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A Comprehensive Review on Cryogenic Grinding

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ABSTRACT

The article aims to improvise the grinding process of elastic materials such as rubber, plastic, composite, metal, wax. These materials are wasted a great deal these days. Certain materials, such as plastic and synthetic rubber, have a negative impact on the environment. In essence, this research will support the responsible handling of the pollutants listed above. For instance, because they are sticky and soft, thermoplastics clump and clog screens when ground into tiny particles at ambient temperature. During the cryogenic grinding process, thermoplastics can be crushed into a powder that is appropriate for electrostatic spraying and other powder processes after being cooled with dry ice, liquid carbon dioxide, or liquid nitrogen. These methods have the advantages of higher productivity through particle size optimization, removal of caked products in the mill, and better fire resistance and product oxidation due to inert grinding.

Keywords : Cryogenic grinding, Cell disruption, Cryo milling, Freezer milling, Polymide

I. INTRODUCTION

The term "Cryogenics" comes from the Greek word meaning to create or produce by cold. It is the study of the growth and behaviour of materials at very low temperatures. It is believed that the freezing process begins at -150°C or below (123 K; -238°C). To obtain extremely low temperature refrigerants, such as (liquid helium 3- 3.19K), (liquid hydrogen 20.27K), (liquid neon 27.09 K), (liquid nitrogen 77.36 K), (liquid air 78.8 K), (Liquid Argon 87.24 K), (Liquid oxygen 90.18 K) are used [1]. The most predominant is liquid nitrogen, as it is inert in nature [2]. The cryogenic substance is stored in a Dewar flask. These tanks are low-pressure tanks, designed to maintain operating pressure and liquid phase content by ventilation, insulation or refrigeration. They have high liquid/gas expansion ratios (>700 for most refrigerants) [3]. Applications of cryogenics are numerous in fields ranging from gas liquefaction to biology, medical, space science, manufacturing and materials [3,4].

This paper aims to use these changes in the behaviour of materials to grind them into fine particles [5]. Cryogenic crushing technology can effectively crush most hard materials and can also facilitate the cryogenic recycling of multi-component materials and multi-component wastes. This process can easily overcome problems encountered in conventional grinding, such as heat generation, tensile stress generation, tool life reduction, grinding machine clogging and gelation, oxidation. The various processes are described as follows:

A. Cryogenic grinding is the process of cooling or freezing materials and reducing them to small particle sizes. Because almost all materials become brittle when exposed to cold. Cryogenic size reduction uses the cold energy available from a defined cryogenic liquid to cool, embrittle and inert materials before and during grinding. This overcomes the difficulties all elastic materials encounter when grinding at room temperature, i.e. because they soften and coalesce into clumps and clog the sieve [5].

B. Grinding with Freezing is a type of cryogenic grinding that uses electromagnetism to grind the sample [6]. The solenoid moves the grinding material back and forth within the vial, grinding the sample to a level suitable for analysis. Since the sample is arc milled at liquid nitrogen temperature (-196°C), this method of grinding is particularly helpful for processing temperature-sensitive materials [7].

C. A cold slurry is used to grind metal particles or other samples, such as volatile materials that are sensitive to temperature, in a manner similar to mechanical grinding or at cryogenic temperatures depending on the processing parameters to obtain the particles have a microscopic structure. The grinding bowl of the cryo-mill performs radial oscillation in a horizontal position. Because of the grinding ball's inertia, the high-energy impact crushes the material sample at the rounded ends of the grinding jar. Throughout the procedure, liquid nitrogen is used to continually chill the jar. Conventional traditional grinding has a number of drawbacks, including excessive heat production, the introduction of tensile residual stresses, a decrease in tool life, and oxidation and related deterioration that clogs and gums up the mill [8].

The freezing process also has a unique ability to recycle difficult-to-separate materials. Freeze grinding is the method of grinding herbs into powder at sub-zero temperatures, from zero to minus 700°F. Herbs and spices are frozen in liquid nitrogen as they are ground. . This process does not damage or change the chemical composition of the plant or grain in any way. The conventional grinding process does not use a cooling system that can reach 200°F.

These high temperatures can reduce volatile and heat-sensitive components in herbs and spices. The freeze-dried grinding process starts with air-dried herbs, instead of freeze-dried herbs. Solid materials are crushed or pulverized using a hammer mill. consumable crusher, granulator or other equipment. Smaller particle sizes are often necessary to improve subsequent solids processing, such as when mixed with other materials. By cooling to cryogenic temperatures with liquid nitrogen, they can become brittle and easily break into small particles. Various studies have been carried out on conventional and cryogenic grinding methods (1-6). A scientifically controlled study using two genotypes of coriander was carried out at the National Seed Spice Research Centre, Ajmer, comparing frozen grinding methods and conventional grinding methods. (7-8) Freeze grinding [6] has been shown to have a significant effect on the active ingredient content of herbs. Test results showed an average increase of 15.6% in the tested ingredients in the four medicinal herbs when cryogenically ground. The range is between 10.7% and 21.8%, which shows that some herbs are more affected than others by the temperature at which they are ground. Cryogenic grinding offers higher production efficiency, lower energy consumption, finer particle size, more uniform particle distribution, lower grinding costs. Does not generate heat, is good for grinding spices and creates an inert atmosphere, eliminating the possibility of oxidation [1,2].

II. Method of Working

The material is cleaned manually. After that it is being added to the hopper. Then it enters the vibratory feeder, which has the capacity to regulate the feed rate, from the hopper's outlet. The screw conveyor is sprayed with liquid nitrogen from the storage container; the conveyor drive's speed may be adjusted to control how long the material stays in the conveyor [2]. When the mill is running, the material is crushed between the studs and emerges as a ground product through an optional filter.

[8,9]. The ground product is gathered in a collecting bin located at the base of the mills. The cyclic process is maintained by sucking the vaporized nitrogen from the mill via the filler assembly in the feedback mill using a centrifugal blower [1].

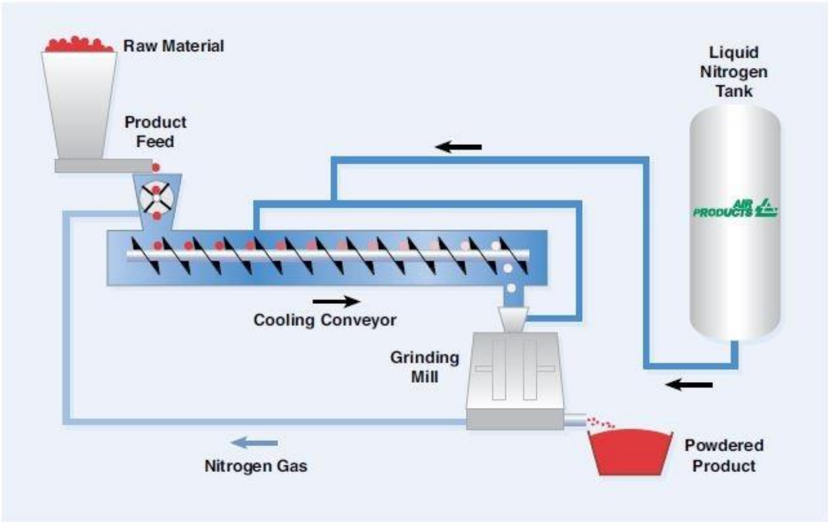

Fig.1 Schematic of cryogenic grinders [10]

A schematic illustration of a different kind of cryogenic grinder that runs on liquid nitrogen is displayed in Fig. 1. This provides a thorough understanding of the parts of a standard cryo-grinder. It consists of a liquid nitrogen container, a dynamometer, flexible piping, a grinder tab, a pressure gauge, a nozzle and a pressure valve in addition to a cover grinding wheel.

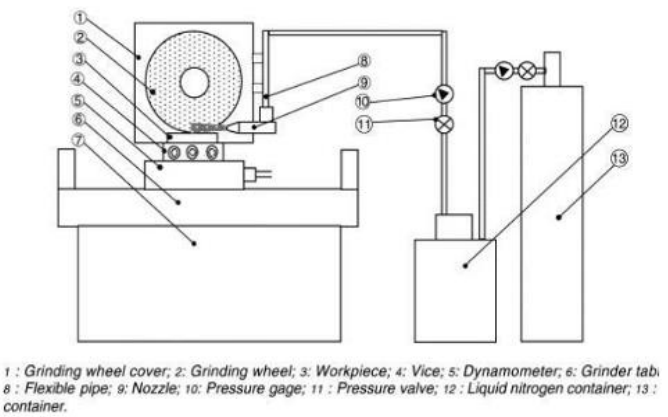

Fig. 2 Schematic of cryogenic grinders [11]

Cryogenic grinders produce particles with a more uniform distribution and a greater output rate. The testing results fluctuate depending on the size and kind of feed material used as well as any modifications made to the cryogenic grinding machine's design [3].

Table 1 Specifications for Cryogenic grinders

Power consumption	Power consumption
160 watts	160 watts
W*H*D	W*H*D

III. Processing Results

The plastic pellets of polyethylene or polyamide are weighed into the mill using a dosing wheel. Normally, the thermoplastics would melt under the grinding heat, making fine-particle grinding impossible. Cryogenic gases, on the other hand, stop this from happening by embrittling the material in a cooling conveying screw. The gas and the plastic that has been cryogenically crushed are gathered in a container [12]. A cellular wheel sluice is used to further process the ground product. After being filtered, the mill gas is expelled after being cleaned. For heat integration, the leftover gas is recycled back into the mill. Thus, the polyamide [8] experimental result employing the Linde cryogenic grinding machine is provided below.

Table 2 Cryogenic grinding for Polyamide

Particle size	Particle size
80μm	80μm
Production rate	Production rate
772 lb./hr.	772 lb./hr.

Specialized for cryogenic grinding is the Cryo-mill. Liquid nitrogen from the integrated cooling system is continuously poured into the grinding jar prior to and during the grinding operation. As a result, volatile components are maintained and the sample becomes embrittled [1,9]. The system is continuously refilled with liquid nitrogen, precisely the right amount via an auto fill system, to maintain the system's temperature at -196°C. A high impact ball milling power produces an ideal grinding efficiency. The auto fill method greatly increases the safety of cryogenic grinding by preventing direct contact with LN2 [3]. For volumes up to 20 ml, the Cryo-Mill is the ideal grinder due to its flexibility, which includes cryogenic, wet, and dry grinding at ambient temperature. Utilizing RETSCH cryo-mills, processed data for Plastic and (Copper + 10%Nb) is noticed [3,5].

The surrounding process typically uses a set of high-capacity conventional crushers and the fed material is ground into small particles [13]. It is common to produce 10 to 30 mesh material using this relatively inexpensive process to produce relatively large scraps. Several crack crushers are often used in series. Typical productivity is 2,000 to 2,200 pounds per hour for 10 to 20 nets and 1,200 pounds per hour for 30 to 40 nets. The finer the desired grain, the longer the material circulates through or through the mill. Additionally, multiple grinding passes may be used to reduce particle size [4].

Actual processes therefore demonstrate that the conventional process produces material with irregular and irregular grain shapes. In addition, this process generates a significant amount of heat in the rubber during processing [7,14]. Extremely high temperatures can degrade rubber quality and if not cooled properly, burning can occur during storage [15,16].

On the other hand, the cryogenic grinding process produces quite smooth fracture surfaces [7]. Little or no heat is generated during this process. This results in less material degradation. In addition, the most important characteristic of this process is that almost all fibres or steel are released from the rubber, resulting in a high usable product yield [17,18].

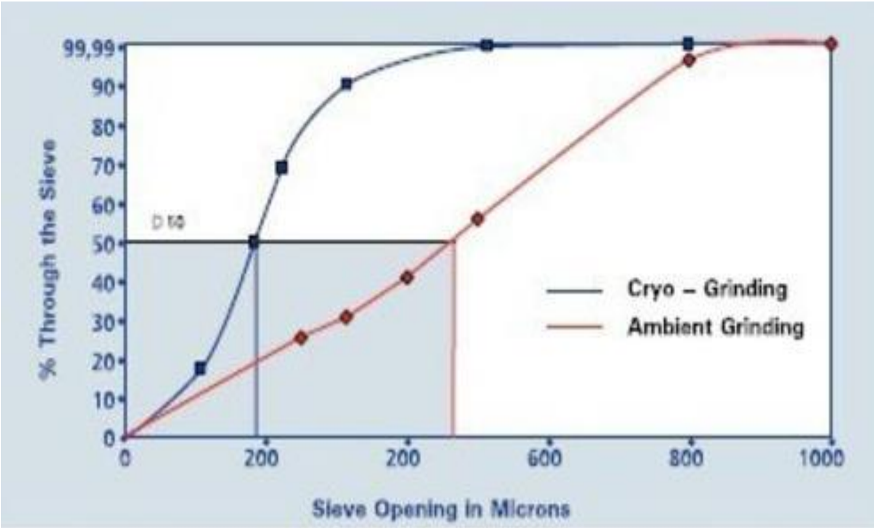

Fig. 3 Comparison between Grinding Process [8]

V. Application of Cryogenic Grinding

- Cryogrinding of steel

Cutting zones experience excessive temperature rise due to the significant quantity of heat created during high speed and feed rate machining/grinding. To solve this issue, the grinding site is given liquid nitrogen.

- Thermoplastics and Thermosets

In addition to synthetic rubber, nylon, PVC, and polyethylene are frequently utilized in powder form for a range of purposes. [8,2].

- Adhesives and Waxes

To avoid some materials becoming sticky and pliable, which cannot be achieved with traditional grinding explosives.

- Spices Production

To get the maximum taste, colour and retention of volatile contents (like phenolics, flavonoids, oil content, antioxidant etc.) [8], cryo-grinding is used to crush the spices in powdered form [19,20].

- Explosives

To grind the TNT (explosive ingredients) below the point of ignition.

- Other uses
  - Reducing fine particles for elastomers and thermoplastics.
  - In an environment of inert gas, oxidizable materials are best protected.

- Recycling the composite ensures both the separation of individual components and good quality, as does the treatment of manufacturing leftovers.
- Another technique used in microbiology to recover proteins from plant or animal tissues is cryogenic grinding, commonly known as cell disruption.

VI. Conclusion

Based on the research, it can be said that fracture surfaces produced by cryogenic grinding are generally smooth. The method produces little to no heat. As a result, the material deteriorates less. Other than this, the technique satisfies the requirements for fineness and uniform distribution of a specific sized particle; it can be changed with the appropriate configuration of cryogenic grinders. The material is shielded against oxidation and rancidity during manufacture because it is done in an inert atmosphere. In comparison, the energy consumption and cost of the cryogenic grinding process are lower. Additionally, the production rate is increased.

VII. Future Aspects

Given the escalating cost of energy and raw materials, a cost-effective method of recycling difficult and composite materials is through the use of cryogrinding technology. Compared to traditional grinding, it offers a number of important advantages that also raise the product's value. If the cost of liquid nitrogen is not too high, cryogrinding is also a financially feasible option. The method may also be readily expanded to PVC and industrial waste plastics processing to recycle non-biodegradable materials.

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