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# A Cool Approach to Size Reduction

Cryogenic grinding solutions can be used to produce fine particles in multiple applications.

## Web Exclusive

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■ **Laboratory Evaluation of Various Grinding Systems**  
The performance characteristics of several different milling systems, including the turbo mill, were compared by the cryogenic grinding of different materials. Particle size reduction efficiency was evaluated and compared for the various milling systems, including a hammer mill, attrition mill, pin mill and a turbo mill.

By Jon Trembley, Air Products

**A**s market demand for finer particles grows, process industries are exploring grinding technologies that are capable of higher throughputs and maximum yields. Historically, cryogenic grinding solutions have been used for hard-to-grind or specialty materials. Recent advances, however, mean they can be employed to produce ultra-fine particles used in the manufacture of high performance plastics and polymers.

Since the early 1990s, cryogenic grinding technology has been used by the waste recycling industry to produce rubber crumb. The main advantage of this

technology is that by cooling the material to cryogenic temperatures using liquid nitrogen (LIN), it becomes more brittle and can be broken up more easily into small particles using less energy. The same technology also has been widely used in the production of plastics that are used to make powder coatings, plastisols, textile coatings and carpet backing, to name a few.

For the plastics industry, cryogenic grinding typically is used to reduce particle size before mixing or formulating materials. Most commonly, it is used in the production of thermoplastics such as nylon, polyvinyl chloride (PVC), polyethylene and polypropylene.

When compared to other technologies, cryogenic grinding systems generally can increase throughput by as much as 100 percent while maintaining the same particle size distribution. Alternatively, they can achieve finer grinding, at the same throughput, while narrowing product particle size distribution. Either way, there are clear advantages to cryogenic grinding.

## Focus on Particle Size

As demand grows for more high performance plastics, the industry has been looking for more efficient, high-tech grinding solutions capable of producing even finer polymer particles that are more evenly distributed — all while maximizing throughputs.

For example, when producing plastic films for the food packaging industry, demand is growing for ultra-fine films that are resilient enough to withstand high temperatures when cooking and protective enough to keep foods fresh and well-contained. Using specific high-tech polymers, the film is considered an integral part of the total packaging solution. When combined with the right food container and mix of atmospheric gases, the packaging will extend the shelf life of the food product. For this kind of advanced film application, plastic particle size reduction is increasingly important and helps to ensure that the end product film delivers high performance and light weight.

## Selecting a Method

One of the most common methods of particle size reduction for the rubber and plastics industries is dry milling. This method involves the use of a “roll” to compress and yield particles of different sizes so they can be sorted and separated more easily. However, as polymer and plastics production becomes more complex and variable, and where the toughest polymers are used, dry milling alone is not always sufficient to achieve the ultra-fine particle size required.

Other particle size reduction technologies include controlled crystal growth or high density jet milling. Like dry milling, these solutions are easier to scale up but do not necessarily deliver the required throughputs

and ultra-fine particle distribution required by some production processes.

As demand for size reduction increases to particle sizes of less than 45  $\mu\text{m}$  (325 mesh), the plastics industry continues to explore cryogenic grinding. These systems achieve ultra-fine particle sizes and uniform particle distribution while maximizing production rates and minimizing overall operational costs.

## The Cryogenic Alternative

Amorphism is a phenomenon of materials where there is no long-range order of the molecules within the compound. Amorphous materials exist in two distinct states: rubbery or glassy. As applied in most industrial environments today, amorphism is the basis for cryogenic grinding. This behavior can be observed from the



*Fine grinding is possible with cryogenic grinding systems. These systems achieve ultra-fine particle sizes and uniform particle distribution while maximizing production rates and minimizing overall operational costs.*

thermal scan by an instrument such as a differential scanning calorimeter (DSC). The DSC identifies, among other properties of the material, the temperature where the material transitions between the glassy and rubbery states, commonly known as the glass transition temperature ( $T_g$ ). The purpose of the cryogenic fluid in dry milling is, therefore, to maintain the temperature below the glass transition temperature, or in the glassy state, where the material is brittle and prone to disintegration.

At room temperature, hammering a piece of glass will break it while hammering a piece

of rubber will not. The rubber will simply absorb the energy by momentarily deforming or stretching. However, if the same piece of rubber is submerged in liquid nitrogen, it will behave like brittle glass — easy to shatter with a hammer. This is because liquid-nitrogen-cooled rubber is below its glass transition temperature.

Used in the context of plastics particle reduction, the term ambient grinding applies to systems where the starting material is fed to the grinding mill at ambient or slightly below ambient temperature. In the case of cryogenic grinding, the starting material temperature is substantially reduced (to well below  $-112^\circ\text{F}$  [ $-80^\circ\text{C}$ ]) immediately prior to grinding. In order to apply the cryogenic fluid, a cooling conveyor must be specified. The cooling conveyor is operated as a closed system — often vacuum jacketed to minimize heat losses — that primarily provides mixing and residence time to effectively lower the temperature of the material to below its  $T_g$ . Liquid nitrogen is sprayed directly onto the product within the enclosed cooling conveyor. The flow of liquid nitrogen to the conveyor is adjusted to maintain a material setpoint temperature as measured at the conveyor or, in some cases, at another point in the process. Unlike ambient grinding, cryogen consumption contributes an additional operating expense that must be accounted for in the final product costs.

Other than the cryogenic cooling conveyor, there is little difference in terms of equipment between cryogenic and ambient grinding. Of course, materials of construction and other processing fluids must be compatible with cryogenic temperatures as well as the material to be processed.

Some commonly used mechanical milling systems include the hammer mill, attrition mill, pin mill and turbo mill. All of these systems use a combination of high speed and close clearance to effect particle size reduction through attrition and impaction.

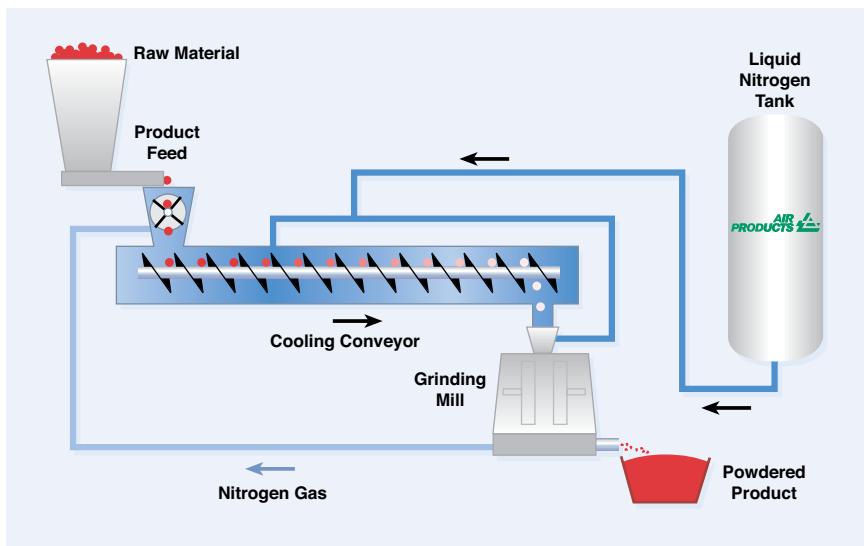
- In the case of a hammer mill, a screen of various hole sizes maximizes the residence time in the grinding zone until the desired particle size is achieved.
- The attrition and turbo mills do not use

screens but rather depend on the gap width between the rotating and stationary parts of the mill to control the resultant particle size.

- The pin mill, like the attrition and turbo mills, does not use a screen to control particle residence time, but unlike either of those mills, the pin mill uses two opposing, rotating surfaces with tightly spaced “pins” to drive particle size reduction.

Advanced cryogenic grinding solutions use a combination of size reduction mechanisms, including impact, attrition and particle-particle collision, to meet the specific needs of the production process. These systems also are highly flexible and easily can be adjusted to help regulate particle size. For example, by adjusting the grinding clearance to its most narrow setting, ultra-fine particles can be separated out, thus enhancing the overall efficiency of the grinding system.

Before selecting a new grinding system, processors are increasingly choosing to test alternative technologies before making any capital investment. Advance-testing services allow the manufacturer to compare grinding technology systems to determine the best solution for a particular product. Under laboratory conditions, it is possible to test whether the required production rates and particle size distribution can be achieved. Laboratory testing also provides insights into how the technology will scale up together with the required consumption of liquid nitrogen.



*With cryogenic grinding, the starting material temperature is reduced immediately prior to grinding. Also, to apply the cryogenic fluid, a cooling conveyor must be specified. The cooling conveyor is operated as a closed system that primarily provides mixing and residence time to effectively lower the temperature of the material to below its glass transition temperature.*

## Looking Ahead

Providers of cryogenic equipment continue to advance the capabilities of cryogenic grinding systems to develop solutions that are more effective and efficient. One particular area of research is designed to help demonstrate the operational efficiency of cryogenic grinding systems. For example, the research is seeking to demonstrate that the use of liquid nitrogen in conventional cryogenic grinding systems can enhance the overall energy efficiency of the system while producing finer particles as a result.

As research into this area continues to progress, cryogenic grinding is gaining rec-

ognition as a sophisticated yet efficient alternative, capable of meeting the increasingly complex process demands of today's plastics industry. **PC**

*Jon Trembley is COE (Centre of Excellence) lead for cryogenic applications, Advanced Technology Group, at Air Products in Basingstoke, United Kingdom. For more information, visit [www.airproducts.com/cryogenics](http://www.airproducts.com/cryogenics) or contact Air Products at one of the locations below.*



### North America, Corporate Headquarters Air Products and Chemicals, Inc.

7201 Hamilton Boulevard  
Allentown, PA 18195  
Tel 800-654-4567 or +1 610-706-4730  
Fax 800-272-4449 or +1 610-706-6890  
Email [gigmrktg@airproducts.com](mailto:gigmrktg@airproducts.com)

### Asia Air Products Asia Inc.

1001, 10/F, Sunning Plaza,  
10 Hysan Avenue, Causeway Bay,  
Hong Kong  
Tel (852) 2527-1922  
Fax (852) 2527-1827

### Europe Air Products PLC

Hersham Place  
Molesey Road  
Walton-on-Thames  
Surrey K12 4RZ - UK  
Tel +44 (0)1270 614314  
Email [apbulkuk@airproducts.com](mailto:apbulkuk@airproducts.com)