JET MILLING & AIR CLASSIFICATION

THE SECRET TO ULTRAFINE PARTICLES

Horiba Webinar - May 17, 2022




OUTLINE

- *AVEKA* Introduction
- Size Reduction Overview
- Classification Overview
- Jet Milling
- Air Classification
- Examples
- Summary

AVEKA Group

an employee owned and operated company

- Particle technology company focused on contract manufacturing and process development
- Spin-off of 3M in 1994
- Over 300 customers each year
  - Chemical
  - Ceramics
  - Automotive
  - Aerospace
  - Personal Care
  - Food
  - Spray Drying
  - Size Reduction
  - Fluid Bed Drying
  - Agglomeration
  - Particle Formation
  - Microencapsulation
  - Membrane Separation
- 50-60 Scale-up and development projects per year

SIZE REDUCTION - OVERVIEW

- Crushing
  (50-100,000 µm)
- Ball Milling
  (10-1000 µm)
- Hammer Milling
  (50-500 µm)
- Jet Milling
  (1-100 µm)
- Bead Milling
  (0.005-10 µm)

Factors

- Input Size
- Final Size
- Size Distribution
- Size Distribution Efficiency
- Energy Efficiency

ENERGY EFFICIENCY

VON RITTINGER, KICK, BOND

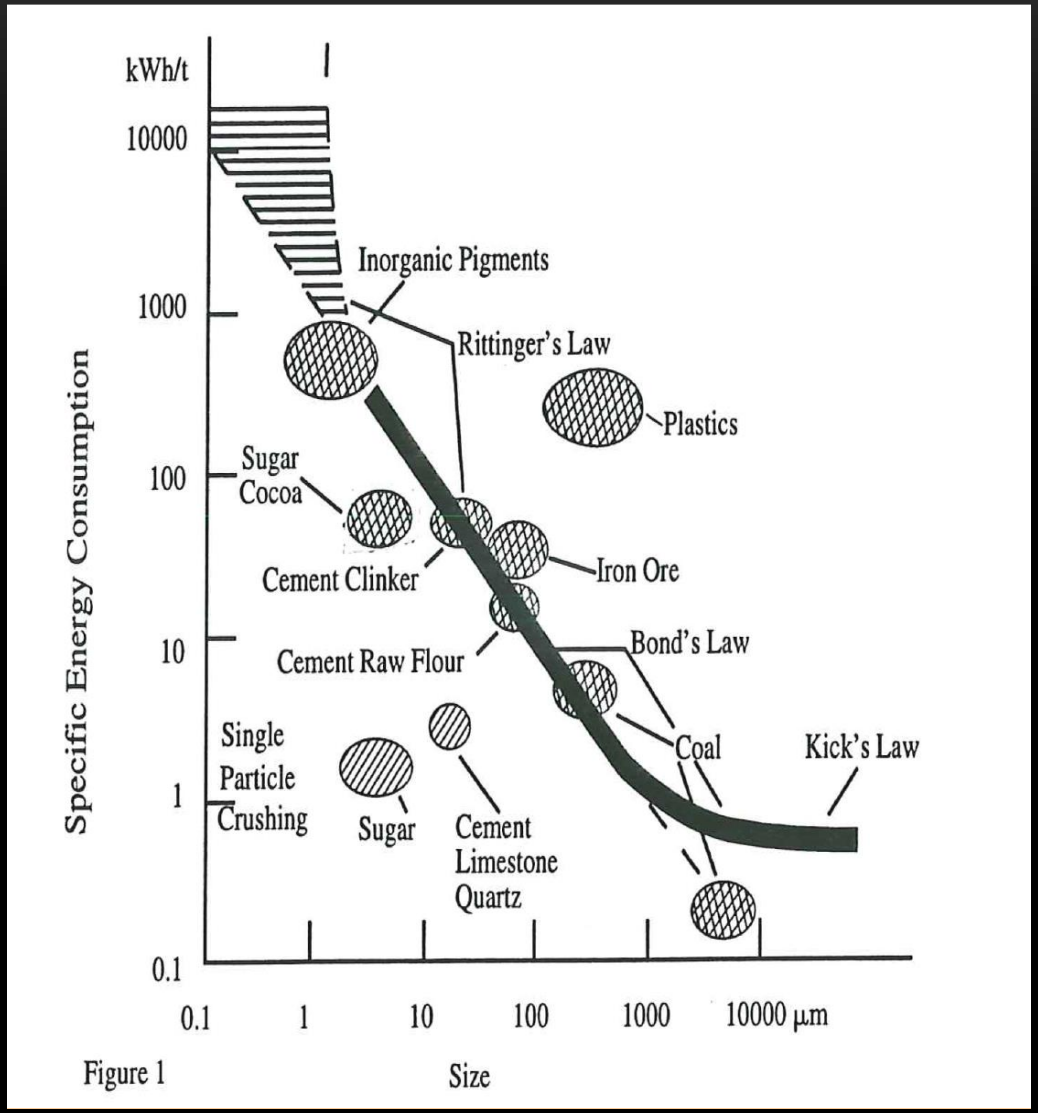


Figure 1

BREAKAGE ENERGY
AS A FUNCTION OF MATERIAL

- Hardness
- Ductility/Plasticity
- Bond Strength
- Crystallinity
- Inherent Defects

Final Particle Size and Breakage Energy a Function of:

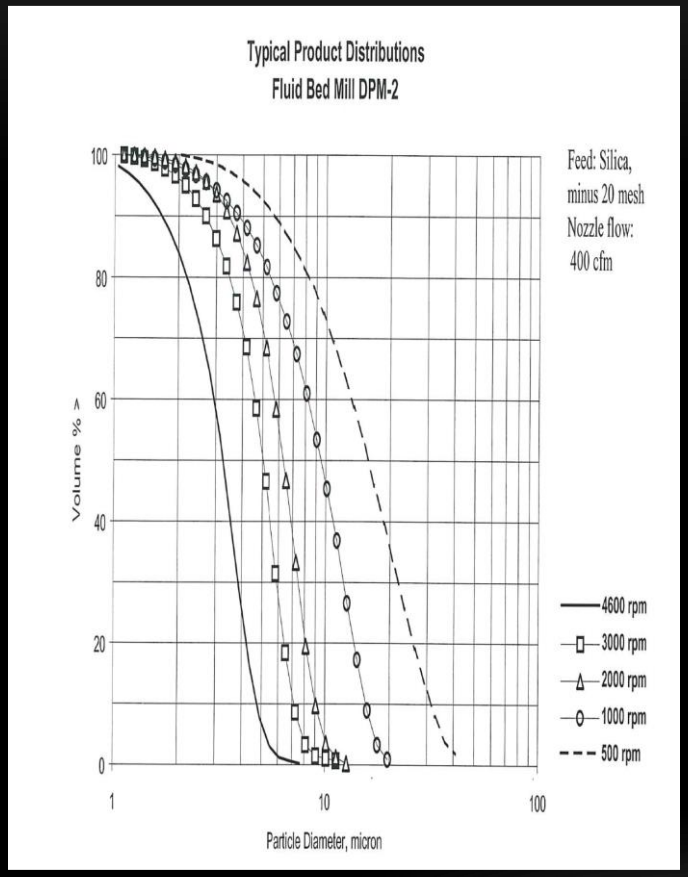
- Inherent Defects
- Produced Defects
- Impact Energy

CLASSIFICATION OVERVIEW

- Grading
- Sieves
- Winnowing
- Elutriation
- Cyclones
- Air Classification

- Physical Sorting
- Medium Induced Drag Combined with Attractive Forces
  - Gravity
  - Electrostatic
  - Magnetic

CLASSIFICATION EFFICIENCY



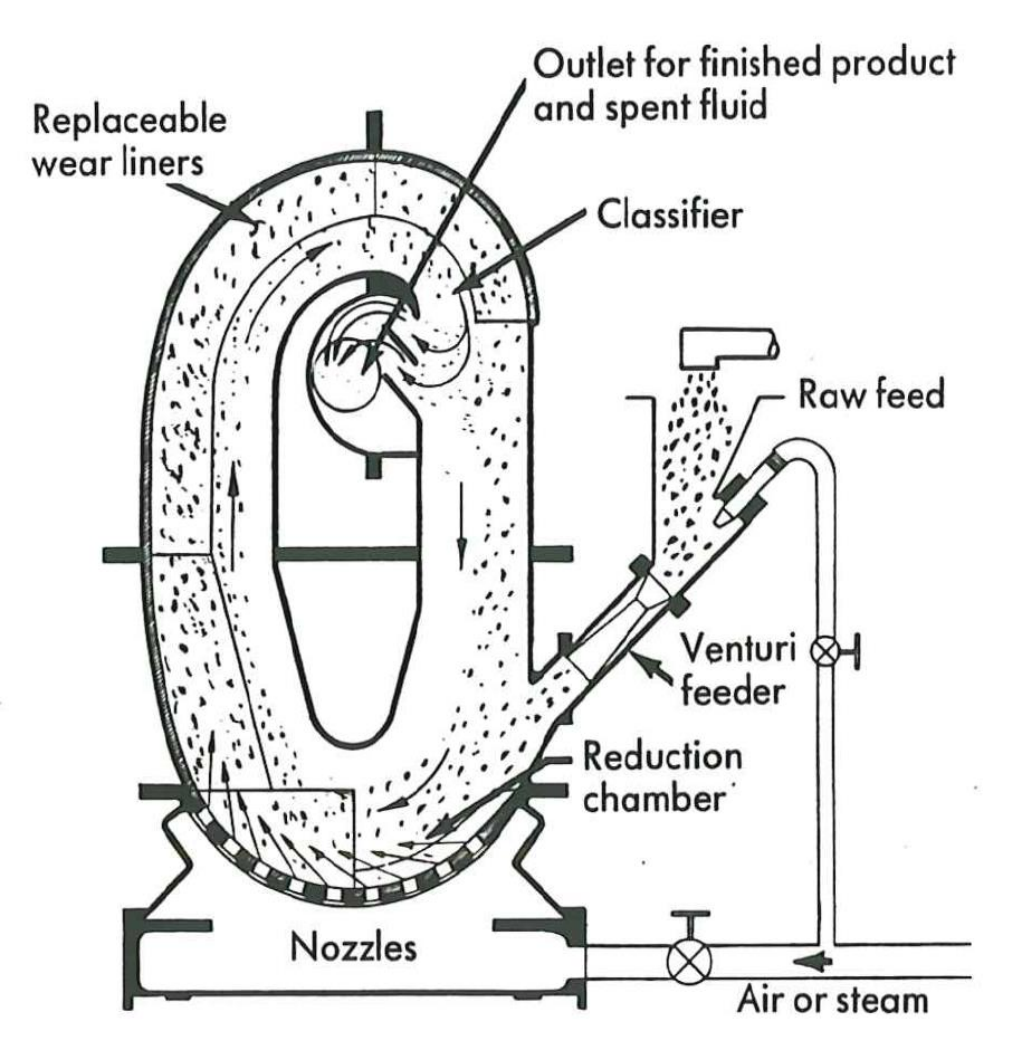
RPM	D_{50}	D_{90}/D_{10}
500	15	0.22
2000	6.2	0.35
4600	3.2	0.31
Perfect Classification	-	1.0

JET MILL TYPES

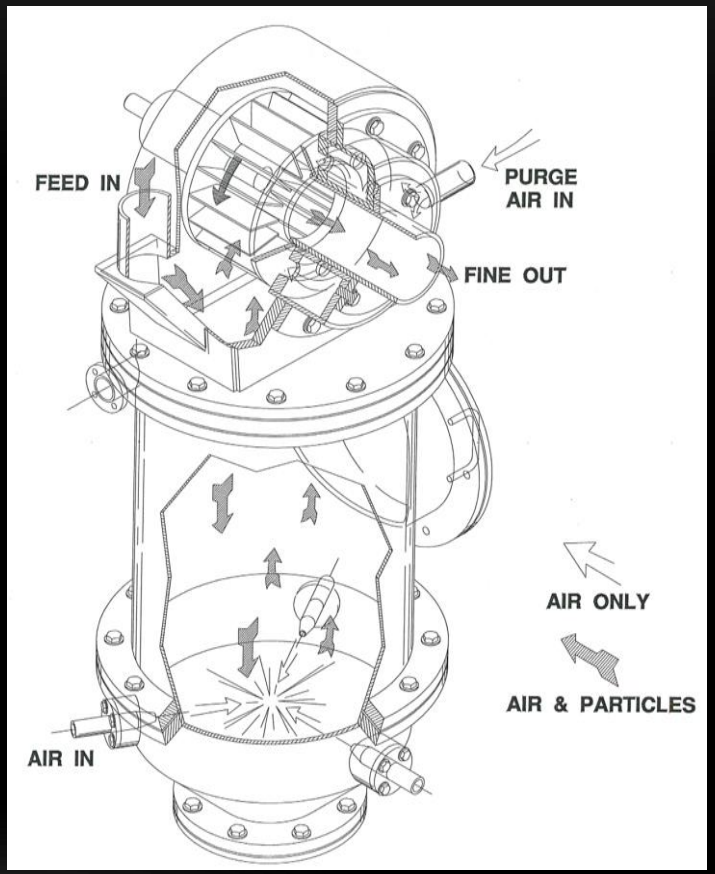
• Opposed Jet	1917	Separate Classifier
• Fluid Bed	1934	Separate Classifier
• Pancake	1934	Inherent Classifier
• Ovaljet	1940	Inherent Classifier

LOOP MILL

OVAL JET MILL

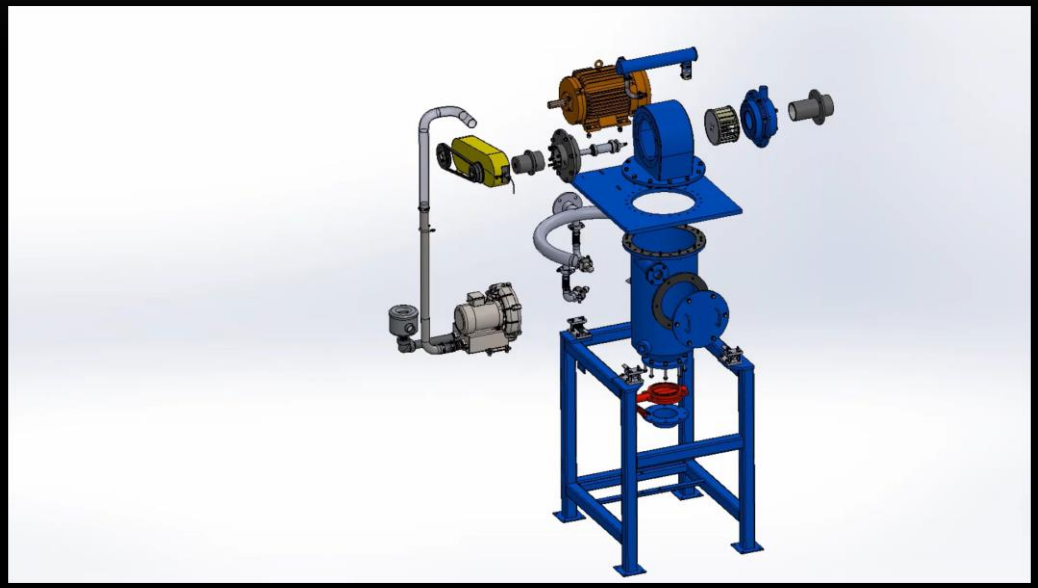


AVEKA JET MILLS



3D ANIMATION

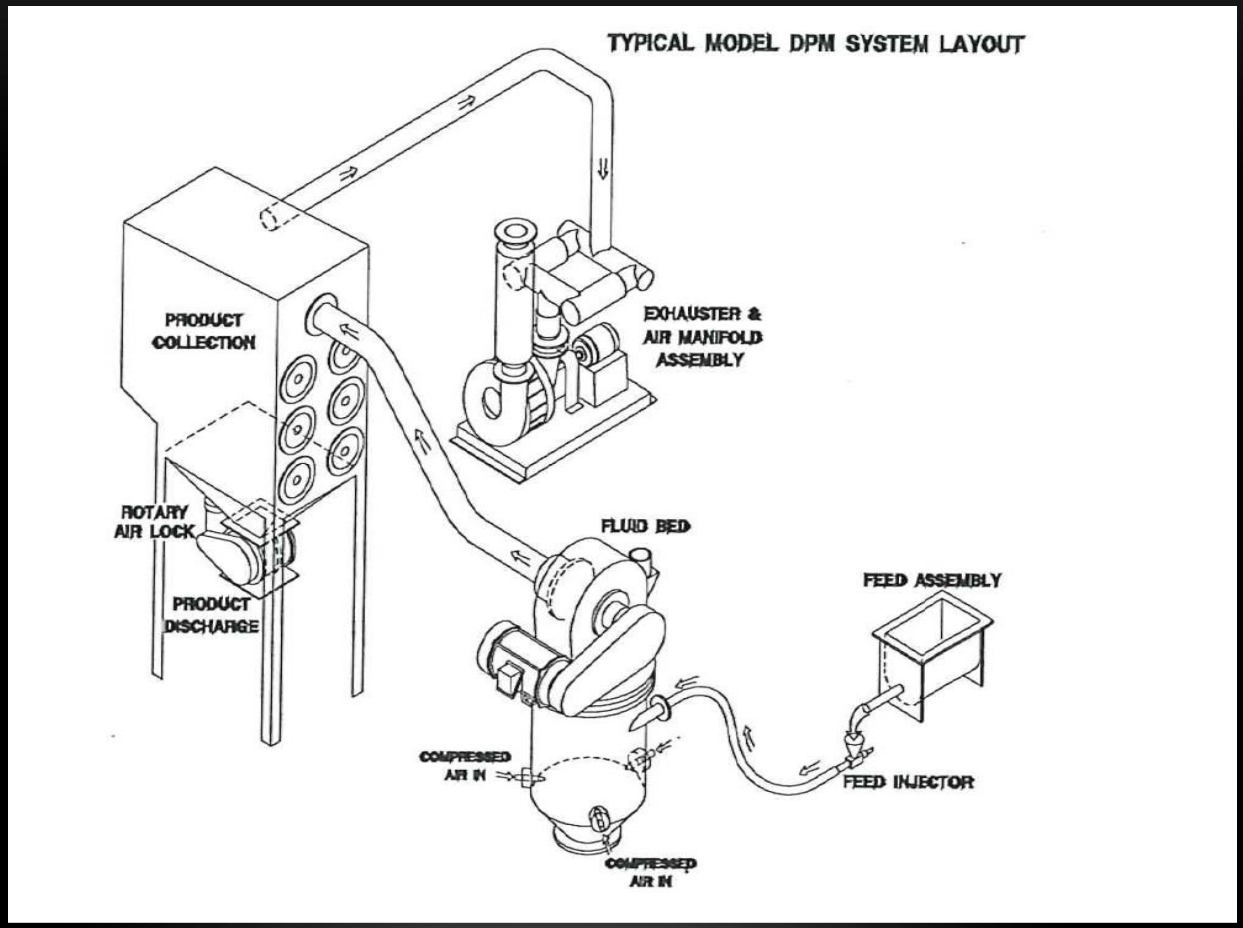
AVEKA – JET MILL & AIR CLASSIFIER



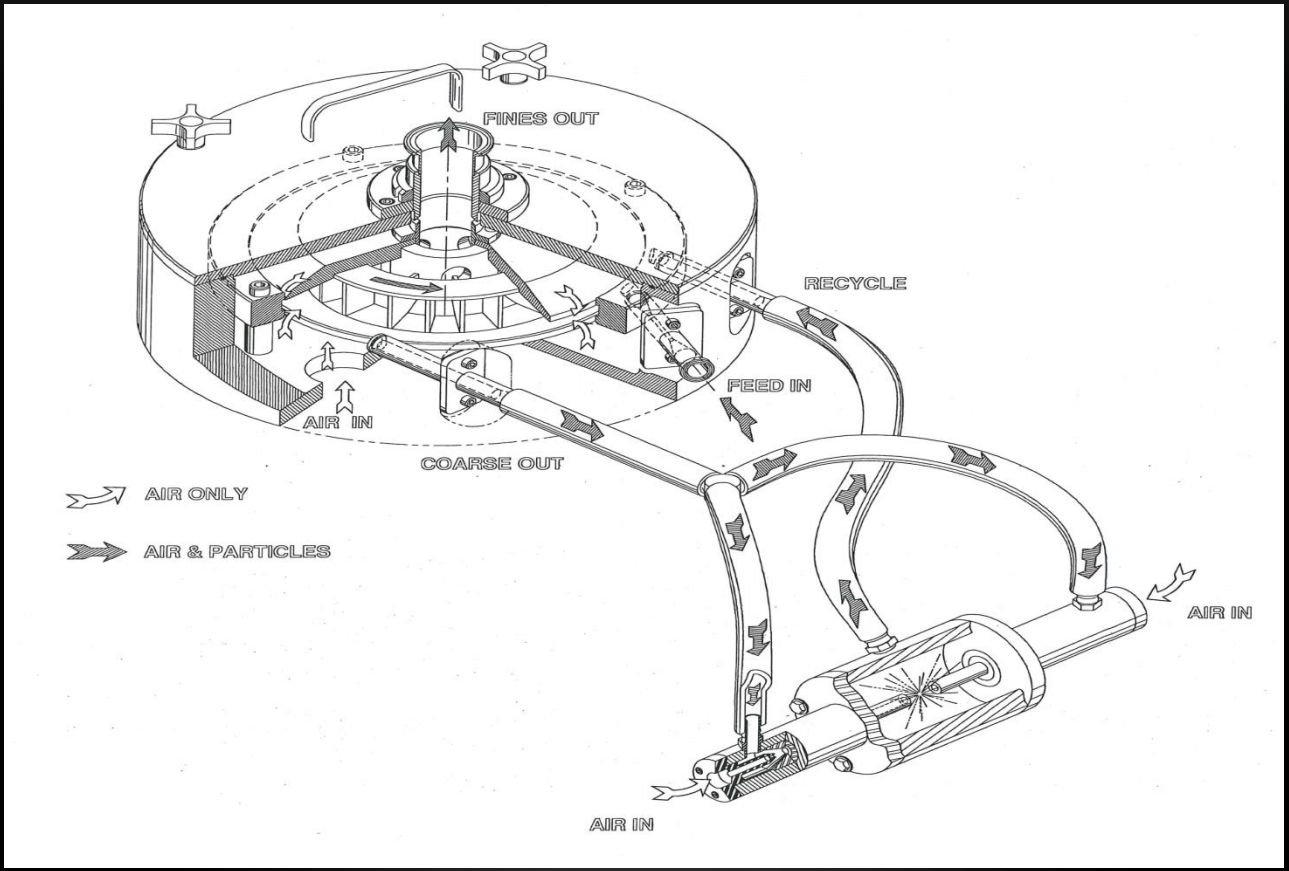
EXAMPLES OF JET MILLED/ AIR CLASSIFIED MATERIALS

- Ceramics
- Polymers
- Drugs
- Metals
- Glass
- Diamonds
- Food
- Cosmetics
- Carbon Black
- Minerals

JET MILLING SYSTEM LAYOUT

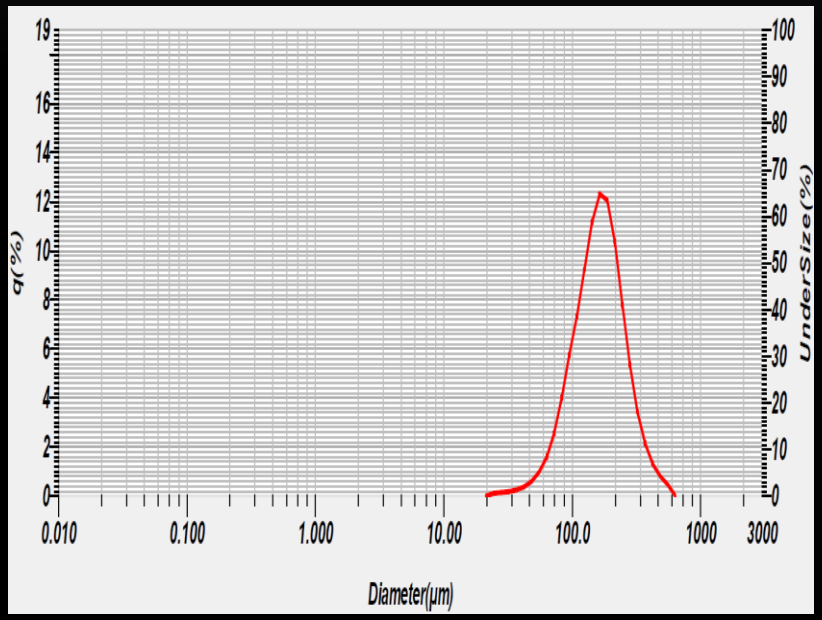


SORTING AIR CLASSIFICATION



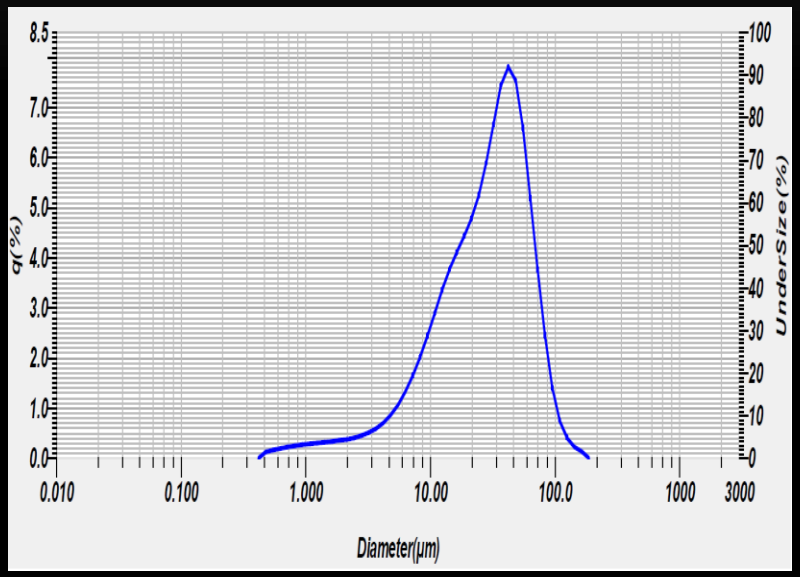
GRINDING & CLASSIFYING TO TIGHTEN DISTRIBUTIONS - CERAMIC

- Jet milling using different rotor classification speeds
  - Removal of fines to minimize over grinding
  - Coarse material remains in mill until ground and exits mill
- Second classification step to optimize particle size distributions
  - Removal of fines



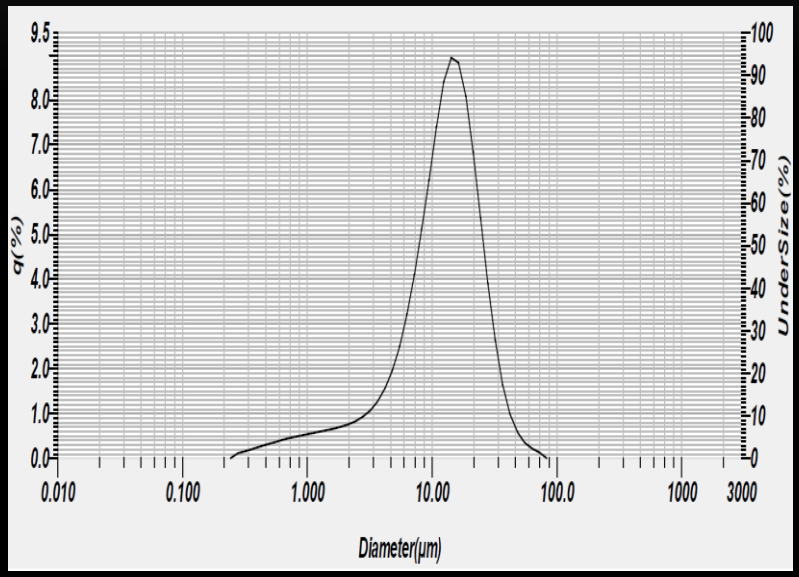
Starting Material – 177 µm

GRINDING AND CLASSIFYING TO TIGHTEN DISTRIBUTIONS - CERAMIC



Coarse Grind – Low Rotor Speed

Coarse Grind - 34 μm

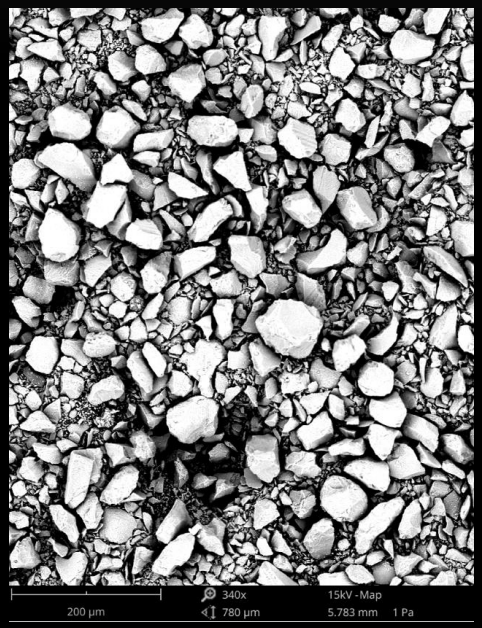


Fine Grind – High Rotor Speed

Fine Grind – 14 μm

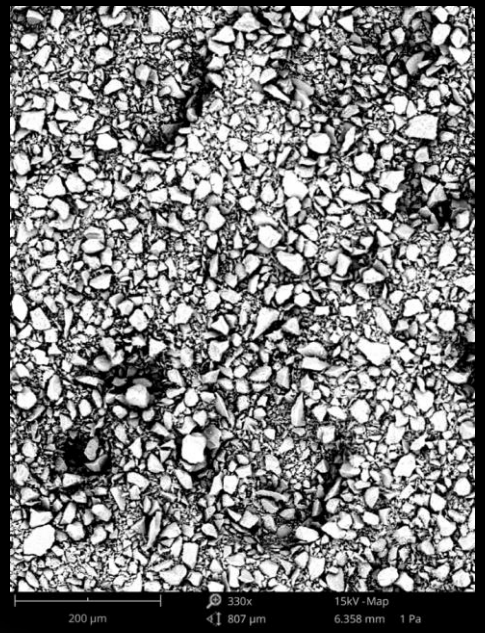
GRINDING AND CLASSIFYING TO TIGHTEN DISTRIBUTIONS - CERAMIC

Raw Material -
86.5 – 285.8 µm

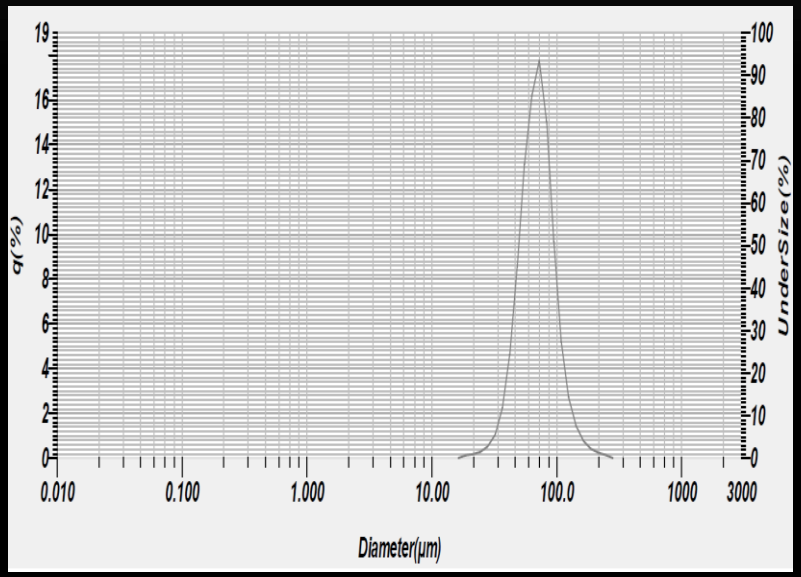


Coarse Grind -
7.2 – 65.9 µm

Fine Grind –
3.4 - 26.5 µm

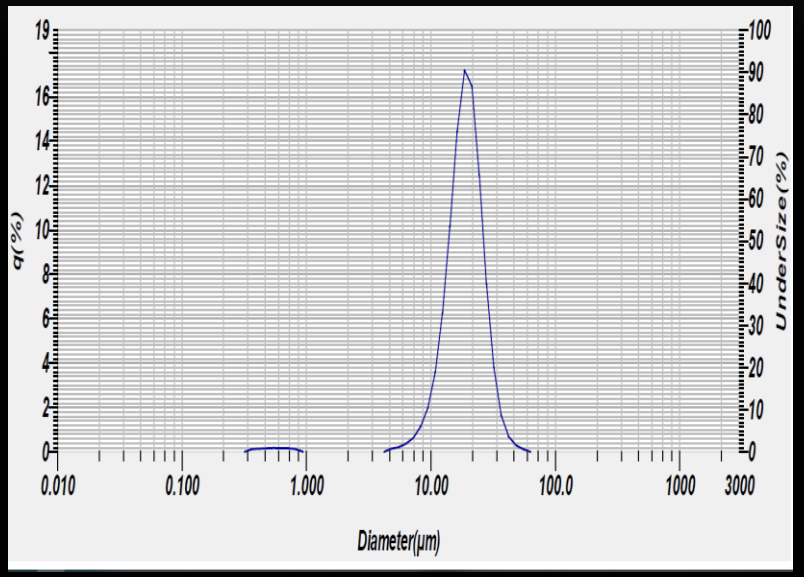


GRINDING AND CLASSIFYING TO TIGHTEN DISTRIBUTIONS - CERAMIC



Coarse Grind and Final Classification

Coarse Product – 73 µm

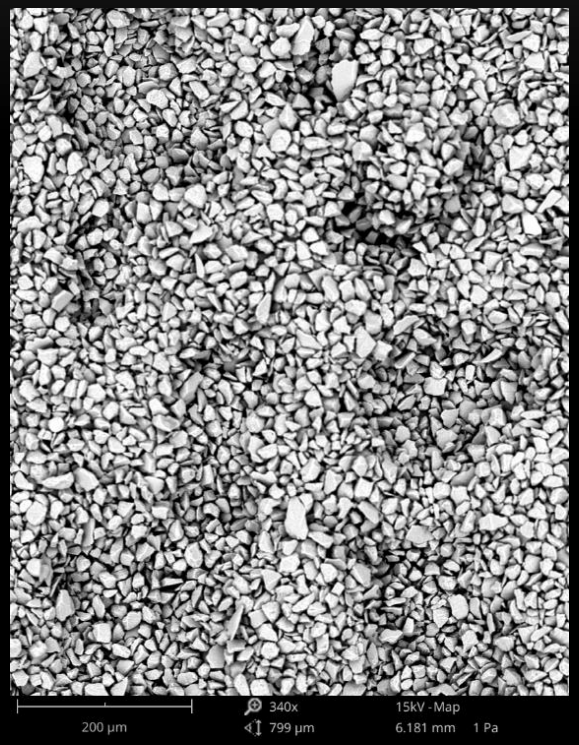


Fine Grind and Final Classification

Fine Product – 19 µm

GRINDING AND CLASSIFYING TO TIGHTEN DISTRIBUTIONS - CERAMIC

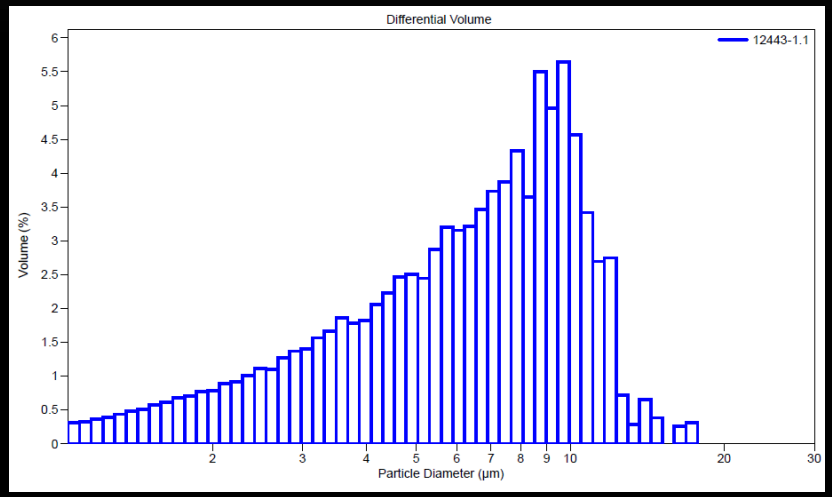
Coarse Product 45 – 103 µm



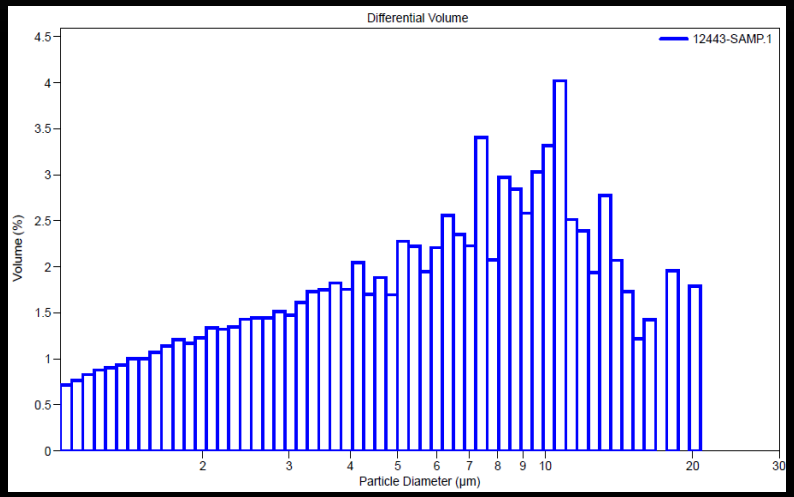
Fines Product 11-28 µm

JET MILLING VS. BALL MILLING OF ZIRCONIA SAND

Jet Milling



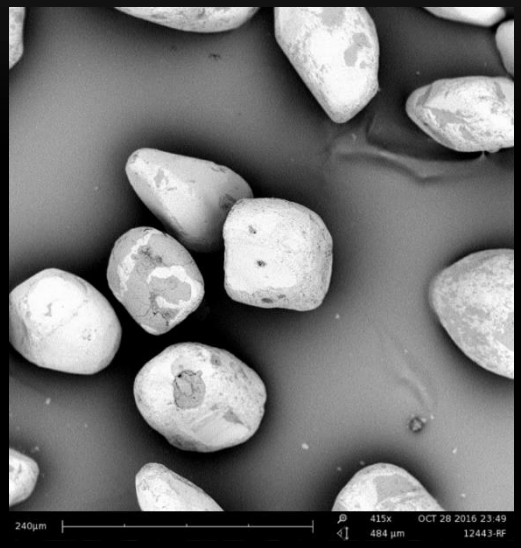
Ball Milling



Objective: Minimization of Fines

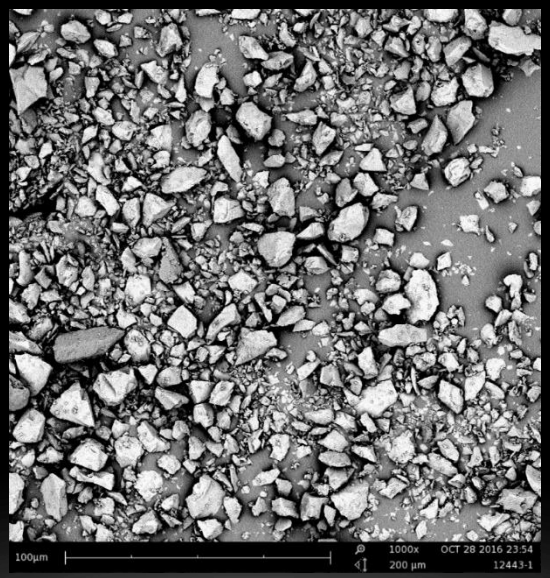
	<10%	<25%	<50%	<75%	<90%
Ball Milling	1.796 µm	3.191 µm	6.317 µm	10.25 µm	13.66 µm
Jet Milling	2.449 µm	4.120 µm	6.671 µm	9.133 µm	10.75 µm

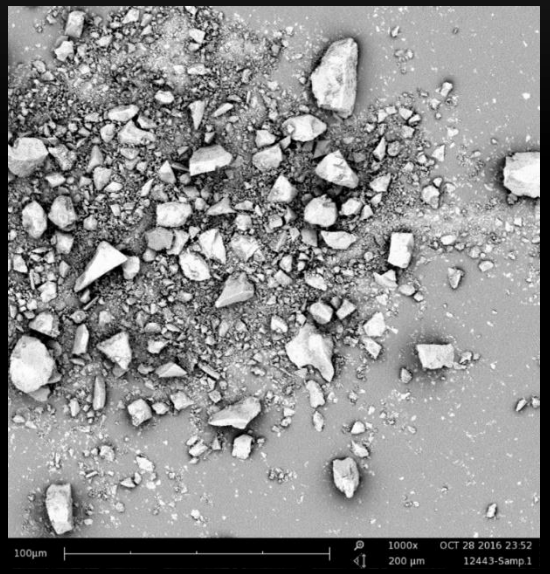
JET MILLING VS. BALL MILLING OF ZIRCONIA SAND



Starting Zirconia Sand

Jet Milled Zirconia



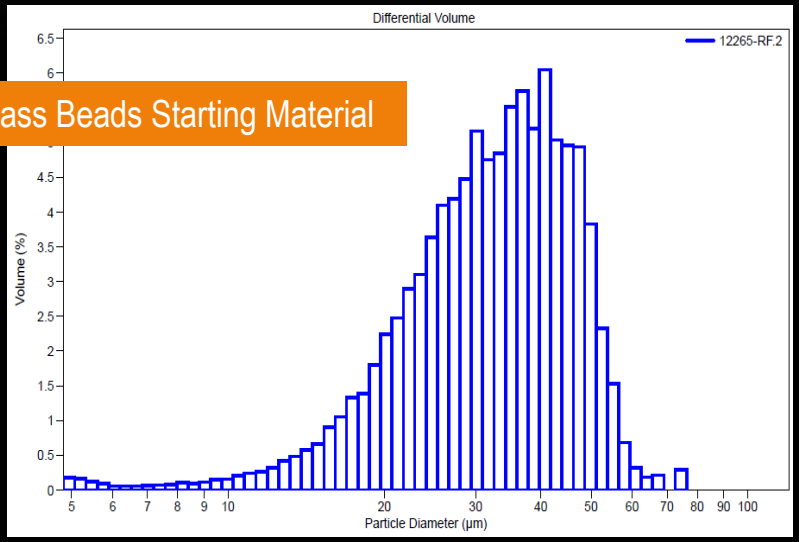


Ball Milled Zirconia

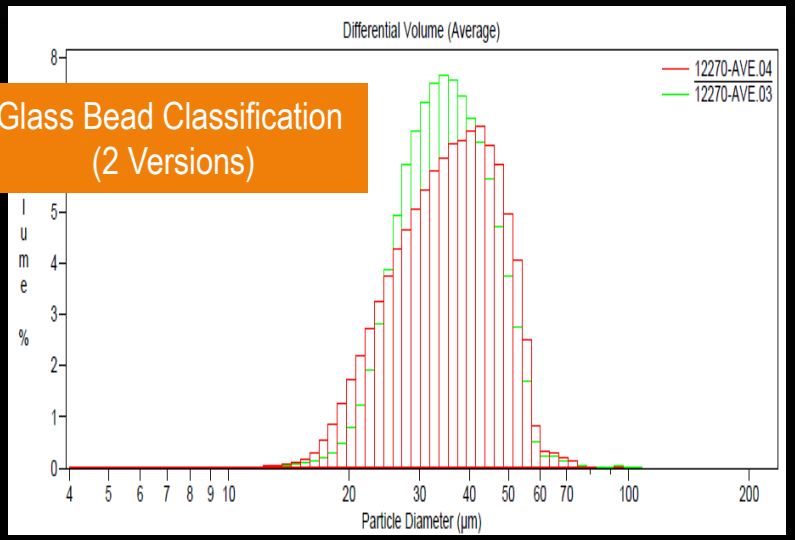
GLASS BEAD CLASSIFICATIONS & YIELDS

Objective: Increase yield after classification

Glass Beads Starting Material

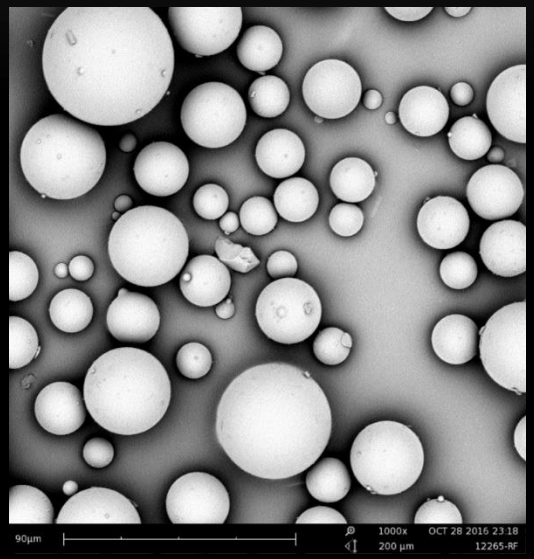


Glass Bead Classification (2 Versions)



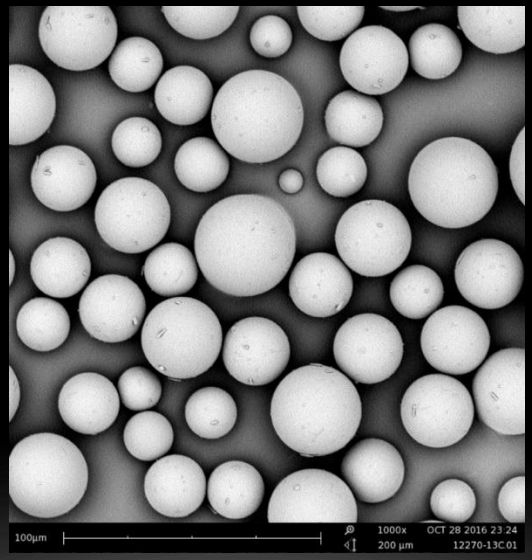
	<10%	<25%	<50%	<75%	<90%
Starting Glass	19.01 µm	25.08 µm	33.10 µm	41.56 µm	48.29 µm
Classification (red)	23.95 µm	28.22 µm	35.82 µm	43.94 µm	50.41 µm
Classification (green)	24.95 µm	29.05 µm	34.89 µm	41.96 µm	48.47 µm

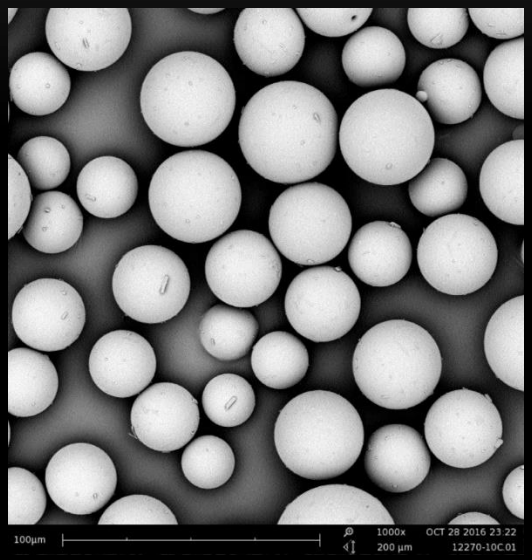
GLASS BEAD CLASSIFICATION & YIELDS



Starting Beads

Broad Cut (24-50 µm)
73% Yield

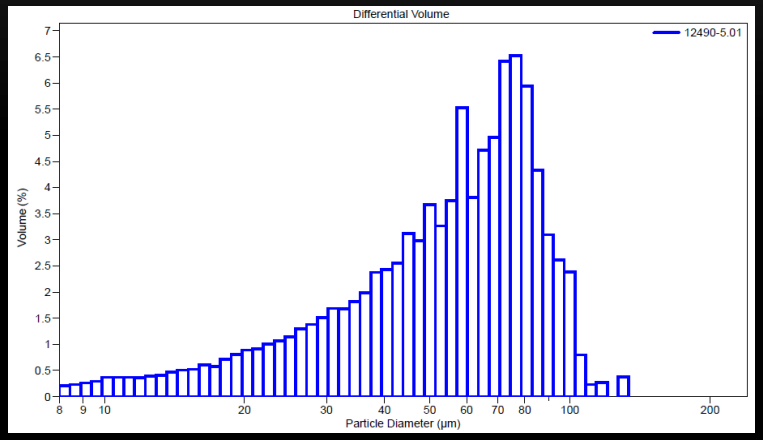


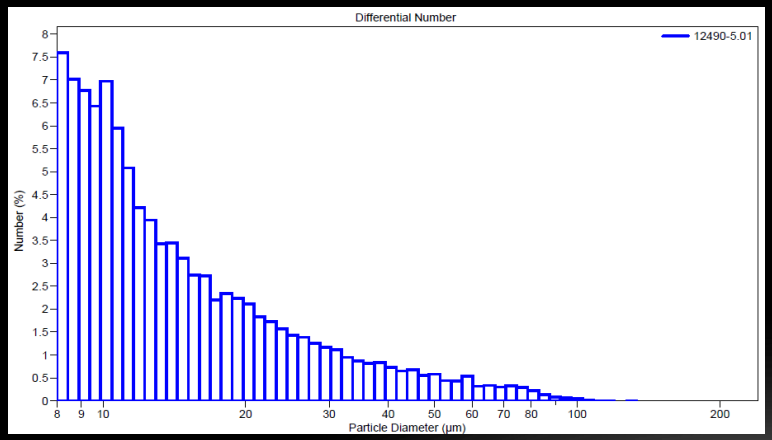


Narrow Cut (25-48 µm)
43% Yield

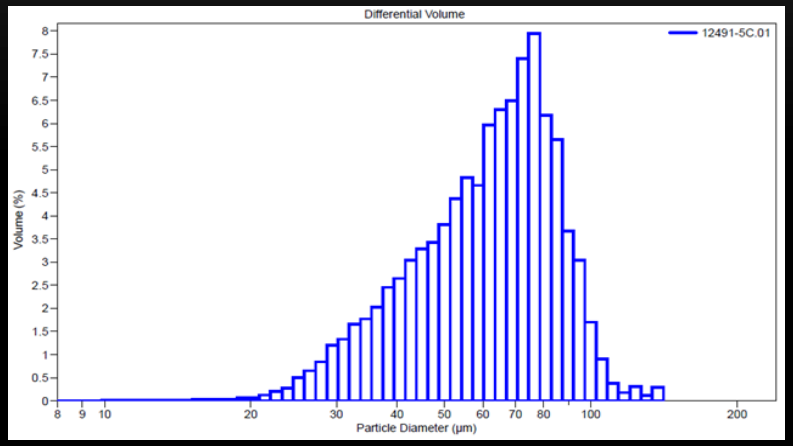
JET MILLING & CLASSIFICATION OF POLYMER

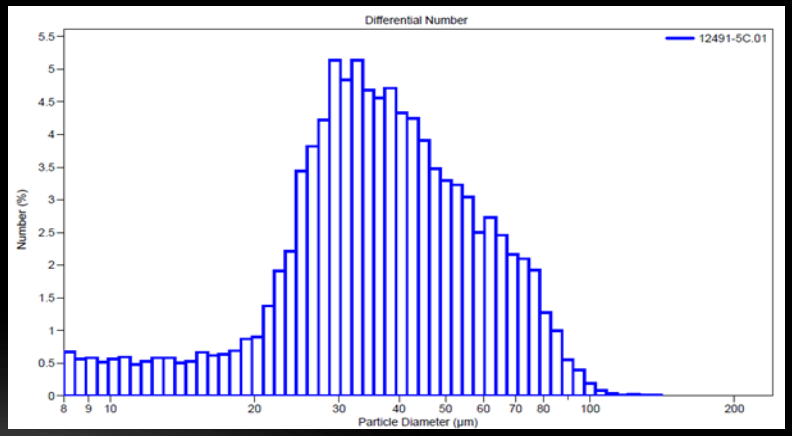
Jet Milled Polymer



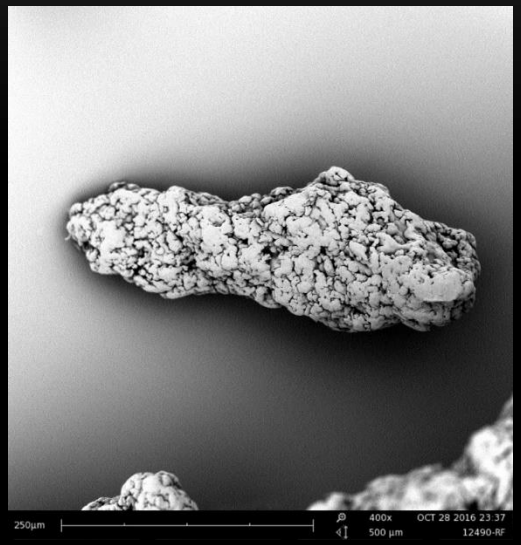


Jet Milled and Classified Polymer



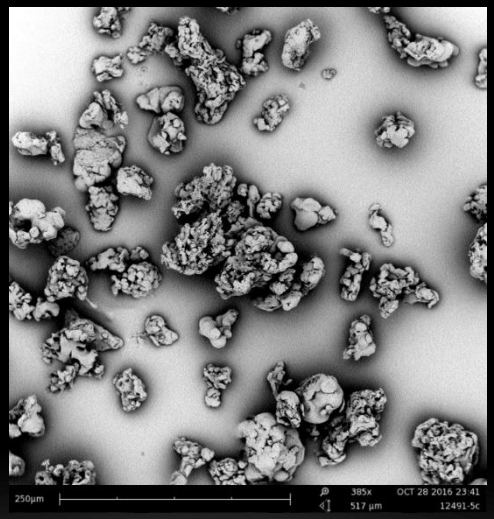


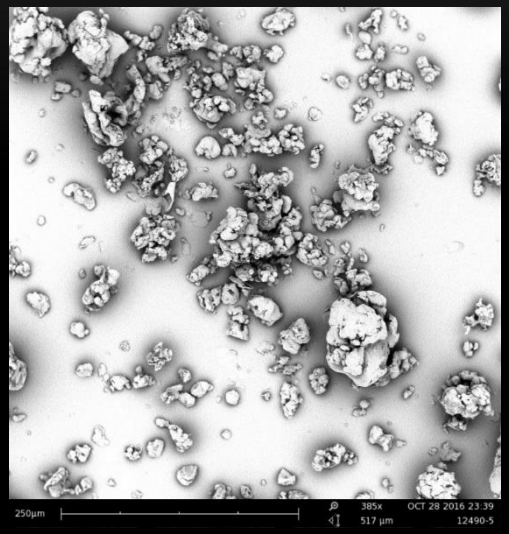
JET MILLING & CLASSIFICATION OF POLYMER



Starting Material

Jet Milled & Classified Polymer

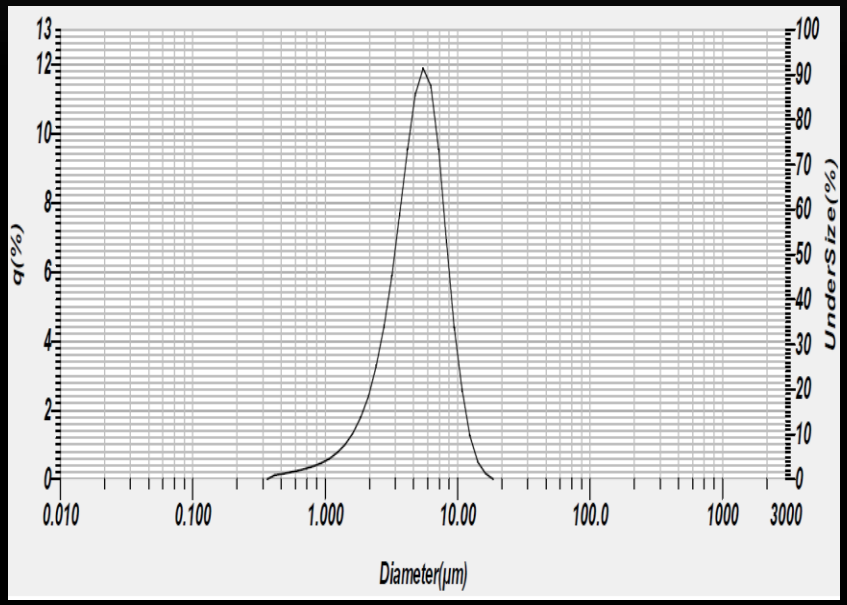




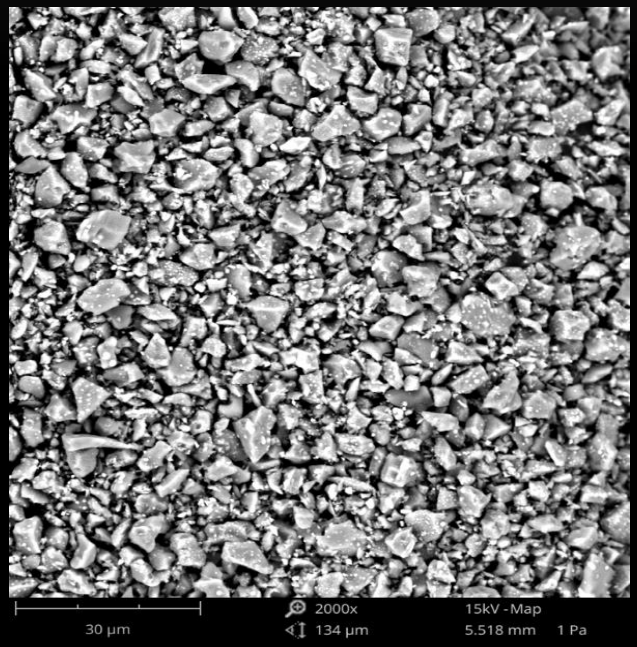
Jet Milled Polymer

TWO STEP CRUSHING & JET MILLING - GLASS

TWO STEP CRUSHING & MILLING – GLASS

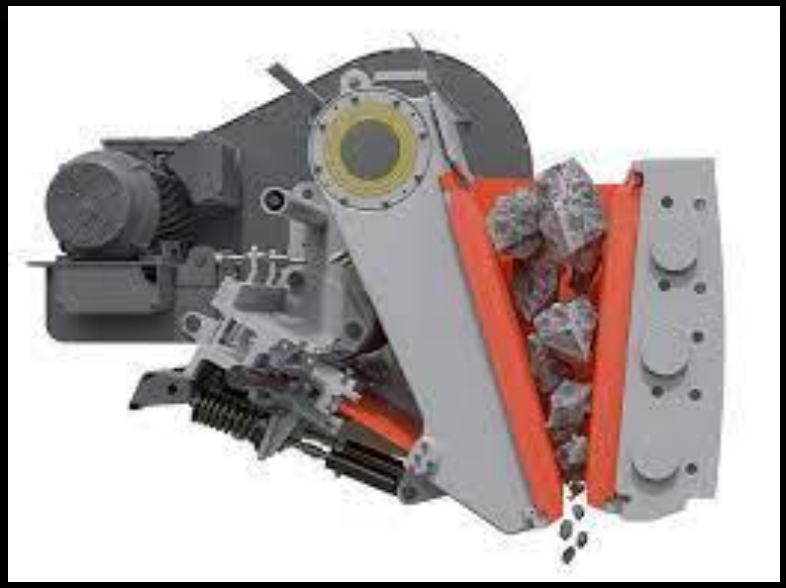


Jet Milled Glass – 5.3 µm



Jet Milled Glass 5.3 µm

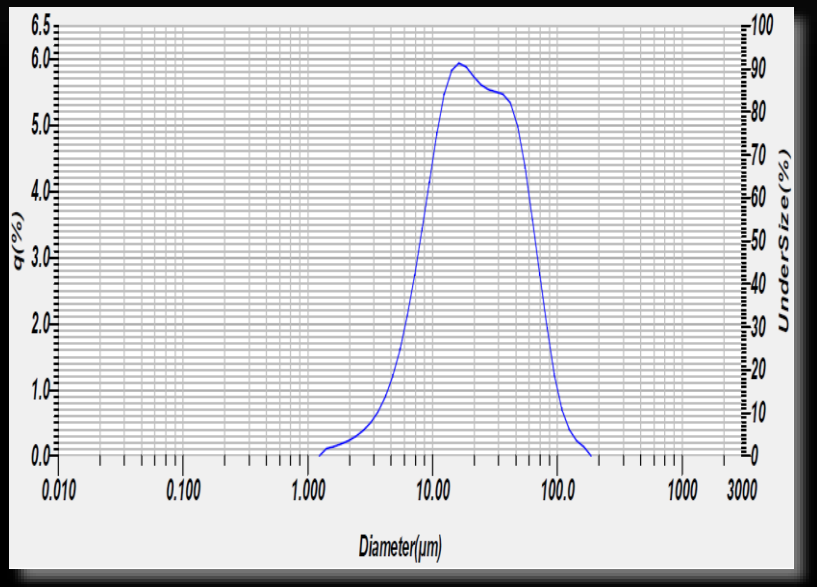
TWO STEP CRUSHING & JET MILLING - CARBON



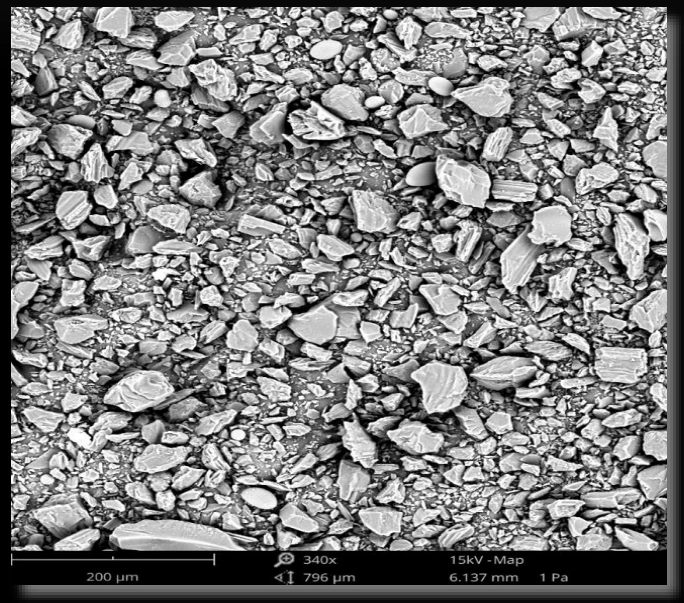
Jaw Crusher Schematic

Raw Material Lumps - Final Product

TWO STEP CRUSHING & MILLING – CARBON



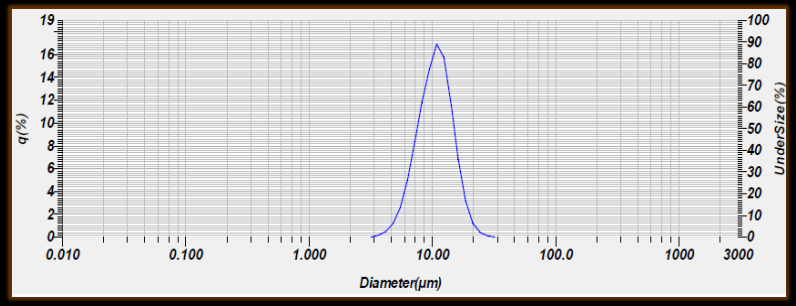
Jet Milled Carbon – 29 µm



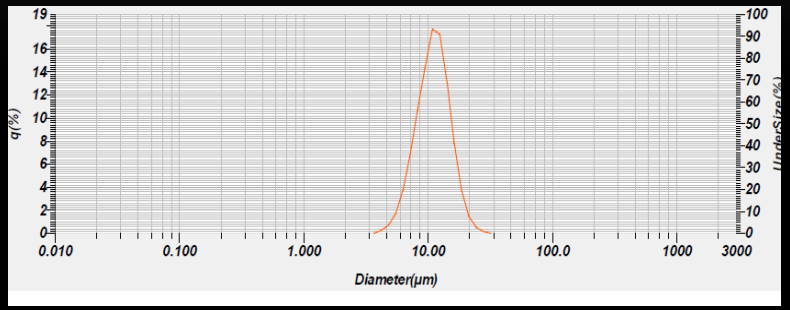
Jet Milled Carbon 29 µm

TWO STEP CLASSIFICATION - SILICA

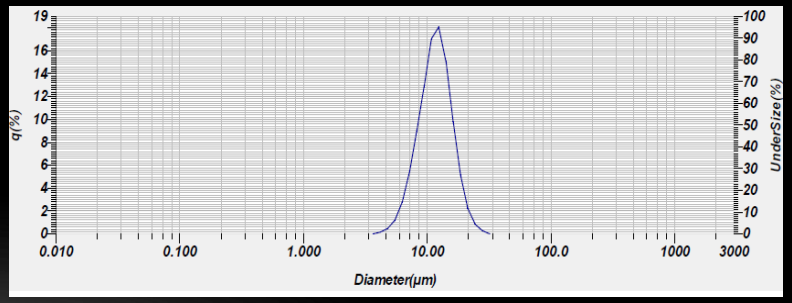
Raw Material - 10.97 µm



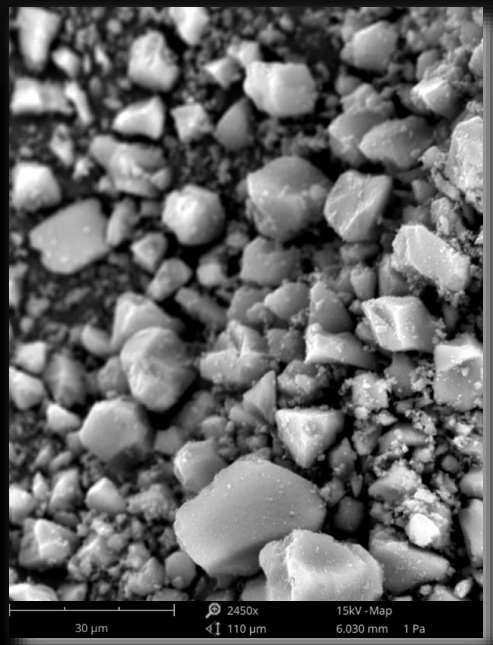
First Pass Classification – 11.43 µm



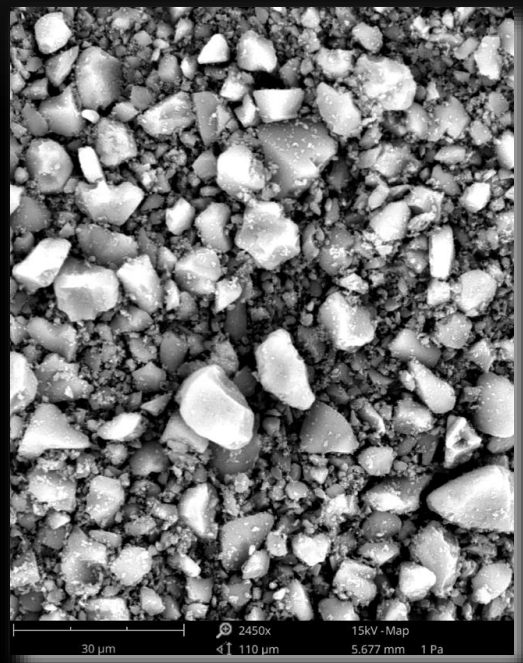
Second Pass Classification – 12.08 µm



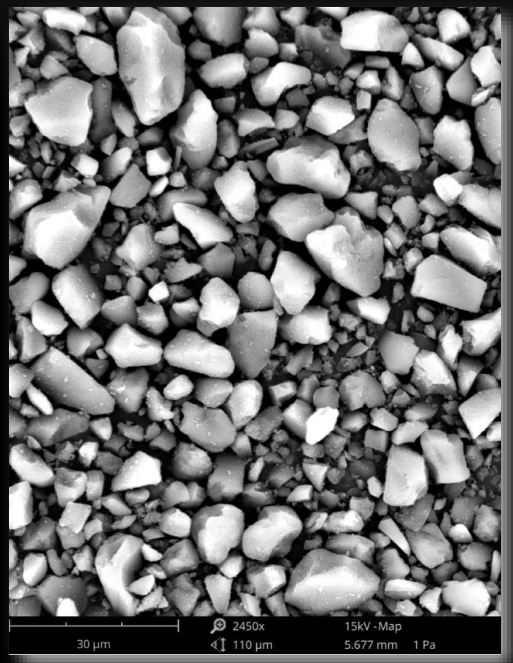
TWO STEP CLASSIFICATION - SILICA



Raw Material
10.97 µm



First Pass Classification
11.42 µm

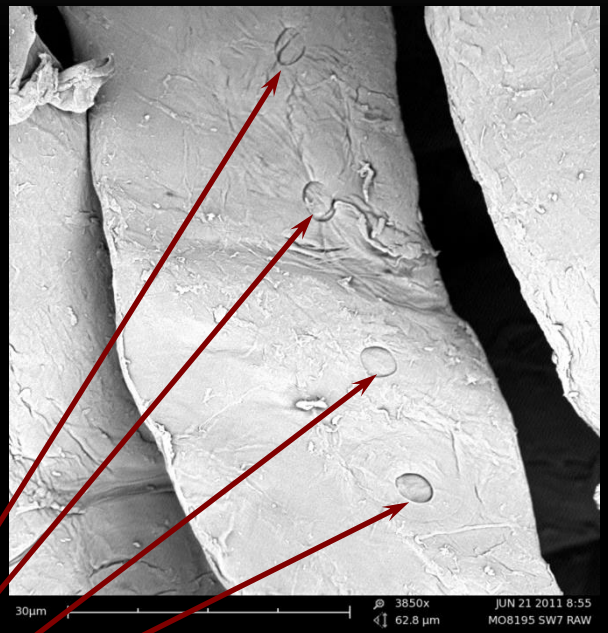


Second Pass Classification
12.08

BALL & JET MILLING OF CELLULOSE FIBER

465x Magnification

1160x Magnification



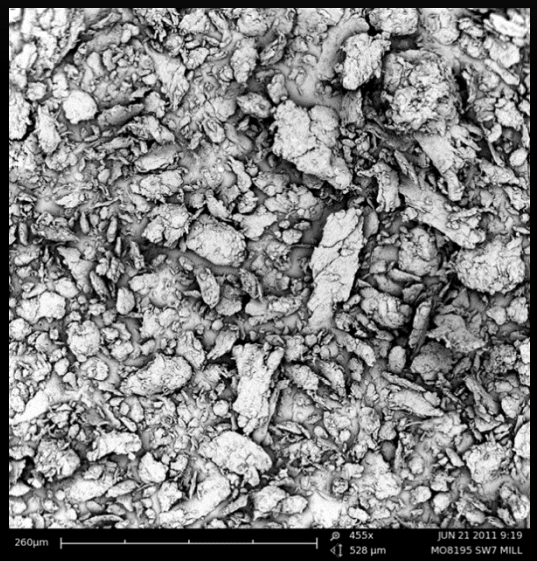
3850x Magnification

Interesting circular feature noticed on ribbons [3 to 5 mm]

CELLULOSE GRINDING RESULTS

Cellulose Fiber Untreated

Jet Milled Fiber



Ball Milled Fiber

SUMMARY

Jet Milling & Air Classification

- Can provide tight distributions at 1-75 microns
- Optimization can require multiple steps
  - Grinding Methods
  - Classification Steps
- Final results are material dependent
- Be prepared for special processing (tricks) to get the optimum final product

Contact Information:
aveka@aveka.com
651-730-1729