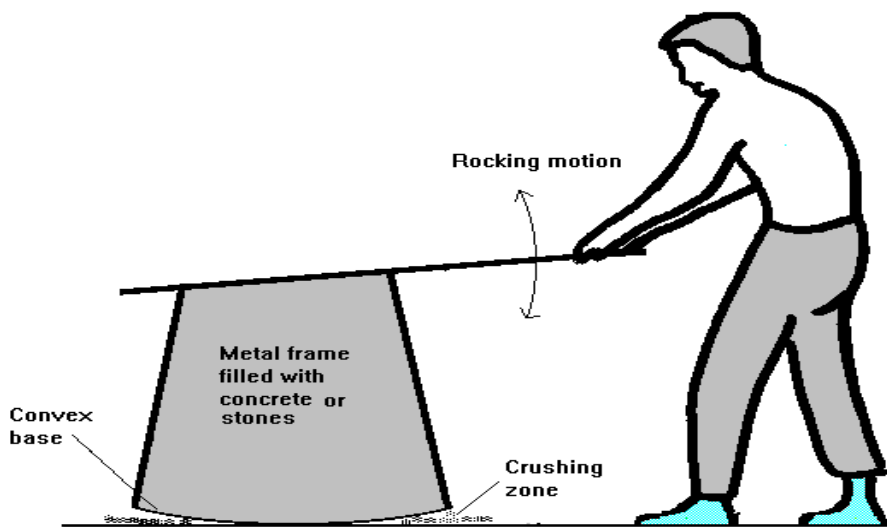


Figure 7: See-saw crusher

- Other traditional mills include pestle and mortar type mills and stamp mills, amongst many others.

**Suitability of different mills to different operations**

Some of the characteristics and requirements to be considered when selecting a mill are given below. The mill manufacturer can usually be consulted concerning the application of a particular mill or for sourcing a mill which is suitable for a particular application.

- *Mineral properties.* The choice of mill type is primarily dependent upon the properties of the material it will be used process. It is vitally important to match the mill and material characteristics properly.
- *Capacity.* The scale of the operation will determine the size of the mill which is required. Throughput or capacity is often given in tonnes per hour (or kg per hour for small mills). Always check capacities with as many sources as possible as sales information can often be biased to encourage sales.
- *Reduction ratio and final size requirement.* This parameter will dictate whether a single mill will be sufficient for final product requirements or if a multi-stage plant will be needed. Generally speaking, the greater the reduction ratio, the larger the likelihood of a multi-stage process being required.
- *Power requirements and type of power supply.* Access to a power supply of suitable capacity is essential. Types of power supply for remote applications are discussed later in this section. The power requirement for a particular mill will be given in the mill specification document provided by the manufacturer. Specific power consumption (e.g. kilowatt hours per tonne) is often quoted and is a good comparative guide.
- *Wet or dry product.* Products which can be accepted in a wet state, such as slurries, can be milled wet which will often save power and reduce dust related problems. As a general rule, only tumbling mills are used for wet grinding, although other mills can be used for wet grinding in certain circumstances.
- *Continuous or batch operation.* Some mills can be designed in such a way as to enable continuous milling. This is important where the throughput is high, as well as making loading and emptying easier within the process. Some mills will only accept batch loads.
- *Portable or stationary equipment required.* Depending on the nature of the operation, the equipment can be sited permanently or can be portable. Portable equipment is useful for operations which move frequently due to the dispersed location of the raw material or where a mobile milling service is offered.
- *Classification.* When considering a mill for a particular application, one needs to consider the classification mechanism that will be required for the process and whether this will have to be purchased separately or if it will be an integral part of the mill.
- *Cost.* Obviously cost is an important factor. It is important to consider all the costs beforehand. For an accurate analysis of the economic viability of a mill to be carried out the following costs need to be considered:
  - capital costs of mill (and capital depreciation against the useful life of the mill)
  - capital costs of peripherals, such as feeding and classification equipment, power supply, dust suppression hoods or sleeves, etc.
  - transport costs
  - running costs of fuel or electricity, labour, etc.
  - maintenance costs

#### **Local availability of mills rather than import**

In developing countries it is usually preferable to purchase a mill in-country. This helps reduce transport costs and helps to support the local economy and engineering capacity (where the mills are manufactured locally). Quality should be checked carefully in such situations as the manufacturing ability and standards in developing countries are often lower than those of developed countries. As mentioned previously, there are a variety of locally produced traditional mills available in some countries which are suitable for certain milling applications.

Sometimes it is possible to find second-hand mills, especially in areas where there is

intensive mineral mining activity. Again great care should be taken when purchasing used plant, as it could be counter-productive if the machinery then has to be shipped overseas for an expensive overhaul or reconditioning.

After-sales service and spare parts is an important consideration in many developing countries where it could be difficult to obtain either, or in remote locations where the time required for a service engineer to arrive could mean a significant 'down-time' for the mill. It is worth looking into this before buying a mill and having contingency plans in place in case of breakdowns. If a mill is purchased locally there is more likelihood of finding spare parts and competent technicians.

## Milling Within an Operational Plant

### Siting

The siting of the mill is dependent upon several factors. Firstly the type of operation will determine whether the mill is placed at a centralised location to where minerals can be transported from a number of sources or, if the operation is confined to one area, how close it should be sited to the operations area at the mine or quarry. There should always be sufficient space around the mill for easy loading, unloading and access and where necessary the mill can be housed. Topographically the mill should be sited in such a way that the flow of minerals can be aided by gravity thus reducing expensive handling costs. A convenient power supply (see the second paragraph following) and a convenient water supply are also prerequisites for a milling operation.

As mentioned earlier the milling process is often part of a larger process of a mining or quarrying operation, and the specific siting of the mill within this process will obviously be dependent upon the overall process and its various components.

### Power supply

There are a variety of options when considering a power supply for a mill.

- *Electricity - the grid.* Commonly, where the mill is sufficiently near a grid electricity supply, advantage will be taken of this facility. Most mills will be sold with an electric drive motor fitted as standard and connection is merely a case of 'plugging in'. Many developing countries suffer problems with regular interruptions in the electricity supply and insufficient capacity to deal with demand. This should be considered when thinking about the power supply for a milling operation. If occasional unpredictable stoppages can be tolerated then this is usually the cheapest option.
- *Independent power supply.* In situations where no grid connection is possible or where the local supply is not sufficiently dependable, an independent or 'stand-alone' power supply will need to be considered. There are various options available, the most common being a diesel engine. This can be used as part of a diesel generator set to provide an electricity supply or can be used to provide a direct shaft drive for the plant. Other options include the construction of a dedicated power supply from a renewable energy source, such as a small-scale hydro-power plant (either generating electricity or providing direct shaft power). Careful analysis of the options and correct selection of power supply can provide great savings in running costs.
- *Animal power.* In certain circumstances animal power can be harnessed to provide power for a milling process. Animal traction is widely used in developing countries for providing power for a range of applications, usually requiring rotary shaft power. Where the milling process is in the small scale range, this is one possible solution to providing a cheap renewable power supply.
- *Human power.* Where very small scale milling is required the power can be provided by humans. Many small hand (or foot) operated mills have been developed in many areas of the world for small grinding operations. Over short periods of time humans can provide a significant amount of power (eg 250 Watts for a few minutes), but this tails off over time. The most efficient way of harnessing human power is to convert it

to rotary motion.

### **Health and safety and the working environment**

Health and safety precautions within the mining, quarrying and processing industries are of utmost importance. This is an industry where there are many risks of injury, death or serious health problems occurring if care is not taken. Many developing countries have regulations which cover health and safety issues within the mining or quarrying industries and any good manager will be well aware of their requirements. It is worth bearing in mind also that legal action can be taken against a company who not comply with the relevant regulations. Below is a summary of some of the common causes of health risk within a milling plant.

#### **Dust**

The most serious long term health threat from mineral processing is that posed by dust inhalation. During any dry milling process a great deal of dust is produced and it can often be very harmful to breathe, especially over long periods of time. Common ways of reducing dust in the work area are:

- Minimisation of the generation of dust at the source
- Containment of the generated dust and prevention of its dispersal
- Good selection and siting of dust abatement equipment
- Good handling of the collected dust

There are a number of ways of achieving the above but it is beyond the scope of this brief to discuss them in any detail. Where dust reduction methods do not achieve the desired results, personnel working in the area should be provided with respiratory equipment such as dust masks.

#### **Machinery protection**

Rotating machinery is potentially dangerous and hence safety is very important when people are working near mills. All rotating parts of the machinery which are exposed, and with which people could come into contact, should be guarded. All shafts, belts, chains, wheels, etc., should be protected to avoid accidental contact. All guards should be regularly checked to make sure they are in place and secure. All electrical equipment should also be correctly installed with no loose wires, cables or switchgear.

#### **Training for personnel**

All personnel working in the area around the mill should be given proper training to ensure that they are aware of the dangers involved. Such training only takes a short time and can pay great dividends. Health and safety posters are useful as reminders to workers.

#### **Maintenance of machinery**

Regular maintenance of machinery is important not only to ensure reliability and to reduce running costs but also to minimise the health and safety risks. Before starting any machine, all moving parts should be inspected to ensure that they will not come loose or fall off during operation. Be sure that the mill is properly at rest and power switched off before carrying out any maintenance work.

#### **Adherence to the health and safety standards**

Above all, if the health and safety standards are observed properly, then there is little likelihood of serious problems occurring within the milling plant.

## References, resources and other information

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[http://www.gate-international.org/documents/publications/webdocs/pdfs/g10toe\\_1.pdf](http://www.gate-international.org/documents/publications/webdocs/pdfs/g10toe_1.pdf)  
[http://www.gate-international.org/documents/publications/webdocs/pdfs/g10toe\\_2.pdf](http://www.gate-international.org/documents/publications/webdocs/pdfs/g10toe_2.pdf)  
[http://www.gate-international.org/documents/publications/webdocs/pdfs/g10toe\\_3.pdf](http://www.gate-international.org/documents/publications/webdocs/pdfs/g10toe_3.pdf)
- \*McDivitt, J.F., and Lock, D. *Small-scale Mining; A guide to appropriate equipment*, Intermediate Technology Publications, 1990.
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- North, R., *Fine Crushing and Grinding*, The Quarry Managers Journal, Page 367- 382, October 1969
- *Proceedings of the Autogenous Grinding Seminar*, Trondheim, Norway, May 28 - 30, University of Trondheim, 1979.
- \*Azam-Ali, S et al., *Small-scale Food Processing: A directory of equipment and methods (2<sup>nd</sup> ed.)*, Intermediate Technology Publications, 2003.
- \*Jonsson L-O et al, *Small-scale Milling: A guide for development workers*, Intermediate Technology Publications, 1994

\*Available from:

Practical Action Publishing,  
 The Schumacher Centre for Technology & Development,  
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[http://developmentbookshop.com/product\\_info.php?cPath=1&products\\_id=484](http://developmentbookshop.com/product_info.php?cPath=1&products_id=484) Small-scale Food Processing)

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### Other publications of interest

World Mining Equipment  
 Email: [contact@womp-int.com](mailto:contact@womp-int.com)  
 Website: <http://www.wme.com/>

International Journal of Mineral Processing  
 Elsevier BV  
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 Academic research journal

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## Mill manufacturers and suppliers

Potential purchasers of equipment are encouraged to obtain further information from the websites of suppliers and by contacting them directly. Some of the suppliers' websites are quite informative and a few also contain technical papers.

New Dawn Engineering,  
3223 Manzini,  
Kingdom of Swaziland.  
Tel or fax: +268 5185016 / 5184194  
Email: [info@newdawnengineering.com](mailto:info@newdawnengineering.com)  
Web: <http://www.newdawnengineering.com/>  
Manufacture hand operated  
rock crushing mill.

Glen Creston Ltd.  
9 Lombard Road  
London  
SW19 3TZ  
England  
Tel: +44(0) 208 545 9140  
Fax: +44(0) 208 417 0857  
Email: [enquiries@GlenCreston.com](mailto:enquiries@GlenCreston.com)  
Web: <http://www.glencreston.com/>  
Supplier of high quality mills, mixers,  
pulverisers, sample and particle sizing  
equipment.

Walker and Partners Ltd.,  
Inkersall Road Industrial Estate,  
Staveley,  
Chesterfield,  
Derbyshire, S43 3JN  
England, UK  
Tel: +44 (0)1246 472147  
Fax: +44 (0)1246 473913  
Email: [sales@walkerandpartners.co.uk](mailto:sales@walkerandpartners.co.uk)  
Web: <http://www.walkerandpartners.co.uk/>  
Stockists of used and reconditioned quarrying,  
crushing, milling, etc. equipment. Published  
regularly updated catalogue of items in stock.

Sepor Inc.  
718N Fries Avenue  
Wilmington, CA 90748,  
USA  
Tel: 310 830 6601  
Fax: 310 830 9336  
Email: [info@sepor.com](mailto:info@sepor.com)  
Web: <http://www.sepor.com/>  
Small rod / ball mills supplier

Gruber Hermanos, S.A.  
Zumalacárregui, 30  
48903 Burceña – Baracaldo (Vizcaya), Spain  
Tel: + 34 94 499 1300  
Fax: +34 94 499 1090  
Email: [gruber@gruberhermanos.com](mailto:gruber@gruberhermanos.com)  
Web: <http://www.gruberhermanos.com/>  
Suppliers of a large selection of milling  
equipment

EcoSur (South)  
Red EcoSur  
P.O. Box 0601-1404  
Riobamba, Ecuador  
Tel / Fax; +593 3 294 0574  
Email: [ecosur@ecosur.org](mailto:ecosur@ecosur.org)  
Web:  
<http://www.english.ecosur.org/index.php?option=content&task=category&sectionid=4&id=17&Itemid=54>  
Producers of small ball mill designated MB-600,  
used in the production of pozzolanic cement

JPM Parry & Associates  
Overend Road, Cradley Heath  
West Midlands, B64 7DD, UK  
Tel: +44 (0) 1384 569171  
Fax: +44 (0) 1384 637753  
Email; [info@parryassociates.com](mailto:info@parryassociates.com)  
Web: <http://www.parryassociates.com/online-catalogue/section14.htm>  
Supplier of manually-operated Pendulum Clay Crusher

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RSG Inc  
 P.O. Box 2158 Sylacauga, AL 351050  
 (119 Crews Lane, Sylacauga, AL 351050)  
 USA  
 Tel. +1 256 378 3836; Fax: +1 256 378 3856  
 Email: [sales@airclassify.com](mailto:sales@airclassify.com)  
 Web: <http://www.ultrafinegrind.com>

Union Process Inc  
 1925 Akron-Peninsula Road, Akron, Ohio  
 44313, USA  
 Tel: +1 330 929 333; Fax: +1 330 929 3034  
 Web: <http://www.unionprocess.com>

Netzsch – Feinmahltechnik GmbH  
 Sedanstrasse 70, 95100 Selb, Germany  
 Tel: +49 9287 797 0; Fax: +49 9287 797 149  
 Email: [info@nft.netzsch.com](mailto:info@nft.netzsch.com)  
 Web: [www.netzsch-grinding.com](http://www.netzsch-grinding.com)

Atlantic Coast Crushers Inc.  
 128 Market Street, Kenilworth, NJ 07033,  
 USA  
 Tel: +1 908 259 9292; Fax: +1 908 259 9280  
 Email: [info@gocrushers.com](mailto:info@gocrushers.com)  
 Web: <http://www.gocrushers.com/>

Eirich Group of Companies  
 International company that operates out of  
 nine countries. See website for supplier  
 address of nearest country  
<http://www.eirich.com/>

Quadro Engineering Corp.  
 613 Colby Drive, Waterloo, Ontario  
 Canada N2V 1A1  
 Tel: +1 519 884 9660; Fax: +1 519 884 0253  
 Email: [sales@quadro.com](mailto:sales@quadro.com)  
 Web: <http://www.quadro.com/>

Kemutec Powder Technologies Inc.  
 130 Wharton Road, Bristol, PA 19007, USA  
 Tel: +1 215 788 8013; Fax: +1 215 788 5113  
 Email: [sales@keminc.com](mailto:sales@keminc.com)  
 Web: <http://www.kemutec.co.uk>

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 193 Hole-in-One Road (P.O Box 2020)  
 Ruimsig, South Africa, 1732  
 Tel. +27 11 958 0273; Fax: +27 11 958 0259  
 Email: [info@deswik.com](mailto:info@deswik.com)  
 Web: <http://www.deswik.com>

Fritsch GmbH Milling and Sizing  
 Industriestrasse 8, 55743 Idar-Oberstein,  
 Germany  
 Tel: +49 67 84 70 0; Fax: +49 67 84 70 11  
 Email: [info@fritsch.de](mailto:info@fritsch.de)  
 Web: <http://www.fritsch.de/en/>

Shanghai Zenith Company  
 No. 416 Jianye Road South,  
 South Jingiao Area, Pudang, Shanghai  
 China, Zip 201201  
 Tel: +86 21 58386256 or +86 21 58386258  
 Fax: +86 21 58385887  
 Web: <http://www.zenithcrushers.com/>

PMT Jetmill GmbH  
 Industriepark 1, A-8773, Kammern in  
 Liesingtal, Austria  
 Tel: +43 3844 80350; Fax: +43 3844 80350 20  
 Email: [jetmill@powder-maker.com](mailto:jetmill@powder-maker.com)  
 Web: <http://www.powder-maker.com/>

Xstrata Technology  
 Level 4, 307 Queen St, Brisbane QLD 4000  
 Australia  
 Tel: +61 7 3833 8500; Fax: +61 7 3833 8555  
 Email: [isamill@xstratatech.com.au](mailto:isamill@xstratatech.com.au)  
 Web: <http://www.isamill.com/>  
 Website contains a number of informative  
 papers including:  
 Fine Grinding and Project Enhancement (2004)  
 By L W Clark & B D Burford

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Sweco  
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 Florence, KY 41022 USA  
 8029 US Highway 25  
 Florence, KY 41042 USA  
 Tel: +1(859)371-4360  
 Fax: +1(859)283-8469  
 Email: [info@sweco.com](mailto:info@sweco.com)  
 Web: <http://www.sweco.com/>

Hicom Technologies  
 Ludowici Australia Pty Ltd  
 67 Randle Road  
 Pinkenba QLD 4008  
 Tel: +61 7 3121 2900  
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 Includes technical papers

#### Other organisations of interest

Institute of Quarrying  
 7 Regent Street,  
 Nottingham  
 NG1 5BS  
 United Kingdom  
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 Fax: +44 (0)115 948 4035  
 Email: [mail@quarrying.org](mailto:mail@quarrying.org)  
 Web: [www.quarrying.org](http://www.quarrying.org)  
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 United Kingdom  
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 Fax: (from UK) 0845 408 9566  
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British Geological Survey,  
 Kingsley Dunham Centre,  
 Keyworth,  
 Nottingham,  
 NG12 5GG  
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 Tel: +44 (0)115 936 3143  
 Fax: +44 (0)115 936 3276  
 E-mail: [enquiries@bgs.ac.uk](mailto:enquiries@bgs.ac.uk)  
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