WHICH MILLS USE GRINDING MEDIA?

Horizontal Mills - Ball Mills - Jar Mills - Shaker Mills
Vibratory Mills - Sand Mills - Vertical Mills - Immersion Mills
Basket Mills - Attritor Mills - Recirculation Mills
This presentation will cover:

- What is milling?
- What is media?
- What do I need to consider when selecting media?
- What types of media are available?
- What size, shape, material, amount do I need?

You will learn which questions to ask when evaluating a process.
DIFFERENT MILLS REQUIRE DIFFERENT MEDIA

Ball Mills: large balls, cylinders, satellites, pebbles, naturals
Vibratory Mills: cylinders
Small Media Mills: small beads
Hi Flow Mills: tough beads
Recirculation Mills: tough beads
Immersion Mills: tough beads
MEDIA MILLING CAN BE DESCRIBED AS BOTH AN ENERGY AND A FILTRATION PROCESS:

**Energy:**

- Force = Mass x Acceleration
- Mass = bead size & bead density
- Acceleration = agitator speed

**Filtration:**

- PSD/particle size distribution is controlled by bead spacing which is determined by bead size, bead distribution and % media charge.
GRINDING FORCES IN MILL

WHAT IS HAPPENING DURING THE MILLING PROCESS?

- **Shear**: material and media move past each other reducing particle size with velocity
- **Impact**: media pounds the material between media/media and media/chamber
- **Impingement**: material pinches between media.
- **Autogenous**: tearing and smashing itself apart
- **Vacuum**: removing air for faster and easier wet out; internal particle air helping to break agglomerates from the inside out
DON’T UNDERESTIMATE PRE-GRINDING

Always know the size of the feed going into the mill

- The mill is the most expensive piece of equipment in the plant; only use it for what it is designed to do – Grind Beyond the Disperser
- Pre-Grinding helps optimize the use of the mill
- Pre-Grinding assures that the product feed is consistent
- Pre-Grinding opens up the door to using smaller media thereby producing finer grinds faster
- Always use the optimum blade for pre-grinding that has been determined through testing, not guessing
- or “always been done this way”
CONSIDERATIONS FOR USING MEDIA

• Initial particle size determines size of media

• Viscosity of slurry determines density of media

• Final particle size determines media charge, filtration effect
NEED CORRECT AMOUNT OF MEDIA IN THE MILL:

GRINDING MEDIA PROPERLY. WILL ONLY WORK IF THE MILL IS CHARGED. YOU ARE NOT SAVING MONEY BY UNDERCHARGING A MILL.

EACH TYPE OF MILL IS CALCULATED DIFFERENTLY.
Bead Charge Effects Grind Time, Heat, Number of Contact Points

• # of beads increases exponentially as bead size decreases. ↑ beads =

• smaller spaces between beads making a tighter filter giving higher efficiencies in grinding

• higher pressure due to more resistance to flow

• higher temperatures due to increased shear and grinding
Beads Per Liter

1.5 mm beads = 970,000/liter
1.0 mm beads = 3,000,000/liter
0.6 mm beads = 10,000,000/liter
0.4 mm beads = 50,000,000/liter

2.0 mm beads = 600,000/liter
0.85 mm beads = 5,300,000/liter
DIFFERENT MILLS REQUIRE DIFFERENT AMOUNTS OF MEDIA

- BASED UPON WORKING VOLUME OR TOTAL VOLUME
- Mills such as the Immersion Mill have a fixed amount determined by size of the basket

- Steel Ball Mill: 33.3%
- Open Head Sand Mill: 35-45%
- Ceramic & Pebble Ball Mill: 50%
- Dry Grind Batch Attritor: 45-60%
- Wet Grind Batch Attritor: 38-45%
- Continuous Attritor: 78-92%
- Circulation Attritor: 85-92%
- Straight Side Vertical Mill: 50-55%
- SW Vertical Mill: 40-45%
- Fryma Vertical Mill: 55-70%
- Horizontal Disk Mill: 70-85%
- Recirculation Mill: 80-100%
- Basket Mill: 100%
MEDIA CHARGE: EFFECT ON SPACING & GRINDING

Theoretical space between grinding media based on random packing

- Solids in slurry to be processed decrease gap between beads
- Increasing bead charge
  - Increases compression
  - Increases power input
  - Increases shear rate
  - Tighter bead spacing results in higher filtration and finer grinding

Bead Spacing calculated Based on 65 % to 95 % Bead Charge

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<td>800</td>
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HOW OFTEN SHOULD MEDIA BE CHANGED?

• **Topping Off**: beads can be added for a period of time when media gets low due to wear and spillage; should be done regularly.

• **Media Replacement**: beads should be completely replaced when the average bead size is 70% that of the original size.

• If the mill has been running for a long time with smaller beads, consider using smaller sized beads for the fresh charge.
CHECKING MEDIA CHARGE

• **Best Way:** check and note the power draw on a high volume product. If power draw decreases gradually it’s probably due to media wear. Recharge with media until the original power draw is restored.

• **Acceptable Way:** measure the initial media level with a stick or mark somewhere visible. Check the level periodically and fill when needed.

• **Alternative Way:** passive maintenance: wait until the screen starts to block.

• **Worst Way:** wait until product doesn’t meet QC standards
SIZE MATTERS

• Use the smallest bead possible determined by the feed size, not the desired final size;

• Use the largest opening possible for the best flow without causing bead plug;

• Standard media should be 3x the opening size;

• Long wearing media can be 2x the opening size but this can vary with mill type
**BEAD SIZE DETERMINES FINAL PARTICLE SIZE BUT SHOULD BE BASED UPON**

**STARTING PARTICLE SIZE:**

- **General rule #1:** Feed particle size should be 90% < 10x bead size. Example: 2.0 mm bead will have a feed size of 90% < 200 micron

- **General rule #2:** final particle size will be 1/1000th of media size. Example: 2.0 mm bead will give a D50 of 2.0 microns

- **The bead has to be large enough to grind the largest particles but small enough to produce the desired final grind.**
Resulting median particle size is 1/1000th median bead size
In general, small media with tight distributions result in more efficient grinding than wide distributions or mono sized beads.

Mono sized beads retard wear and extend the life of the media.

Broad distributions or mixing sizes create accelerated wear as the large beads grind the small beads.
WHAT HAPPENS TO THE MEDIA WHEN IT WEARS?

IT GOES INTO YOUR PRODUCT!

MEDIA CAN BE A MAJOR CONTAMINANT IF THE PRODUCT IS NOT FORMULATED TO USE THE MEDIA AS A RAW MATERIAL.

steel media will cause graying or rust
glass media can change the refractory index
Media should be chosen to be the major wearing part of the mill OR the least destructive to the mill because it’s cheaper to replace media than mill parts.

*Low Viscosity* can also lead to mill wear.
FORMULATION TIP

Mills are expensive. There is no reason to mill products like resin and solvent. These types of products should only be added for flowability.

If possible, it is best to make a high solids concentrate. This will reduce grind times and also the required mill size.
MATERIALS OF CONSTRUCTION

• Media hardness should match liner hardness to prevent excessive wear.
• High density media can cause high wear of stainless or alumina parts; Use 440 stainless if possible.
• High heat can destroy polymer parts.
• Mills are available in various steels, polymers and ceramics.
• Be aware that alternative liner materials can reduce heat transfer. A compromise is to make the parts from alternative materials and keep the liner as some time type of metal.
CONSIDER TEMPERATURE

THE MILLING PROCESS IS AN ENERGY PROCESS CREATING HEAT AS A BY-PRODUCT.

↑ density, ↑ bead charge, 
↑ viscosity; ↓ bead size, 
↓ batch size = MORE HEAT
WEAR PROPERTIES OF MEDIA CAN VARY GREATLY. CHOOSE WISELY.

Cheap can be expensive.

Look at VALUE rather than price.

More wear =
• more contamination
• more time to recharge the mill
• less efficient grinding with time

Not always less wear on mill parts
Media Wear Comparison
All beads 1 mm range
Tested on Minizeta with Polyamide shaft
Water circulated

- Ceroglass GSR-11 (Soda Lime Glass) 1.0-1.25 mm
- Ceroglass GAR-11 (Low Alkaline Glass) 1.0-1.25 mm
- Ceroglass SLZ-9 (Zircon) 0.8-1.0 mm
- Ceroglass SLYTZ-9 (Zirconia) 0.8-1.0 mm
- Chinese YTZP 1 mm
- Ferro ZTA 0.8-1.0 mm
- Jyoti Zirconox Narrow 0.8-1.1 mm
- Zirpro ZIRMILL 0.9-1.1 mm
- Zirpro ZIRNEF 0.8-1.0 mm
- Torayceram 1 mm
- Zircoa MM Lot 1 mm
- Zircoa MM Spcl 1 mm
BEAD SPHERICITY (ROUNDNESS) EFFECTS BEAD WEAR AND MILL WEAR

• **Round**: uniform in shape, will roll and move through the mill making consistent contact. The smooth rolling action causes less wear on the mill.

• **Oblong**: or other non-round shapes such as pyramids or flats will not roll smoothly causing erratic flow, inefficient mill wear and premature mill wear

• **Starting Shape influences wear shape** which effects media life and mill wear
MEDIA WEAR PHOTOS

Cerium Brand, New

Yttria Brand, New

24 hours of grinding
BEAD WEAR PATTERNS

Before                           After Horizontal Mill             Flats & Misshapen

This is an example of an expensive high density bead which lasts a long time but can cause excessive wear on the mill due to its initial shape which effects the wear pattern.
CAN CRUSH STRENGTH PREDICT MEDIA WEAR?

- This test can be misleading due to the difficulty in obtaining good alignment of the same point on a sphere with the compressive axis.
- Vickers Microhardness test on the mirror-finished surface of the media is a more reliable indicator about wear performance of media.
- The higher the Vickers Number, the higher the crush strength, the higher the wear resistance.
- Example: Yttria ZirOx might be 1300; Cerium ZirOx 1150; & Zirconia Silicate 800.
CHEMISTRY COUNTS

• How will heat effect the mill and the formulation?
• Does the media density match the viscosity?
• Can the product tolerate metal contamination or rust?
• Can all traces of the media be removed from the product?
• Will media wear effect the performance of the final product?
**BEAD DENSITY MATTERS**

The bead should be heavier than the product which is being milled, especially in a vertical mill, to prevent “media float.”

- higher viscosity  \[\uparrow\] density
- higher solids \[\uparrow\] density
- faster grind time \[\uparrow\] density
- lower temperature  \[\downarrow\] density
- shear sensitive  \[\downarrow\] density
- deagglomeration \[\downarrow\] density
## BEAD DENSITY

**THERE IS A CORRECT BEAD FOR EVERY APPLICATION**

<table>
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<th>Density Range</th>
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<th>87%</th>
<th>90%</th>
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DENSITY & MILL WEAR

• High Density Media is best used in standard mills if viscosity is 1500+ cps;

• In Ceramic, Urethane, Rubber lined mills viscosity isn’t as much a wear issue as it is a heat transfer issue;

• The crystalline structure of the media has a greater impact on abrasiveness than density;
  • For example, YTZ media is dramatically LESS abrasive than Alumina or Zirconia Silica which are lower in density. It’s not just HARDER, it’s TOUGHER.
Determining how much you need in a vertical or horizontal mill

Void Volume of Mill \textit{multiplied by} \% Charge for the Mill \textit{multiplied by} kg/liter, kg/gal,#/liter,#/gal of grinding media

40\% of the media volume is open space
DON'T MIX MEDIAS
UNLESS RECOMMENDED BY AN EXPERT

• Never ever mix different types of media.

• Always put in a fresh charge when making a media change. This includes same type/same size but different manufacturer.

• In most cases, if mixed, both medias will wear prematurely due to differences in hardness, toughness, surface finish, size distribution, and density.

• There is a simple method for transitioning to a new media by removing the media from 1 mill, screen it, use the on-size media to replenish the other mills. When the replenishment is used up, move on to emptying the next mill and repeat the same procedure until there is only one mill remaining.
JOG THE MILL
WHEN MEDIA IS WASHED

• Never run a mill dry or continuously with beads in wash water or solvent.

• Both will deteriorate the mill rapidly.

• One option is to make a resin rinse before a final cleaning.
MEDIA TRENDS

• Glass, Alumina & Zirconia Silicate is still used due to the low cost especially in the older mills;

• Steel medias are still the best value due to the high density and low cost if using steel shot and high sphericity if using steel balls. Removable with magnets. However, many customers cannot use this due to graying and/or rusting;

• Zirconia Oxides are growing the fastest due to the long life and lower abrasion. The value of paying extra to buy less, lower maintenance, higher operating efficiencies are paying off;

• Very high quality media has been developed for the mining industries at much lower costs due to the high volume. These lower cost high value medias are now available to the coatings industry;
Zirconium Oxide

- Magnesium stabilized
- Cerium stabilized
- Yttria stabilized
MAGNESIUM STABILIZED ZIRCONIA OXIDE
5.4 GM/CC

• High density with reasonable $;

• Small beads are extremely abrasive;

• Very popular in jar and ball mills;

• Not a viable option for small media mills.
ALUMINA TOUGHENEO ZIRCONIA OXIDE
5.1 GM/CC

- Spherical
- 73% ZrO, 25% AlO
- High density with reasonable $^*
- 1.0 mm-1.7 mm
- Very Hard/Tough
- Vickers 1300
- Excellent wear rates
- Mining, Minerals, Inorganics
- Not abrasive
CERIUM STABILIZED ZIRCONIA OXIDE
6.0-6.25 GM/CC

• High density - reasonable price
• Low wear rate, 1200 HV
• Less abrasive than Mg but more than Yt
• High viscosity or lined mill is needed, 1500 cps
• Widely used for fast grinding
• 2 High Value Suppliers; 2 Very Good Value Suppliers; 1 Average Value Supplier
• A new and better yttria bead may replace cerium zir ox in the future
CERIUM STABILIZED ZIRCONIA OXIDE

6.1-6.25 GM/CC

1. Japan
2. France
3. India
4. US
5. Korea
6. China
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<td>usually in stock</td>
<td>usually in stock</td>
<td>3-4 months if not in stock</td>
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<td>Comments</td>
<td>better in med-high viscosity</td>
<td>long lead time can flatten and pyr</td>
<td>on the small side</td>
<td>flattens, abrasive</td>
<td>higher wear rate</td>
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<td>Best Value</td>
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YTTRIA STABILIZED ZIRCONIA OXIDE
6.0 GM/CC

• Used to be the most expensive but now not necessarily
• Longest Life with some exceptions in high temp water based products with extreme pH
• Most brands offer high sphericity
• Tight sizing
• Not abrasive
• Not all are equal! beware of poor quality
• 1 top producer, 2 excellent, 2 good, many poor
• .03 mm - 60 mm
YTTRIA STABILIZED ZIRCONIA OXIDE

6.0 GM/CC

1. Japan
2. France
3. Japan
4. Korea
5. France
6. China
NEW ALTERNATIVE TO CERIUM: LOWER COST YTTRIA WITH HIGH QUALITY

• COMPARISON TO EXPENSIVE YTTRIAS:
  • 93% ZirOx; 5% Yttria
  • Density 6.0
  • Sizes 0.6 – 2.0 mm
  • Narrow size distribution
  • Fine microcrystalline structure
  • Polished
  • Cream color
  • Slightly broader distribution
  • Not quite a spherical
  • Vickers 1150
<table>
<thead>
<tr>
<th>Name</th>
<th>Tosoh YTZ</th>
<th>CYZ</th>
<th>Zirmil-Y</th>
<th>Zirmil TZP</th>
<th>SLYTZ</th>
<th>YZP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Yttria</td>
<td>Yttria</td>
<td>Yttria</td>
<td>Yttria</td>
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<td>Yttria</td>
</tr>
<tr>
<td>Country of Origin</td>
<td>Japan</td>
<td>Japan</td>
<td>France</td>
<td>France</td>
<td>Korea</td>
<td>China</td>
</tr>
<tr>
<td>Chemistry</td>
<td>95 ZrO/5 YO</td>
<td>94.75 ZrO/4.9 YO</td>
<td>93 ZrO/5 YO</td>
<td>93 ZrO/5 YO</td>
<td>99.7 ZrYO?</td>
<td>94.8 ZrO/5.2 YO</td>
</tr>
<tr>
<td>Density: gm/cc</td>
<td>6.1</td>
<td>6.1</td>
<td>6.1</td>
<td>6.0</td>
<td>5.9</td>
<td>5.9</td>
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<tr>
<td>Bulk Density: kg/l</td>
<td>3.7</td>
<td>3.7</td>
<td>3.7</td>
<td>3.65</td>
<td>3.6</td>
<td>3.55</td>
</tr>
<tr>
<td>Color</td>
<td>iridescent white</td>
<td>polished white</td>
<td>polished white</td>
<td>polished cream</td>
<td>off white</td>
<td>white</td>
</tr>
<tr>
<td>Polish</td>
<td>hi gloss smooth</td>
<td>glossy smooth</td>
<td>glossy smooth</td>
<td>low gloss smooth</td>
<td>satin smooth</td>
<td>polished smooth</td>
</tr>
<tr>
<td>Shape</td>
<td>very round</td>
<td>very round</td>
<td>round</td>
<td>round</td>
<td>round, undulates</td>
<td>round, undulates</td>
</tr>
<tr>
<td>HV Hardness</td>
<td>1300</td>
<td>1250</td>
<td>1250</td>
<td>1150</td>
<td>1100-1400</td>
<td>1020</td>
</tr>
<tr>
<td>Packaging</td>
<td>1 or 10 kg</td>
<td>15 kg</td>
<td>20 kg</td>
<td>20 kg</td>
<td>22.7 kg</td>
<td>25 kg</td>
</tr>
<tr>
<td>Norstone Rating</td>
<td>A+</td>
<td>A+</td>
<td>A+</td>
<td>A</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>Price Low to High</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>2</td>
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<tr>
<td>Lead Time</td>
<td>usually in stock</td>
<td>3-4 months</td>
<td>usually in stock</td>
<td>new, stock as needed</td>
<td>usually in stock</td>
<td>3-4 months</td>
</tr>
<tr>
<td>Comments</td>
<td>best in the world</td>
<td>on the smaller side</td>
<td>excellent</td>
<td>best value for most</td>
<td>wears fast</td>
<td>100% prepay</td>
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<tr>
<td>Best Value</td>
<td>**</td>
<td>***</td>
<td>*</td>
<td>*</td>
<td></td>
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</tr>
</tbody>
</table>
New Medias
Many Developed for the Mining Industries

- Beads are Alumina, Zirconia, Silica and a combination of the three
- Density ranges from 2.6 – 6.0
- Vickers Hardness ranges from 742 – 1431
- Size ranges from .4-.6 mm up to 8.0 mm
- Used for minerals & mining in stirred ball mills, vertical mills, small media mills. Also used for armor, surface treatments, fillers, etc.
Newer Medias are far more expensive than in prior decades.

We now offer special screening services to recover media if you can’t do this in house.

Keeping the distribution narrow will extend the life of the media and make grinding more efficient.

Screening will save a lot of money since only enough media for top off needs to be purchased.
UNDERSTAND THE PERSONALITY OF THE PLANT & NATURE OF THE PRODUCT

**B E C A U S E**

- It doesn’t matter if the media lasts a long time if …
- Common practice is to find a lot of it on the floor or down the drain;
- The product wears down the media so fast that the value of long wearing media can’t be realized
TRAINING SAVES MONEY

- Tell the people who are working with the media how much it costs. They will treat it with more respect.

- Train the operators in proper handling and charging of the media.

- Put the cost of the media on the mill along with the correct per cent charge for the mill. Operators will respect it more.
We are always available to assist with choosing the right grinding media, educating users on what is new and helping in any areas of need. We represent all medias and have exclusivity with none so that we can better help you choose the best value option.

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484.684.6986