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A Review on Cryogenic Grinding

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Abstract*: The paper aims in improvisation of the grinding process for elastic materials like rubber, plastic, composites, metals, waxes etc. Nowadays, we find a lot of wastage of these materials. Some of them like plastic, artificial rubber composites are very much harmful for our environment. This research will basically help in cautious use of the above mentioned pollutants. For example, Thermoplastics are difficult to grind small sized particle at ambient temperature because they are soften adhere in lumpy masses and clog screens. In cryogenic grinding when thermoplastic is chilled by dry ice, liquid carbon dioxide or liquid nitrogen they can be finally grounded to powder suitable for electrostatic spraying and other powder processes. Advantages of these processes are to increase productivity through optimized particle size, elimination of caking product within the mill, increases protection from the fire and product oxidation due to inert milling atmosphere*

Keywords: Cryogens, Cell disruption, Cryogenic grinding, Polyamide, Cry milling, Freezer milling

I. INTRODUCTION

The Greek phrase for creation or manufacture using cold is where the term "cryogenics" comes from. It is the study of how materials behave and are produced at extremely low temperatures. Although it is not precisely defined, scientists think that cryogenics begins at -150 0C (123 K; -2380C) or lower.Cryogens such as liquid helium (3.19K), liquid hydrogen (20.27K), liquid neon (27.09K), liquid nitrogen (77.36K), liquid air (78.8K), liquid argon (87.24K), and liquid oxygen (90.18K) are used to reach extremely low temperatures. Since liquid nitrogen is inert by nature, it is the most common. Dewar flasks are used to hold cryogens. These vessels are low pressure tanks, designed to maintain the operating pressure and contents within liquid phase by venting, insulation, or refrigeration. They have large liquid to gas expansion ratios(>700 for most cryogens).

Applications for cryogenic engineering are many and span a wide range of industries, including manufacturing, material science, biology, medicine, and space.

The purpose of this work is to discuss how to exploit these material behaviour changes to grind materials into fine particles. Most difficult materials can be effectively ground using cryogenic grinding technology, which also makes it easier to recycle multi-component materials and trash. The issue of heat that arises in traditional grinding can be readily resolved by this method.

creation, tensile stress introduction, reduced tool life, mill clogging and gumming, and oxidation. The different procedures are explained as follows:

1) The technique of chilling or cooling materials to reduce them to tiny particles is known as cryogenic grinding. Because practically all materials embrittle when they come into contact with frigid temperatures. Cryogenic size reduction cools, embrittles, and inerts materials before and/or during the grinding process by using the cold energy from specific cryogenic fluids. Because they are softer and stick to lumpy masses and clog screens, this helps to overcome the challenges of all the elastic materials seen in ambient temperature grinding.

2) A solenoid is used in freezer milling, a form of cryogenic milling, to grind materials. To ground the sample down to analytical fitness, the solenoid oscillates the grinding medium in the vial.

Samples that are sensitive to temperature, such as those that are arc milled at liquid nitrogen temperature (-1960C), benefit greatly from this form of milling.

Cryomilling is a variation ofmechanical milling, in In order to achieve microstructured particles, metallic powder or other samples—such as temperature-sensitive samples with volatile components—are ground in cryogen slurry or at a cryogenic temperature under processing conditions. The cryomill's grinding jar oscillates radially while in a horizontal

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position. The grinding ball's inertia leads it to strike sample material at the rounded ends of the grinding machine with tremendous energy. jar and crushes it. Throughout the process, liquid nitrogen is used to continually cool the jar. High heat generation, the introduction of tensile residual stresses, a loss in tool life, clogging and gumming of the mill oxidation, and related degradation are some of the issues that come with traditional conventional grinding.

II. HOW CRYOGENIC GRINDERS OPERATE

After being manually cleaned, the material to be ground is placed into the hopper. The material enters the vibratory feeder from the hopper's outlet. The feeder may regulate the feed rate and is positioned with a slight inclination towards the helical screw conveyor's entrance. The screw conveyor is sprayed with liquid nitrogen from the storage container; the drive's speed, or conveyor drive, can be adjusted to maintain the material's duration in the conveyor.

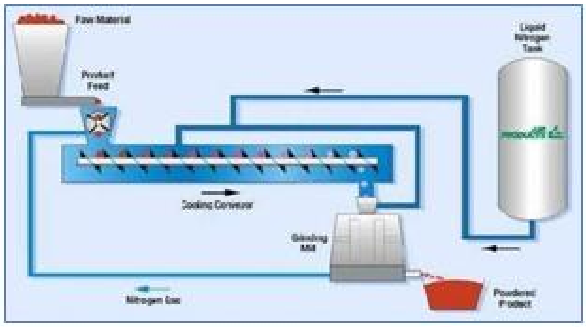

Fig 1.1 Schematic of cryogenic grinders

The material is ground when it passes through an optional filter after being crushed between the studs and cones while the mill is operating.The material is ground when it passes through an optional filter after being crushed between the studs and cones while the mill is operating.The ground product is collected in a collecting bin located at the bottom of the mills.A centrifugal blower draws the mill's vaporised nitrogen, which is then passed through the fed-back mill's filler assembly to complete the cycle.

Fig 1.2 Solenoid operated Cryogenic grinder(Freezer milling)

A schematic illustration of a different kind of liquid nitrogen-powered cryogenic grinder is displayed. This provides a thorough understanding of the parts of a standard cryogrinder. A dynamometer, a grinder tab, a flexible pipe, a nozzle, a pressure gauge, a pressure valve, a liquid nitrogen container, and a grinding wheel and cover are among its components.

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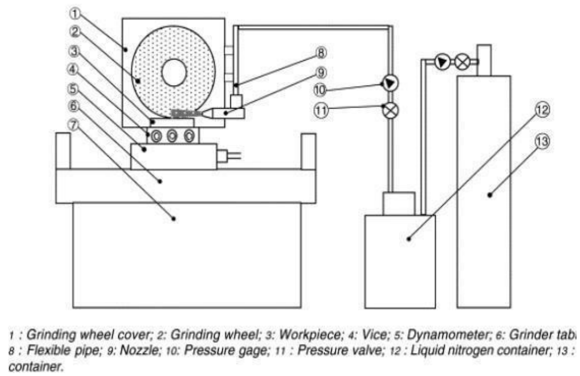

Fig 1.3 Schematic of cryogenic grinders

III. PERFORMANCE DATA

In addition to their more consistent particle dispersion, cryogenic grinders have a higher production rate. The experimental data vary with different sized, nature of feed material and also with change in configuration setting of cryogenic grinding machine.

Power consumption	160 watts
W*H*D	385*370*570mm
Net weight	Approx.46 Kg

Table1.1 Specifications for Cryogenic grinders

Field of application	Size reduction, Homogenization
Feed material	Hard, Brittle, Soft, elastic and fibrous
Feed size	Up to 8mm
Final fineness	Approx. 5 microns
Sample volume	Max.20ml
Mean time	Pre-cooling time 10 min Grinding 1min

Table 1.2 Technical data (Specifications of a cryogenic grinder)

IV. PROCESSING RESULTS

The polyethylene or polyamide plastic pellets are meter-fed into the mill by a dosing wheel. The thermoplastics would typically melt under the grinding heat, avoiding the potential for grinding of tiny particles. However, by embrittling the material in a cooling conveying screw, cryogenic gases stop this from happening. The gas and the plastic that has been cryogenically crushed are gathered in a bin. A cellular wheel sluice is used to further treat the ground-up material. After passing through a filter, the mill gas is discharged. For heat integration, the leftover gas is recycled back into the mill. Therefore, the experimental result employing a linde cryogenic grinding machine for polyamide is shown below.

Particle size	80µm
Production rate	772 lb./hr.
Nitrogen consumption	1.25 lb./lb. polyamide
Driving power	21KW(28 hp)

Table 1.3 Cryogenic grinding for Polyamide

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The Cryomill is tailored for cryogenic grinding. The grinding jar is continually cooled with liquid nitrogen from the integrated cooling system before and during the grinding process. Thus the sample is embrittled and volatile components are preserved. The liquid nitrogen circulates through the system and is continually replenished from an auto fill system in the exact amount which is required to keep the temperature at -1960C. Powerful impact ball milling results in a perfect grinding efficiency. The auto fill system avoids direct contact with LN2 and makes cryogenic grinding very safe. Its versatility (cryogenic, wet and dry grinding at room temperature) makes the CryoMill the idea grinder for quantities up to 20 ml. Processed data for Plastic and (Copper + 10%Nb) is observed using RETSCH cryomills.

A] Application field: Chemistry / Plastics Material:
Mixture of plastic granules. Feed size: 0-5 mm Feed quantity: 8 g
Material specification(s): elastic, temperature sensitive
Configuration(s): Grinding jar stainless steel 50 ml for CryoMill; grinding ball stainless steel 25 mm, Frequency 25 Hz
Time: 5 min. (for grinding, 10 min pre-cooling) Achieved result(s): 500µm

Fig1.4 Grain size before and after grinding

B] Application field: Cu + 10 % Nb
Feed size: 0-200 µm Feed quantity: 7 g
Material specification(s): Ductile Configuration(s): Grinding jar stainless steel 50 mm; Grinding ball (stainless steel) 25mm; Grinding ball stainless steel 10 mm Frequency: 25 Hz
Time: 3 x 20 min. (grinding, sampling every 20 min, 10 min precooling)
Achieved result(s): 200µm Remark(s): After > 40 min a pressure increase inside the grinding jar has to be expected.

Fig1.5 Cryo-Mill

V. A COMPARISON OF CONVENTIONAL AND CRYOGENIC GRINDING METHODS

The ambient method typically grinds the feed material into tiny particles using a traditional high-powered mill set. This comparatively low-cost process is frequently used to create material with a mesh size of 10 to 30 to create comparatively large crumb. It is common practice to employ many cracker mills in sequence. Yields for 10–20 mesh are typically 2,000–2,200 pounds per hour, whereas yields for 30–40 mesh are 1200 pounds per hour. The longer the material is allowed to run on or in the mill, the finer the desired particle. Additionally, the particle size can be decreased by using several grinds.

The manufacturing of 40 mesh material is the process's lowest feasible limit. An air separation or an air table must be used to remove any fibre and superfluous material. A magnetic separator is used to separate metal. The final product is

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reasonably clean. Typically, cryogenic grinding begins with chips or a fine crumb. This is cooled with a cryogenic chiller. A mill is used to process the frozen material. Usually, this is a paddle mill. A variety of particle sizes make up the finished product, which is then sorted and either used exactly as is or passed on for more size reduction. The average procedure produces between 4,000 and 6,000 pounds per hour.

Therefore, real-world procedures demonstrate that the traditional method yields a material with a jagged, uneven particle form. Additionally, a considerable amount of heat is produced in the rubber during manufacturing. Rubber can be deteriorated by excessive heat, and if it is not adequately chilled, it may catch fire while being stored.

On the other side the cryogenic grinding process produces fairly smooth fracture surfaces. Little or no heat is generated in the process. This results in less degradation of the material. In addition, the most significant feature of the process is that almost all fibre or steel is liberated from the rubber resulting in a high yield of usable product.

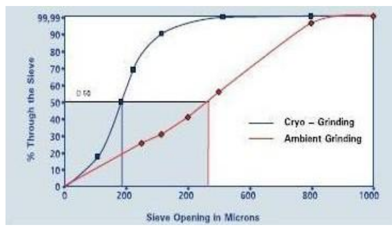

Fig.1.6 Comparison between Grinding Process

Advantages of Cryogenic Grinding

Increased productivity through optimized particle-size and increased throughput.
Elimination of caking product within the mill.
Decreased wear on grinding equipment.
Separation of composite materials within the mill.
Higher production rate.
Lower energy consumption.
Fine particle size.
More uniform particle distribution
Lower grinding cost.
Decreased wear on grinding equipment. - Improved
pouring properties due to finely grounded materials.
Reduction in microbial load.

Application of Cryogenic Grinding

Cryogrinding of steel
The large amount of heat generated during machining/grinding at high speed and feed rate raises the temperature at cutting zones excessively.
To overcome this problem liquid nitrogen is fed to the grinding spot.
Thermoplastics and Thermosets
To which nylon, PVC, polyethylene, synthetic rubber are commonly used in powder form , but not limited to ,a variety of applications such as adhesives, powdered coatings, fillers and plastic sintering and molding.
Adhesives and Waxes
To avoid pliable and sticky of certain materials which is unable in conventional grinding
To grind the explosive materials(TNT) below their ignition temperature
Other Application
Fine particle size reduction for thermoplastics and elastomers.
Oxidizable materials are best protected in an inert gas atmosphere.

The treatment of production residues guarantees high quality as well as the separation of individual components by recycling the composite.

Cryogenic grinding also used in microbiology where plant or animal tissues are broken called method of cell disruption for protein extraction.

VI. FUTURE PROSPECTS

As the cost of raw materials and energy is increasing day by day, it is very necessary to use optimum quantity at the same time getting the required quality.

By using CryoGrinding technology these aspects can be met efficiently. By using this we can also recycle tough and composite materials.

It has many significant advantages over conventional grinding .This also leads to value addition to product. CryoGrinding iseconomically viable, if liquid nitrogen costs are not formidable.

The technique can be easily extended toprocessing of PVC and industrial waste plastics in view of recycling of non-biodegradable materials.

VII. CONCLUSION

From the research it can be concluded that the cryogenic grinding process produces fairly smooth fracture surfaces. Little or no heat is generated in the process. This results in less degradation of the material. Apart from this Fineness and uniform distribution of particular sized particle is met in this process according to requirement; it can be adjusted using suitable configuration of Cryogenic grinders. As the production is in inert atmosphere the material is protected from oxidation and rancidity. Comparatively the cost of Cryogenic grinding process is less and energy consumption is reduced. Production rate is also improved.

REFERENCES

[1]. Rohit Saxena, Cryogenic Grinding: A Physical Technique To Retain Volatile Content In Natural Products, Department of Humanities and Science.

[2]. Charles Astafan and Rudi Kohler (October 1995.)Comparison of Scrap Tire Processing Technologies: Ambient Processing vs. Cryogenic Processing,'ACS Rubber Division MeetingCleveland', paper #35

[3]. S.S Thipse, Cryogenics, Narosapublication, pp(149-157) Mc graw Hill encyclopedia of science and technology,pp(341-346).