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Review Article

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.*

1. Introduction

The term 'Cryogenics' originates from the Greek word which means creation or production by means of cold. It is the study of the production and behavior of materials at very low temperature. It is not well defined but scientist believe that cryogenics start at or below -150 ^{0}C (123 K; -238^{0}C).To achieve extremely low temperature cryogens, like (liquid Helium 3-3.19K), (liquid Hydrogen 20.27K), (liquid Neon 27.09 K), (liquid Nitrogen 77.36K), (liquid Air 78.8K), (liquid Argon 87.24K), (liquid Oxygen 90.18K) are used. The most predominant is liquid nitrogen, since it is inert in nature. Cryogens are stored in Dewar flask. 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).

The applications of cryogenic enginnering are numerous in various fields starting from liquefaction of gases to biological, medical, space, manufacturing and material science.

This paper aims at the use of these changes in behavior of materials to grind them in fine particles. Cryogenic grinding technology can efficiently grind most tough materials and can also facilitate cryogenic recycling of multi component materials and multi component scrap. This process can easily overcome the problem faced in conventional grinding like heat generation, introduction of tensile stresses, less tool life clogging and gumming of mill, oxidation. The various processes are describe as-

1) Cryogenic Grinding is the process of cooling or chilling materials and reducing it to small sized particles. Since almost all material embrittle when exposed to cold temperature. Cryogenic size reduction utilizes the cold energy available from defined cryogenic fluids to cool, embrittle and inert materials prior to and or during the grinding process. This helps to overcome the difficulties of all the elastic materials observed in ambient temperature grinding i.e. because they are soften adhere in lumpy masses and clog screen.
2) Freezer milling is a type of cryogenicmilling that uses a solenoid to mill samples. The solenoid moves the grinding media back and forth in the vial, grinding the sample down to analytical fitness. This type of milling is especially useful in milling temperature sensitive samples as sample arc milled at liquid nitrogen temp (-196^{0}C).
3) Cryomilling is a variation ofmechanical milling, in which metallic powder or other samples such as temperature sensitive samples with volatile components are milled in cryogen slurry or at a cryogenic temperature under processing parameters so to attain micro structured particles. Grinding jar of cryomill performs radial oscillation in horizontal position. The inertia of grinding ball causes them to impact with high energy on samples material at the rounded ends of grinding

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jar and pulverizes it. Jar is continuously cooled with liquid nitrogen during process. There are various problems associated with conventional traditional grinding such as, high heat generation , introduction of tensile residual stresses , reduction in tool life & clogging and gumming of the mill oxidation and related degradation.

2. Working of Cryogenic grinders

Material to be grounded is cleaned manually and fed into the hopper. From the exit of the hopper the material enters into the vibratory feeder, which ispositioned with a small inclination towards the entry of the helical screw conveyor, it has ability to control the feed rate. Liquid nitrogen from the storage container is sprayed into the screw conveyor; the time of stay of material in the conveyor can be maintained by varying the speed of the drive i.e. conveyor drive.

When the mill is running, the material gets crushed between the studs and cones out through an optional sieve as a ground product.When the mill is running, the material gets crushed between the studs and cones out through an optional sieve as a ground product.To the bottom of the mills a collecting bin is housed where the ground product gets collected.The vaporized nitrogen from the mill is sucked by a centrifugal blower and through the filler assembly in fed back mill, and the cyclic process is continued.

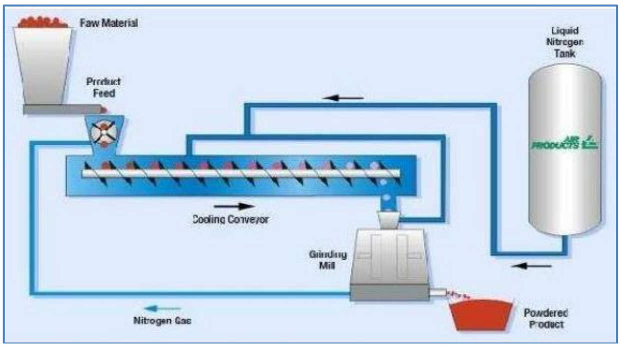

Fig 1.1 Schematic of cryogenic grinders

Fig 1.2 Solenoid operated Cryogenic grinder(Freezer milling)

Schematic representation of another type cryogenic grinder which uses liquid nitrogen is shown. This gives detailed idea of components of a typical cryogrinders. It consists of grinding wheel, cover grinding wheel, Dynamometer, grinder tab, flexible pipe, Nozzle, pressure gauge, pressure valve, liquid nitrogen container.

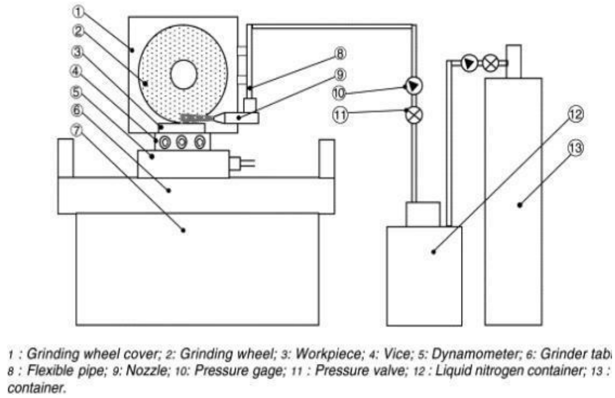

Fig 1.3 Schematic of cryogenic grinders

3. Performance Data

Cryogenic grinders have higher production rate along with it more uniform particle distribution. The experimental data vary with different sized, nature of feed material and also with change in configuration setting of cryogenic grinding machine.

Table1.1 Specifications for Cryogenic grinders

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

Table 1.2 Technical data (Specifications of a cryogenic grinder)

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

4. Processing Results

A dosing wheel meters the plastic pellets of polyethylene or polyamide into the mill. The grinding heat would normally melt the thermoplastics, preventing the possibility of fine-particle grinding. However, cryogenic gases prevent this by embrittling the material in a cooling conveying screw. The cryogenically ground plastic and the gas are collected in a bin. The pulverized product is then further processed through a cellular wheel sluice. The mill gas is purified with a filter and is released. The remaining gas is recycled back into the mill for heat integration. So, the experimental result is given below using linde cryogenic grinding machine for polyamide.

Table 1.3 Cryogenic grinding for Polyamide

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

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 -196^{0}C. Powerful impact ball milling results in a perfect grinding efficiency. The auto fill system avoids direct contact with LN_2 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

5. Comparison between Cryogenic and Conventional Grinding Process

The ambient process often uses a conventional high powered mill set and fed material is ground into a small particle. It is common to produce 10 to 30 mesh material using this relatively inexpensive method to produce relatively large crumb. Several cracker mills are often used in series. Typical yields are 2,000-2,200 pounds per hour for 10-20 mesh and 1200 pounds per hour for 30-40 mesh. The finer the desired particle, the longer the material is let to run on or in the mill. In addition multiple grinds can be used to reduce the particle size.

The lower practical limit for the process is the production of 40 mesh material. Any fibre and extraneous material must be removed using an air separation or an air table. Metal is used using a magnetic separator. The resulting material is fairly clean. Cryogenic grinding usually starts with chips or a fine crumb. This is cooled using a chiller, cryogenic. The frozen material is put through a mill. This is often a paddle type mill. The final product is a range of particle sizes which are sorted and either used as is or passed on and further size reduction performed. A typical process generates 4,000 to 6,000 pounds per hour.

Thus, practical processes prove that the conventional process produces a material with an irregular jagged particle shape. In addition the process generates a significant amount of heat in the rubber during processing. Excess heat can degrade the rubber and, if not cooled properly, combustion can occur upon storage.

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.

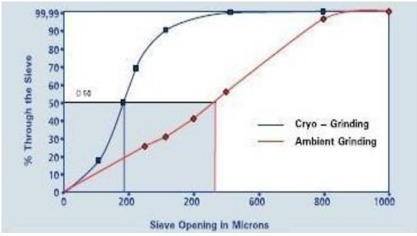

Fig.1.6 Comparison between Grinding Process

6. 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.

7. Application of Cryogenic Grinding

Cryogrinding of steel

a. The large amount of heat generated during machining/grinding at high speed and feed rate raises the temperature at cutting zones excessively.
b. To overcome this problem liquid nitrogen is fed to the grinding spot.

Thermoplastics and Thermosets

c. 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

d. To avoid pliable and sticky of certain materials which is unable in conventional grinding

Explosives

e. To grind the explosive materials(TNT) below their ignition temperature

Other Application

f. Fine particle size reduction for thermoplastics and elastomers.
g. Oxidizable materials are best protected in an inert gas atmosphere.
h. The treatment of production residues guarantees high quality as well as the separation of individual components by recycling the composite.
i. Cryogenic grinding also used in microbiology where plant or animal tissues are broken called method of cell disruption for protein extraction.

8. 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.

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.

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