CRYOGENIC COMMUNIATION SYSTEM


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Primary Examiner—Granville Y. Custer, Jr.
Attorney—Ronald B. Sherer et al.

ABSTRACT

A cryogenic comminution system is disclosed including a mixer-conveyor and a comminution mill wherein cryogenic liquid refrigerant is introduced into the mixer-conveyor to embrittle the material to be comminuted before the material is fed into the mill; and wherein auxiliary cryogenic liquid refrigerant is separately introduced into the mill in order to overcome heat generated in the mill, and thereby maintain the internal components of the mill at a predetermined low temperature.

2 Claims, 1 Drawing Figure
CRYOGENIC COMMINUTION SYSTEM

BACKGROUND OF THE INVENTION

The present invention relates to the field of grinding, pulverizing or size reduction, hereinafter collectively referred to as comminution. More particularly, the present invention relates to the comminution of relatively soft or resilient materials which are difficult or impossible to comminate in high speed mills such as, for example, polymeric and rubber materials including polypropylene, polyethylene, polyvinylchlorides, polyisobutylene and other natural or synthetic rubber materials, pigments and color concentrates herein-after collectively referred to as relatively non-brittle materials.

With regard to such relatively non-brittle materials, it has long been recognized that various refrigerants may be used to cool the material well below its embrittlement temperature, and thereby comminute the material at low temperatures. However, previous systems have been thermally and economically inefficient in that the material has been deeply subcooled well below its embrittlement temperature so as to attempt to overcome the large amount of frictional heat which is generated in a high speed mill. However, the residence time of the material in contact with the mill is so short that the material must be very deeply subcooled; i.e., 100°F to 150°F or more below its embrittlement temperature, in order to keep the mill sufficiently cold.

Thus, the deeply subcooled material gives up only a small fraction of its refrigeration value to the mill, and is discharged at excessively low temperatures which is highly wasteful of costly refrigerant.

Attempts have also been made to introduce the refrigerant directly into the mill, however, the short residence time of the material in the mill produces highly inefficient cooling of the material, which is equally wasteful of the costly refrigerant. That is, optimum speeds of comminuting can only be achieved when the material has had sufficient time in contact with the refrigerant so as to be embrittled before it is comminuted.

SUMMARY OF THE INVENTION

The present invention substantially reduces the amount of refrigerant by carefully controlled cooling of the material to, or only slightly below, its embrittlement temperature in a cooling zone, and separately supplying a controlled amount of auxiliary refrigerant into the mill to directly cool and maintain the internal components of the mill at an optimum operating temperature. In the preferred embodiment of the present invention, the cooling zone includes a refrigerant injection zone, and a subsequent equilibration zone, whereby the temperature gradient between the surface and core portions of the particles is substantially reduced before they are fed into the mill.

BRIEF DESCRIPTION OF THE DRAWING

The drawing is a simplified illustration of one embodiment of the cryogenic comminution system showing some of the components in cross-section.

DETAILED DESCRIPTION OF ONE PREFERRED EMBODIMENT

Referring to the drawing, numeral 10 indicates one form of a conventional mixer-conveyor having a rotating shaft 12, a screw 14 and a plurality of mixing blades which operate to mix and convey the particulate material 16 from the left-hand inlet end adjacent hopper 18 to the right-hand discharge end adjacent discharge duct 20. Of course, it is to be understood that other types of conventional mixer-conveyors may be employed, including, for example, plain or perforated screw conveyors, or vibratory conveyors so long as they are capable of agitating the particles and conveying them through an elongated, closed chamber such as that formed by housing 24 which may be of circular or U-shaped cross-section. In order to reduce wasteful heat leak and consequent loss of refrigerant, the housing 24 is preferably covered with a thermal insulation material 26, such as sponge rubber, foamed polyurethane, or other well known insulation materials. The mixer-conveyor may be horizontal, or inclined, and may be in the order of 5 to 10 feet long. Shaft 12 is preferably driven at a relatively low and variable speed by a motor 28, first gear reducer 30, variable speed pulley 32, belt 34, pulley 36, and a second gear reducer 37. Thus, the rotational speed of mixer-conveyor 10 may be widely varied, and is preferably in the range of 5 to 10 RPM which results in a residence time of the material in mixer-conveyor 10 in the range of 1 to 10 minutes for a mixer-conveyor having the above-indicated length of 5 to 10 feet.

In order to cool the relatively non-brittle material 16 to a temperature equal to or slightly below its embrittlement temperature, a liquefied cryogenic refrigerant is stored in a conventional cryogenic storage tank 38. As used in the present specification and claims, the term "cryogenic refrigerant" is intended to denote a refrigerant fluid having a normal boiling point below minus 100°F which includes, for example, liquefied carbon dioxide, liquefied air, various liquefied halogenated hydrocarbons, liquefied nitrous and nitric oxide, and liquefied noble gases such as helium and argon. However, for thermodynamic, safety and economic reasons, liquefied nitrogen having a normal boiling point of minus 320°F is preferred as the most ideal cryogenic refrigerant.

The liquefied cryogenic refrigerant, such as liquid nitrogen, is conveyed through insulated transfer lines 40, 42 and 44 to elongated spray header 46. Spray header 46 may comprise an elongated pipe having discharge ports 48 spaced along its length through which the cryogenic liquid refrigerant is injected into the mixer-conveyor. Alternatively, separate injection nozzles may be spaced along the mixer-conveyor so as to inject the cryogenic liquid into contact with material 16. In either event, it has been discovered that for optimum efficiency, one end of the liquid injection system should be positioned immediately adjacent the product inlet end, and the points of liquid injection should extend toward the discharge end for one-half to four-fifths of the length of the mixer-conveyor. That is, it is preferred that the cryogenic liquid injection portion of the mixer-conveyor should terminate before the discharge end of the mixer-conveyor so as to provide a portion wherein the particulate material is in contact with only the cold refrigerant vapors resulting from the vaporization of the cryogenic liquid refrigerant, and the particulate material should have a sufficient residence time in the vapor zone to enable the temperature gradient between the surface and the core of the particles to at least partially equilibrate. Thus, the preferred mixer-conveyor includes a cryogenic liquid injection zone, and an equi-
libration zone so that the entire mass of the particle is cooled to its embrittlement temperature, or slightly therebelow.

As previously indicated, the discharge end of mixer-conveyor 10 is provided with a discharge duct 20 through which the embrittled particulate material is discharged into the impact mill 50 which is illustrated as being of the conventional high-speed rotating hammer type. Of course, other types of well known comminution mills may be used such as, for example, other types of rotary impact mills, pin mills, or ball mills depending upon the type of particulate material and the final size reduction desired. In any event, the feed inlets to such mills usually include either an inclined feed chute, or a feed conveyor which may be connected to the discharge duct 20 of the mixer-conveyor either directly, or through an optional intermediate duct 22.

In the illustrated embodiment, the feed inlet to the mill comprises a relatively short feed conveyor 52 comprising a housing or duct 54 containing a feed screw 56 which is driven by a motor 58 through a gear reducer 60, variable speed pulleys 62, belt 64, and pulley 66. Whereas, the mixer-conveyor is relatively long and rotates at low speed in order to provide a relatively long residence time in order to cool the particulate material, feed conveyor 52 is relatively short such as, for example, in the order of two to ten inches, and the feed screw is driven at relatively high speed, such as in the order of 50 to 100 RPM. As a result, the residence time of the particulate material in discharge ducts 20, 22 and the feed conveyor 52 is very short, such as for example, in the order of one to ten seconds, and the volume of the feed conveyor filled by the particulate material is less than one-half of its total volume. Thus, the discharge ducts 20, 22 and high speed, partially filled, feed conveyor 52 provide an essentially open passage for the conduction of auxiliary cryogenic refrigerant directly into the mill as will now be described in detail.

Where an existing mill has such a feed conveyor, or an inclined feed chute, the preferred mode of auxiliary refrigerant injection is through an auxiliary transfer line 68 the discharge end of which is preferably provided with a spray nozzle 70 located within the feed conveyor or feed chute. However, if the mill does not have a feed conveyor or feed chute, auxiliary refrigerant line 68 may terminate within discharge ducts 20 or 22, or it may terminate directly within the mill itself, the latter two locations being illustrated in phantom line. Thus, the point of auxiliary refrigerant injection may be anywhere downstream of the mixer-conveyor, so long as the auxiliary refrigerant does not have sufficient contact time with the particulate material so as to appreciably subcool the particulate material, but rather, such that the liquid refrigerant goes immediately into the mill and into direct contact with the internal components of the mill. Thus, the mill is directly cooled by the auxiliary liquid refrigerant and the heat generated in the mill is overcome without overcooling the particulate material substantially below its embrittlement temperature.

Referring now to the refrigerant control system, main transfer line 42 is provided with a flow control valve 72 which may be of the on-off or modulating type, and which includes an actuator 74 for controlling the opening and closing movements of the valve. Actuator 74 is connected by an electrical or pneumatic signal line 76 to an indicator-controller 78 which is connected through a signal line 80 to a temperature sensor 82, such as a thermocouple, which is preferably located in the mill outlet. Thus, sensor 82 detects the discharge temperature of the comminuted particles, which is also an indication of the internal mill temperature, and indicator-controller 78 actuates controller valve 72 to increase or decrease the flow of refrigerant through main line 42 so as to maintain the discharge temperature of the comminuted material as warm as possible while still maintaining optimum size reduction of the material. That is, depending upon the composition of the material and the final size desired, the discharge temperature is preferably maintained within 30°F above or below its embrittlement temperature.

In order to properly proportion the amounts of refrigerant supplied to spray header 46 and auxiliary nozzle 70, refrigerant transfer line 44 includes a flow control valve 84, and auxiliary refrigerant transfer line 68 includes a flow control valve 86. A second temperature sensor 88 is positioned in the discharge portion of the mixer-conveyor adjacent discharge duct 20 and is connected via signal line 90 to a temperature indicator 92. Thus, the temperature of the embrittled particulate material discharged from the mixer-conveyor can be closely monitored and valve 84 may be regulated so as to cool the material to, or slightly below, its embrittlement temperature while also maintaining an optimum temperature of the internal components of the mill by regulating valve 86.

While the size of flow control valve 72 is selected such that its maximum flow rate is more than sufficient to supply the required flowrate of cryogenic refrigerant during steady-state operation, a substantially larger flowrate is highly desirable during start-up when the complete system is at ambient temperature and must be cooled down to operating temperature. Accordingly, the preferred embodiment of the invention provides a by-pass line 94 having a manual by-pass valve 96 which permits higher refrigerant flowrates during cooldown of the system. In addition, valve 96 permits a steady flowrate to be established in lines 44 and 68, regardless of the action of temperature responsive valve 72, so that the optimum settings of proportioning valves 84 and 86 may be established. In this regard, extensive tests have indicated that between one-third to one-fifth of the total cryogenic refrigerant should be injected through auxiliary line 68, and that optimum efficiencies for most materials are obtained by injecting approximately one-fourth of the total refrigerant through auxiliary line 68.

**OPERATION**

In the preferred mode of operation, by-pass valve 96 is opened to permit a high flowrate of cryogenic liquid refrigerant to both spray header 46 and nozzle 70. Since the system is initially warm, a substantial portion of the cryogenic liquid is initially vaporized in cooling the lines, mixer-conveyor 10, and mill 50. Once all of the components have been cooled down to a predetermined temperature, the material to be comminuted is introduced into hopper 16 and motors 28 and 58 are energized. Temperature indicators 92 and 78 are monitored and valves 84 and 86 are initially adjusted so as to proportion the flow of refrigerant between spray header 46 and nozzle 70. By-pass valve 96 is then closed, and the temperature indicators are further
monitored as the system approaches steady-state operation. Final adjustments of valve 84 and 86 are then made so that the temperature of the material at the discharge end of the mixer-conveyor is at, or slightly below, the embrittled temperature of the material to be comminuted. That is, valve 84 is adjusted such that the average equilibrated temperature of the material in the discharge end of the mixer-conveyor is held in the range of 0 to 50°F below its embrittled temperature; while valve 86 is adjusted so as to provide the optimum amount of additional refrigerant which is necessary to overcome the frictional heat generated in the mill and keep the internal components of the mill at or near the embrittled temperature of the material. Of course, it will be understood that the precise temperature of the material is not absolutely determinable by sensors 88 and 82 since there is always a mixture of material and vaporized refrigerant at the sensor locations. However, operating experience quickly enables the operator to determine the relationship between the sensed temperatures and the actual temperatures of the material and the mill. Also, it will be apparent that the embrittled temperature varies significantly with different compositions of material, and that the optimum residence time in the mixer-conveyor is also dependent upon the initial size and mass of the material fed into hopper 16. Thus, the residence time of the material in the mixer-conveyor may also be adjusted by varying the rotational speed of shaft 12 through variable speed pulley 32 which, in turn, optimizes the amount of refrigerant supplied to spray header 46 in order to maintain the average equilibrated temperature of the material discharged from the mixer-conveyor between zero to 50°F below the embrittled temperature of the material being processed.

From the foregoing description it will be apparent that the present invention provides for carefully regulating the degree of cooling of the material to, or only slightly below, its embrittled temperature, and thereby prevents significant waste of refrigerant which results from subcooling the material 100°F to 150°F below its embrittled temperature in order to overcome the heating effects of the mill. Thus, instead of attempting to rely upon the inefficient heat exchange between substantially subcooled material and the mill components, the present invention separately injects auxiliary refrigerant into the mill for direct contact and heat exchange with the components of the mill. As a result, extensive tests have shown that the present invention requires 10 to 20 percent less refrigerant, which represents a substantial savings in operating costs as compared with all known prior systems.

From the foregoing description of one preferred embodiment of the invention it will be readily apparent that numerous variations and modifications will become readily apparent to those skilled in the art, such as, for example, the substitution of an automatic indicator-controller for temperature indicator 92, whereby valve 84 may be automatically varied in response to the temperature sensed by sensor 88. Therefore, it is to be understood that the foregoing description is intended to be illustrative of the principles of the invention, and that the invention is not to be limited other than as expressly set forth in the following claims.

I claim:

1. A cryogenic system for comminuting relatively non-brittle material comprising:
   a. elongated rotary mixer-conveyor means including inlet means, discharge means spaced at least 5 to 10 feet from said inlet means, and variable speed conveyor means for varying the residence time of material conveyed through said mixer-conveyor within the range of one to ten minutes,
   b. a source of liquid nitrogen,
   c. first refrigerant injection means connected to said source for introducing liquid nitrogen into said mixer-conveyor, said injection means comprising a spray header positioned within the interior of said mixer-conveyor and extending from adjacent said inlet means throughout the major portion of the length of said mixer-conveyor,
   d. a comminution mill including feed inlet means connected to said mixer-conveyor discharge means, and internal comminution means for comminuting the embrittled material fed to said mill from said mixer-conveyor,
   e. temperature sensing means positioned in the discharge portion of said mixer-conveyor for determining the temperature of the material discharged from said mixer-conveyor,
   f. first flow control means connected to said first refrigerant injection means for regulating the flowrate of liquid nitrogen supplied to said mixer-conveyor such as to maintain the temperature of the material discharged therefrom within a range of 0°F to below 50°F below the embrittled temperature of said material,
   g. second refrigerant injection means positioned downstream of said mixer-conveyor for supplying additional liquid nitrogen into direct liquid contact with said internal comminution means,
   h. second temperature sensing means in said comminution mill for determining the temperature therein, and
   i. second flow control means connected to said second refrigerant injection means for separately regulating the flowrate of liquid nitrogen supplied to said mill such as to remove substantially all of the heat generated by said mill.

2. The cryogenic system as claimed in claim 1 wherein said comminution feed inlet means comprise a high-speed feed conveyor and said second refrigerant injection means are positioned such as to inject liquid nitrogen into and through said high-speed feed conveyor into direct liquid contact with said internal comminution means.

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