METHOD FOR BLASTING ICE PARTICLES IN A SURFACE TREATMENT PROCESS
Abstract

A method for air blasting freshly formed ice particles toward a substrate to perform work on the substrate surface is provided. The method comprises: forming fresh ice particles of a desired particle sizing and at a desired mass flow rate; immediately drawing downwardly the freshly formed ice particles at the mass flow rate directly into a proximal end of a transport hose (18) of reduced pressure; developing the reduced pressure in the hose (18) by introducing blast air at a first volumetric flow rate to a blast nozzle (14) which develops a sufficient velocity at the blast nozzle (14) located at a distal end (15) of the hose to blast the freshly formed ice particles at the mass flow rate towards the substrate surface to perform work on the surface; and introducing into the proximal end (17) of the hose (18) a cool stream of air at a second volumetric flow rate to cool the fresh ice particles as such particles flow along the hose (18) towards the nozzle (14), the second volumetric flow rate of refrigerated air (54) being determined by the reduced pressure in the hose (18).
METHOD FOR BLASTING ICE PARTICLES
IN A SURFACE TREATMENT PROCESS

FIELD OF THE INVENTION

This invention relates to material removal from a substrate surface by air blast techniques and more particularly by the air blasting of freshly formed ice particles to perform work on the substrate surface.

BACKGROUND OF THE INVENTION

Particle blasting has been employed for some time to remove material from surface structures. Sand blasting and other types of grit blasting have been used to remove surface finishes from building exteriors, vehicle surfaces, mechanical parts and the like. Sand or grit blasting, however, requires expensive recovery systems to reduce pollution and other environmental hazards. Water can be used in conjunction with the grit blasting procedure to reduce particle losses and consequent harm to the environment.

Although grit blasting is very effective in treating building and vehicle surfaces, great care has to be exercised in treating more sensitive surfaces such as airplane skin which cannot be abraded during the surface treatment process.

The blasting of ice particles resolves a number of the above problems so that several attempts have been made in providing commercially viable ice blasting equipment. It is appreciated that the blasting of ice particles provides significantly less environmental harm because subsequent to impact the ice particles melt hence assisting in the removal and disposal of abraded material. As a result there is a considerable reduction in fines contributed to the environment. Due to the nature of ice particles, there are several problems associated with blasting the ice particles to achieve sufficient work on the surface to be treated. By their nature, ice particles are not free-flowing. Normally, to provide an accumulation of ice particles during
machine shut-down and the like, an inventory of ice particles is provided by various mechanical devices interposed between the ice making system and the blast nozzle. However, this results in the ice particles packing and causing plugging problems in the system at various points in the intervening mechanical devices. The variety of mechanical devices normally employed in developing and transporting the ice particles are rotors, augers, classifiers, cyclone separators, metering devices, overflow receivers, surge tanks and the like. All of these components are provided in an attempt to manage the problems associated with ice packing in the system due to the development of ice accumulation. But, by virtue of the provision of these various components, their own interaction can inadvertently result in packing of ice particles at various points in the processing system. Furthermore, the operation of these mechanical components has to be precisely controlled with special precautions to attempt to avoid ice packing in their components and also avoid system clogging. As is appreciated, these problems can be further magnified when ice blast systems are required to operate at distances some 20 to 50 metres from the ice-forming equipment.

U.S. Patent 4,703,590 discloses a particle moulding apparatus suitable for moulding ice particles for blasting purposes. As the ice particles are formed, they are collected in a reservoir at the base of the moulding machine. As the blast system is operated, particles are sucked from the reservoir in the moulding apparatus and transported to the nozzle for purposes of doing work. However, it has been found that the inventory of ice particles within the reservoir of the ice particle making device still causes ice packing and subsequent system clogging, particularly during intermittent blasting operations.

Another system which provides for the delivery of ice particles to the blast nozzle is disclosed in U.K. Patent Application 2,171,624. The ice particles are delivered in segments to a Venturi restriction for pick up by the high speed air. However, when blasting ceases, the ice particles tend to
clog up and pack in their segment portions, resulting in further down-time of the system until the clogging is dislocated.

An attempt to overcome these problems is disclosed in PCT International Publication Nos. WO90/14927 and WO91/04449. The systems which are disclosed in these applications, provide for the development of ice, ice crushing, particle sizing, cyclone separation, fluidization and delivery of ice particles to the blast nozzle. As already mentioned, such systems require very precise control and, by virtue of the number of interactive components, defeated the objective in attempting to deal with the accumulation of ice particles and their resultant, by their nature, packing in the system and causing clogging with consequent significant down-time.

In accordance with this invention, a method and apparatus is now provided which overcomes the above problems in a direct procedure where intermittent delivery of the ice particles is readily accommodated. This has been achieved by creating, on demand, the ice particles required at the blast nozzle. The freshly formed ice particles are immediately delivered to the blast nozzle at the mass flow-rate at which they are created. Accumulation of the ice particles in the system is thereby avoided.

SUMMARY OF THE INVENTION

According to an aspect of the invention, a method for air blasting freshly formed ice particles toward a substrate to perform work on a substrate surface is provided. The method comprises:

- forming fresh ice particles of a desired particle sizing and at a desired mass flow rate;

- immediately drawing downwardly the freshly formed ice particles at the mass flow rate from the ice particle forming step directly into a proximal end of an ice particle transport hose at reduced pressure;

- developing the reduced pressure in the hose by introducing to a blast nozzle at the hose distal end, air at a first volumetric flow rate which develops a sufficient velocity at the blast nozzle to blast the freshly formed
ice particles at the mass flow rate towards the substrate surface to perform work on the surface; and

providing in the proximal end of the hose a cool stream of air at a second volumetric flow rate to cool the fresh ice particles as such particles flow along the hose towards the nozzle, the second volumetric flow rate of cool air being determined by the reduced pressure in the hose.

According to another aspect of the invention, an apparatus for air blasting freshly formed ice particles toward a substrate to perform work on a substrate surface is provided. The apparatus comprises:

means for forming fresh ice particles of a desired particle sizing and at a desired mass flow rate to perform the work;

means for immediately transferring downwardly at the mass flow rate, from the ice particle forming means the fresh ice particles to a proximal end of an ice particle transport hose;

means for introducing blast air at a distal end of the hose at a first volumetric flow rate to a blast nozzle located at the distal end, the blast air introducing means developing due to blast air velocity at the nozzle, a reduced pressure in the ice particle transport hose to draw at the mass flow rate the fresh ice particles from the ice particle transferring means into the hose; and

means for providing cool air into the proximal end of the hose at a second volumetric flow rate to cool such fresh ice particles, the second volumetric flow rate of cool air provided by said means being determined by the reduced pressure in said hose.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic of the apparatus in accordance with a preferred embodiment of this invention in which the process of this invention is carried out.

Figure 2 is a schematic of an alternative embodiment of this invention.
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DETAILED DESCRIPTIONS OF THE PREFERRED EMBODIMENTS

A schematic flow diagram for the ice blast apparatus and process according to a first preferred embodiment is shown in Figure 1. The apparatus comprises an ice particle forming device 10, a high pressure air compressor 12 and a blast nozzle 14. High pressure air is delivered to the blast nozzle 14 through air hose 16 where the nozzle 14 is connected thereto at hose distal end 15. The ice particles generated in system 10 are delivered to the blast nozzle through the ice particle transport hose 18. The hose 18 is usually insulated to minimize heat gain by the flowing particles.

The air compressor system comprises a high pressure, high volume air compressor 20 which may be a single- or multi-stage compressor. Due to high volume, high pressure compression, the high air temperature, as it emerges from the compressor in line 22, is passed through an after-cooler and filter 24 to remove condensate and reduce the temperature to a desired operating temperature which may be close to ambient. It is understood that the air in line 16 may be at a temperature higher than ambient as long as the blast nozzle is not heated by the air to a temperature which is uncomfortable for the operator to hold.

The ice particle forming device 10 may comprise in accordance with this embodiment an ice maker 26 and an ice fracturing device 28. Water is introduced to the ice maker 26 through line 30. The water is converted by the ice maker 26 into flakes or sheets of ice which are removed from the ice maker by a tool 31 and then immediately and directly delivered downwardly to the ice fracturing unit 28 via chute 32. The ice maker 26 is driven by motor 34 which generates ice at a reasonably constant mass flow rate sufficient to meet the needs of the work to be performed.

The ice fracturing unit 28 fractures the ice sheets at the same mass flow rate as generated by the ice maker 26, so that there is no build up of ice in the ice maker or on chute 32. As schematically indicated, the ice fracturing unit 28 may comprise counter-rotating rollers having fracturing
devices on their surfaces to fracture the ice into ice particles of a desired sizing. The ice fracturing unit 28 is driven by motor 36. The fractured ice particles as freshly made are then delivered to the ice transport hose 18 through the ice particle chute 38. Such delivery of ice particles to the ice hose 18 is at the same mass flow rate as the ice is generated in ice maker 26. The immediate downward delivery avoids any accumulation of ice sheets or ice particles above the ice fracturing unit or above the hose 18. By virtue of gravity the ice particles fall freely towards and into the hose 18 without hang-up on any portion of the transfer device in moving ice from the ice maker through to the hose 18.

In accordance with the illustrated embodiment, the ice maker 26 may comprise a rotating drum which is partially immersed in a water bath. The drum has a cooled surface to cause water picked up by the drum to freeze into sheets of ice which are removed from the drum by docter blade 31. The ice is then fractured by the fracturing unit 28. In accordance with this embodiment, the refrigeration unit 40 supplies refrigerant through line 42 to the rotating drum of the ice maker 26. The refrigeration unit 40 delivers sufficient refrigerant through line 42 to ensure formation of ice sheets at the desired mass flow rate.

Refrigerant is also delivered through line 44 to an air chiller 46. According to this embodiment, a portion of the high pressure air in hose 16 is drawn off through the tee connector 48 through line 50. The portion of air drawn off of line 16 is first dried in dryer 52 and then chilled to a temperature below 0°C to provide high quality cool, dry air in line 54.

That air is used to provide cooling within the housing 56 for the ice particle forming device 10 and as well provide make up air in the manner to be discussed for delivering the freshly formed ice particles through the ice hose 18. This cool dry air also functions to reduce and maintain at a minimum any moisture which develops in the ice fracturing unit, ice particle transfer unit and ice hose 18.
The blast nozzle 14 is of the typical blast nozzle design where the air hose 16 is connected to the throat of the venturi portion of the nozzle and the ice hose 18 is connected to the low pressure side of the venturi. By virtue of high speed air travelling through the throat of the venturi of blast nozzle 14 at a first volumetric flow rate, a reduced pressure is developed in ice hose 18. The blast nozzle is opened by actuating switch 58 to permit the high pressure air to flow therethrough, the developed reduced pressure in ice hose 18 draws the cool air from the housing 56 into the hose proximal end 17 at a second volumetric flow rate. The cool air enters via line 54 into housing 56. The cool air provided at the second volumetric flow rate is sufficient to satisfy the negative pressure within the hose 18 as generated at the nozzle and to provide necessary cooling and ice particle transport through the hose 18 to the blast nozzle 14. The flow of the cool dry air through the hose 18 is sufficient to ensure fluidization of the particles as they move along the hose 18 to avoid accumulation of the particles in the hose. The second volumetric flow rate is determined by the reduced pressure in ice hose 18. The secondary flow rate is directly proportional to the first flow rate through hose 16 because the velocity of the first flow rate through the nozzle 14 determines the extent of reduced pressure in line 18. That is, the greater the first volumetric flow rate, the greater the reduced pressure or vacuum developed in line 18.

In accordance with this invention, ice accumulation is not permitted in the system. Once the ice particles are formed, in accordance with this invention, there are no intervening mechanical devices to disrupt flow of the ice particles to the blast nozzle. In order to achieve this feature, ice is only made when ice particles are required at the blast nozzle 14. By use of appropriate process controls, activation of blast nozzle switch 58 initiates one or more components of the system to effect ice blasting. It may be that on closing switch 58 of the blast nozzle, the air compressor is ramped up to develop the high volume, high pressure air in line 16. The refrigeration
unit 40 is operating and solenoid control valve 60 is opened to allow refrigerant to cool the ice maker 26. At the same time, refrigerant is provided to the chiller 46 to cool the air delivered through line 50. As the high pressure air commences to flow through the blast nozzle 14, a reduced pressure is formed in line 18 so that the air flowing through line 54 into housing 56 flows through the housing 56 and into line 18. Sensors may be provided to determine the temperature of the ice maker 26 and when it has achieved a desired ice making temperature, motor 34 is turned on to start rotation of the cold drum surface of the ice maker whereby the blade 31 removes the ice flakes which are immediately conveyed along chute 32 into the ice fracturing unit 28 which processes the ice flakes at the same mass flow rate to form an equivalent amount of ice particles in chute 38. By virtue of the reduced pressure in line 18, and as well the make up air introduced through line 54, the ice particles are immediately delivered along the ice hose 18 to the blast nozzle 14. The ice particles are then introduced to the high velocity air travelling through the blast nozzle 14 to accelerate the ice particles to perform work on the surface of the desired substrate. When the switch 58 is deactuated to signal a waiting period, the air compressor is ramped down to supply air in line 16 at a reduced flow rate and continue to supply air to line 50. In addition, the refrigeration unit continues to operate. However, the processor controlled solenoid operated valve 60 is closed to recycle refrigerant and to stop continued formation of ice flakes. This prevents accumulation of ice within the ice generating system so that any ice remaining is immediately processed through the ice fracturing unit 28 and delivered to the blast nozzle 14. It is appreciated that when blast ceases, the blast air reduction in line 16 is delayed, until the ice particles in the process line back as far as the ice maker are cleared from the system, to avoid any accumulation of the particles.

The reduced amount of air flowing through the blast nozzle continues to develop a reduced pressure in line 18 where, again, air travelling through
line 54 provides the make up air to cool and satisfy the reduced pressure within the housing 56 and hose 18.

The ice fracturing unit 28 fractures ice sheets into particles of desired sizing. The fracturing unit may be set to deliver particles of a desired size and in particular a nominal particle size selected from the range of 2 mm to 10 mm. The preferred type of ice fracturing unit has, as already noted, the counter-rotating rollers ice fracturing formation. Such fracturing systems are designed to minimize ice crushing so that few, if any, fines are produced in the fracturing operation. The ice fracturing system operates at a rate to ensure that all ice produced is immediately fractured and delivered to chute 38. By virtue of the cool, dry air from line 54 equalizing the reduced pressure in line 18, there is a flow of air which fluidizes the ice particles as they enter line 18 and ensures that they remain cool in transport to the blast nozzle. This is particularly important when the blast nozzle is connected to hose which may deliver the ice particles over extended distances to the work surface. Normally this is in the range of 20 to 100 metres. It is understood, however, that the hose lengths may be considerably shorter in the range of 5 to 20 metres.

In accordance with a preferred embodiment of the invention, the compressor delivers air in the range of 150 to 350 SCFM at a pressure in the range of 60 to 250 psig. In this operating configuration, approximately 100 to 300 SCFM is delivered to the blast nozzle and in the range of 30 to 80 SCFM is delivered to the chiller 54. The pressure of the air delivered through line 50 to the chiller 46 is normally in the range of 80 psig. The chiller is capable of cooling the air down to less than 0°C and preferably in the range of -15°C. As the high quality air exits the chiller 46, the pressure is usually dropped down to approximately 10 psig. With these operating parameters it has been found that the mass flow rate of ice should preferably be in the range of 120 lbs/hr to 300 lbs/hr.
In accordance with the invention, it is understood that when blasting ceases and solenoid valve 60 is turned off, the refrigeration fluid is diverted back to the refrigeration unit 40 to ensure optimum operation of the refrigeration unit. As already noted, blast air may be continuously delivered to the blast nozzle 14 at a rate in the range of 50 SCFM. In addition, cool dry air continues to circulate through the housing 56 to keep the components cool so that upon resumption of ice making everything is at sub-zero temperature to ensure immediate delivery at the desired mass flow rate of the ice particles.

In accordance with an alternative embodiment of the invention, the ice blast system of Figure 2 includes the same components as that of Figure 1 as identified by like numerals. The distinction over the embodiment of Figure 1 is with respect to the handling of the ice particles when blasting ceases. In accordance with the embodiment of Figure 2, when the blast nozzle switch 58 is opened to indicate a pause in blasting, solenoid valves 62 and 64 are actuated by an electronic controlled system to divert the ice particles to a discard 66. In accordance with standard process-controlling techniques solenoid valve 62 is closed and valve 64 is open. Conversely, when switch 58 is closed to indicate resumption of blasting, valve 62 is opened and valve 64 is closed to permit the ice particles to pass through ice hose 18. In this manner, the ice particle generation unit operates at full capacity at all times. When the blasting ceases, high quality air continues to flow through housing 56 to transport the formed ice particles through line 18 and out through discard 66. Such diverting of the ice particles ensures that the ice particle making system operates at optimum temperatures at all times.

In accordance with the preferred embodiments of the invention, the principle thereof has been demonstrated in providing, on demand, ice particle blasting without any accumulation of ice particles in the system. This approach ensures consistent blast quality with no shut down time to clear ice accumulation in the system.
Although preferred embodiments of the invention are described herein in detail, it will be understood by those skilled in the art that variations may be made thereto without departing from the spirit of the invention or the scope of the appended claims.
CLAIMS:

1. A method for air blasting freshly formed ice particles toward a substrate to perform work on a substrate surface, said method comprising:
   i) forming fresh ice particles of a desired particle sizing and at a desired mass flow rate;
   ii) immediately drawing downwardly said freshly formed ice particles at said mass flow rate from said ice forming step and directly into a proximal end of an ice particle transport hose at reduced pressure;
   iii) developing said reduced pressure in said hose by introducing to a blast nozzle at the hose distal end, air at a first volumetric flow rate which develops a sufficient velocity at the blast nozzle to blast said freshly formed ice particles at said mass flow rate towards said substrate surface to perform work on said surface;
   iv) providing in said proximal end of said hose a cool stream of air at a second volumetric flow rate to cool said fresh ice particles as such particles flow along said hose towards said nozzle, said second volumetric flow rate of cool air being determined by the reduced pressure in said hose.

2. A method of claim 1 wherein:
   i) forming said ice particles by use of an ice forming device through which refrigerant is circulated,
   ii) diverting refrigerant from said ice forming device when ice particle blasting is to cease.

3. A method of claim 1 further comprising:
   i) diverting said ice particles away from said hose when ice particle blasting is to cease.
4. A method of claim 1 wherein said step of forming ice particles provides particles having a nominal particle size selected from the range of 2 mm to 10 mm.

5. A method of claim 1 wherein step iv) said cool air is introduced at a second volumetric flow rate in the range of 5 to 80 SCFM where the first volumetric flow rate is in the range of 100 to 350 SCFM.

6. A method of claim 2 or 3 wherein said ice particles are transported along an extended length of hose exceeding at least 5 m.

7. A method of claim 1 wherein step iv) the introduction of said cool stream of air, fluidizing said freshly formed ice particles as they travel along said hose.

8. A method of claim 1 wherein step iii) said first volumetric flow rate of blast air is sufficient to provide air pressure to an inlet of said nozzle in the range of 60 psig to 250 psig.

9. An apparatus for air blasting freshly formed ice particles towards a substrate to perform work on a substrate surface, said apparatus comprising:
   i) means for forming fresh ice particles of a desired particle sizing and at a desired mass flow rate to perform said work;
   ii) means for immediately transferring downwardly at said mass flow rate, from said forming means said fresh ice particles to a proximal end of a hose;
   iii) means for introducing blast air at a distal end of said hose at a first volumetric flow rate to a blast nozzle located at said distal end, said blast air introducing means developing due to blast air velocity at said nozzle, a reduced pressure in said hose to draw at said mass flow rate
said fresh ice particles from said ice particle transferring means into said hose; and

iv) means for providing cool air in said proximal end of said hose at a second volumetric flow rate to cool such fresh ice particles, said second volumetric flow rate of cool air provided by said means being determined by said reduced pressure in said hose.

10. An apparatus of claim 9 wherein:

said means for forming ice particles at said mass flow rate having means for directing a flow of refrigerant therethrough.

11. An apparatus of claim 10 wherein said refrigerant flow directing means diverts flow of refrigerant from said ice making means when ice particle blasting is to cease.

12. An apparatus of claim 10 further comprising:

v) means for diverting said flow of fresh ice particles from said hose when ice particle blasting is to cease, said diverting means diverting said flow of fresh ice particles at said mass flow rate.
**INTERNATIONAL SEARCH REPORT**

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC 5 B24C1/00 B24C7/00

According to International Patent Classification (IPC) or to both national classification and IPC.

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

IPC 5 B24C F25C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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Further documents are listed in the continuation of box C. Patent family members are listed in annex.

**Date of the actual completion of the international search**

29 April 1994

Date of mailing of the international search report

1.06.94

Name and mailing address of the ISA

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