Ball Milling Guide

These are general setups for medium hardness dry powders and if not optimum, they are a good starting point for further refinement if required.

Terminology

Media – Short for ‘Grinding Media’, this is the balls, cylpebs or bars used for grinding.
Charge – This is the contents of the milling jar, milling media and the material being milled.
Strike – The impact between two balls, crushing powder between.

Loading

A typical efficient milling charge would be 50% media and 25% material to be milled, measured by volume. So for example, a 6 litre mill jar will have 3 litres of milling media and 1.5 litres of material to be milled.

Speed

Jar rotation speed should be tuned so the media cascade over each other. If rotation is too slow it may be noticed that the charge does more sliding than tumbling, too fast and the charge will be flung to the outside of the jar like a centrifuge. The speed can be tuned by ear, listening for the loudest point, indicating the highest strike rate and a good cascade.

An optimum speed can be calculated and depends on ball diameter and jar internal diameter.

Jar Diameter	13mm media	20mm media	30mm media	40mm media
97mm (650ml & 1300ml jars)	95 rpm	100 rpm	*Not suitable*	*Not suitable*
190mm (3L & 6L jars)	65 rpm	67 rpm	69 rpm	71 rpm
266mm (10L, 15L & 20L jars)	55 rpm	55 rpm	57 rpm	58 rpm

Jar size

This property is mostly guided by the intended batch size, but larger jar diameters lead to greater strike energy. Harder materials may require a larger diameter for efficient milling.

Ball material

Heavier balls allow grinding of harder materials, or faster grinding of hard materials by using smaller ball size of the same weight as a larger ball of lower density.

Some ball densities are given below:

Material	Specific Gravity (g/cm^2)
Wood	~0.8
Porcelain	2.4
H.D. Alumina	3.5
Zirconia	5.9
Steel	7.9
Lead	11

The milling charge also needs to be compatible with the media material, chemical reactions can occur with some mixes, most commonly steel, which is only suitable for a limited number of operations. Lead, wood, and some other materials are soft and can wear quicker than harder materials, which can contaminate the material being milled.

Ball size

All balls should be the same size. To allow a stable cascade, ball diameter should not be much larger than 20% of the jar diameter. Smaller balls have more surface area and will have more strikes per revolution allowing for faster milling, but each strike has less energy, reducing effectiveness against harder materials. Larger balls are heavier and will be able to crush harder materials, but with less strikes per revolution, they will mill slower.

Particle size

Ball milling has been used to grind materials to average particle sizes of 20 nanometres and finer, with extended milling time continuing to reduce particle size but with diminishing returns. Some materials may start to cake and will require additives to prevent aggregation.

Additives

Cab O Sil M5 can be added, typically 0.5% by weight can be used with a wide range of materials, including potassium perchlorate and strontium nitrate to improve flow and prevent caking.