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(54) **BLAST MACHINING METHOD AND BLAST MACHINING DEVICE**

STRAHLBEARBEITUNGSVERFAHREN UND STRAHLBEARBEITUNGSVORRICHTUNG

MÉTHODE D'USINAGE PAR SABLAGE ET DISPOSITIF D'USINAGE PAR SABLAGE

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## Description

TECHNICAL FIELD

**[0001]** The present invention relates to a blasting method, according to the preamble of claim 1, in which an abrasive is ejected together with a compressed gas to perform processes on a workpiece including cutting, surface polishing, deburring and paint stripping, and also relates to a blasting apparatus, according to the preamble of claim 2, for use in the blasting method Such a method and such an apparatus are known from document JP 2006 297568 A (Patent Document 3 below).

BACKGROUND OF THE INVENTION

**[0002]** Blasting, which uses a cutting force that is exerted when an abrasive ejected together with a compressed gas strikes with a workpiece to process the workpiece, is widely used in various applications including cutting, surface polishing, surface satin finishing, deburring, paint stripping and removal of stains such as rust.

**[0003]** In such blasting, when an abrasive is ejected onto a workpiece together with a compressed gas, static electricity is generated by friction that is created when the abrasive strikes with the workpiece or friction that is caused by the strike of the abrasive with interior walls of a cabinet as a working space, causing the ejected abrasive or swarf produced during cutting of the workpiece to adhere not only to the workpiece and the interior walls of the cabinet but also to the interior walls of the ducts, cyclone, abrasive tank and so on constituting a circulating system for the abrasive. This makes smooth recovery or supply of the abrasive impossible.

**[0004]** In particular, with the increasing demand for microfabrication by blasting, abrasives used are becoming finer and finer. As a result, abrasives are more likely to adhere to the workpiece or the interior walls of the cabinet by static electricity and, once attached, they are hard to remove completely by, for example, air blowing. This is one reason for low productivity because there is a need to provide a cleaning process after blasting to remove the abrasive adhering to the workpiece.

**[0005]** One possible way to prevent adhesion of abrasive due to static electricity is to provide a voltage-applying static eliminator ("ionizer") in the blasting apparatus.

**[0006]** However, provision of such an expensive device increases the price of the blasting apparatus and thus causes it to lose price competitiveness in the market. In addition, the electrode probes provided in an ionizer to generate ions are easily get dirty and hence need frequent maintenance. Moreover, because static electricity removal (neutralization) is carried out while the abrasive adheres to the processing object, static electricity remains in the areas where the abrasive has been removed.

**[0007]** Further, an ionizer is not structurally suited for use in a blasting apparatus because it performs corona discharge to generate ions and can therefore be an ignition source for dust explosion and other combustion problems.

**[0008]** Thus, to solve such a problem caused by static electricity, it has been suggested that moisture is provided in the working space or the circulation pathway for the abrasive to eliminate static electricity.

**[0009]** As one example of such a method, it has been suggested that a compressed gas humidified by humidification means is introduced into a blast nozzle for abrasive ejection to adjust the humidity in the circulating system for the abrasive in order to prevent generation of static electricity (See Paragraph [0011] and FIG. 2 in Patent Document 1).

**[0010]** It has been also suggested that an ultrasonic heater or heating is used to supply water in the form of water vapor to a compressed gas that is introduced into a blast nozzle for abrasive ejection (See Paragraph [0026] in Patent Document 2).

**[0011]** As a blast nozzle for use in wet blasting designed to prevent dust generation, a blast nozzle that mixes a compressed gas, an abrasive (medium) and water in approximately equal amounts in a chamber formed therein and ejects a three-phase stream consisting of gas, liquid and solid (abrasive) has been suggested (See Paragraph [0006], FIG. 1, FIG. 2 and Table 1[3] in Patent Document 3).

RELATED ARTS PATENT DOCUMENTS

**[0012]**

Patent Document 1: Japanese Patent No. 3846842
Patent Document 2: Japanese Unexamined Patent Application Publication 2011-237378
Patent Document 3: Japanese Unexamined Patent Application Publication 2006-297568

## SUMMARY OF THE INVENTION

### PROBLEM TO BE SOLVED BY THE INVENTION

**[0013]** Among the related arts described above, the blasting method that uses a blast nozzle as described in Patent Document 3, which ejects as large an amount of water as 160 to 200 cc/min (See Table 1 [2] and [3] in Patent Document 3), is one of the wet blasting methods generally called "wet blasting" or "liquid honing."

**[0014]** When a workpiece is processed by such a wet blasting method, the generation of static electricity can be reduced because the surface of the workpiece gets wet with the water ejected.

**[0015]** However, when a workpiece is processed by such a wet blasting method, the surface of the workpiece absolutely gets wet. Thus, such a wet blasting method cannot be applied to a workpiece that should avoid contact with water, such as a workpiece made of a material that rusts easily. In addition, a washing and drying step are required after the processing in some cases, and these processes contribute to low productivity.

**[0016]** In addition, in a wet blasting method in which an abrasive is ejected together with a large amount of water as described above, the processing amount (cutting speed or rate) decreases compared to dry blasting because the water ejected together with the abrasive absorbs the strike energy resulting from the strike of the abrasive with the surface of the workpiece. When conditions including the material and particle size of the abrasive used and the ejection pressure are the same, the processing amount (cut amount) in wet blasting decreases to approximately 1/7 to 1/14 of that in dry blasting.

**[0017]** As one example, FIG. 23 and FIG. 24 show the results of measurements of the difference in coverage between dry blasting and wet blasting. The processing was performed on a 150 mm square glass plate at an ejection pressure of 0.3 MPa using an alumina-based abrasive ("FUJIRUNDUM WA #1000" manufactured by Fuji Manufacturing Co., Ltd.) as the abrasive in both dry and wet blastings.

**[0018]** FIG. 23 shows the changes in processing time until the coverage reaches 100% with changes in the distance between a distal end of the blast nozzle and the workpiece (nozzle distance), and FIG. 24 shows the changes in processing time until the coverage reaches 100% with changes in the particle size of the abrasive. It can be understood that the processing time necessary to achieve a coverage of 100% is longer in wet blasting than in dry blasting in all cases.

**[0019]** The term "coverage" as used herein refers to the ratio in percent of a total indentation area to a processed area. Because the processing amount can be predicted from the degree of coverage, it can be understood from FIG. 23 and FIG. 24 that the wet blasting is inferior in processing amount (cutting speed) to the dry blasting.

**[0020]** In contrast to the wet blasting described above, in the blasting method described in Patent Document 1, the humidity in the cabinet as a working space is increased by adding moisuture to the compressed gas used to eject the abrasive in order to prevent the generation of static electricity and the resulting adhesion of the abrasive to the surface of the workpiece and the interior walls of the cabinet.

**[0021]** However, in the blasting apparatus described in Patent Document 1, water is added to the compressed air flowing through a compressed air supply pipe provided between a compressed air supply source and the blast nozzle. Because the compressed air flowing through the compressed air supply pipe has a lower velocity than the compressed air flowing through the small-diameter flow path in the blast nozzle, when water is introduced into the compressed air supply pipe in a liquid state, it is not atomized by strike with the compressed air stream and remains in a liquid state, and then is introduced into the blast nozzle, which causes aggregation of the abrasive. This causes clogging of the blast nozzle and results in malfunction of the blasting apparatus.

**[0022]** Thus, although no detailed explanation about the method for adding water is given in Patent Document 1, when water is added to the compressed air flowing through the compressed air supply pipe, the water must be converted into water vapor by an ultrasonic or heating method before the addition to the compressed gas as described in Patent Document 2 to avoid the malfunction caused by such clogging. The need to provide an additional water addition mechanism that has a function of converting water into water vapor as described above makes the apparatus complicated in configuration and expensive.

**[0023]** In the methods described in Patent Documents 1 and 2, although water is added to the compressed gas before it is introduced into the blast nozzle, the fluid that is ejected from the blast nozzle contains no "liquid" because the water is added in the form of water vapor (gas). Thus, the inventions described in Patent Documents 1 and 2 still remain in the category of "dry" blasting in spite of the addition of water.

**[0024]** Thus, the methods described in Patent Documents 1 and 2 have the advantages of being applicable to a workpiece that should avoid contact with water as these methods can carry out processing without wetting the surface of the workpiece and of providing a larger processing amount (cutting speed or rate) than wet blasting.

**[0025]** However, in the blasting methods described in Patent Documents 1 and 2, the generation of static electricity cannot be sufficiently prevented when the amount of water supplied is too small to humidify the interior of the processing chamber sufficiently. On the other hand, when the amount of water supplied is greater than the amount of saturated water vapor, the water condenses in the working space and wets the surface of the workpiece and the interior walls of

6the cabinet. In this case, the generation of static electricity can be prevented but the merits of dry blasting are lost.

**[0026]** Thus, in the blasting method described in Patent Document 1, the humidity in the processing chamber is detected to calculate the amount of water needed before supplying water. The control for it is very complicated and makes the apparatus complex in configuration and expensive.

**[0027]** As described above, the inventions described in Patent Documents 1 and 2 still remain in the category of dry blasting and can therefore maintain a larger processing amount (higher cutting speed or rate) than wet blasting, and, at the same time, can overcome the challenge of preventing the generation of static electricity. In order to achieve this, however, the adoption of a special apparatus configuration and complicated control are indispensable.

**[0028]** On the other hand, as described in Patent Document 3, wet blasting can significantly reduce the generation of static electricity with a relatively simple apparatus configuration and without the need for complicated control. However, wet blasting requires washing and drying after the processing because it wets the workpiece, and the addition of these steps lowers its productivity. In addition, because the processing amount (cutting speed or rate) significantly decreases in wet blasting compared to that in dry blasting, wet blasting is much inferior in machinability (processing performance) and productivity to dry blasting also in this respect. Each method has both advantages and disadvantages.

**[0029]** In view of the above, the inventors of the present invention have conducted intensive studies for the purpose of achieving blasting that can prevent the generation of static electricity without sacrificing the processing amount and, consequently, have found that the generation of static electricity can be prevented and the processing amount can be significantly improved by supplying water in an atomized state at a position immediately upstream of the ejection port of the blast nozzle and limiting the amount of water added to a predetermined range that is much smaller than that used in known wet blasting.

**[0030]** In addition, it has been confirmed that the processing amount that can be obtained by this method is greater than that obtained by wet blasting and, surprisingly, even much greater than that obtained by dry blasting, and some additional effects that cannot be expected from Patent Document 1 can be obtained in addition to the improvement in processing amount.

**[0031]** The present invention has been made based on the findings obtained by the inventors as a result of the intensive studies, and an object of the present invention is to provide a blasting method and a blasting apparatus that can be adopted simply by adding minor structural changes to an existing dry blasting apparatus and that not only can prevent the generation of static electricity during blasting but also can improve the processing amount (cutting speed or rate) compared to conventional dry blasting and even to conventional wet blasting.

MEANS FOR SOLVING THE PROBLEMS

**[0032]** Means for solving the problems will be described below using reference numer als used in embodiments of the invention. It is to be noted that these reference num erals are only provided for clarifying the correspondence relationship between the scop e of the claims and the embodiments of the invention, but should not be used for lim iting the interpretation of the technical scope of the claims of the present invention.

**[0033]** In order to achieve the above objective, a blasting method according to the pre sent invention in which an abrasive is ejected together with a compressed gas onto a workpiece W through a blast nozzle 8 comprises the steps defined in claim 1, namely among other the step of:
introducing a liquid into the blast nozzle 8 and atomizing the liquid by causing the liquid to contact or strike with the compressed gas flowing through the blast nozzle 8 or the compressed gas ejected from the blast nozzle 8, and ejecting the liquid together with the compressed gas and the abrasive, an amount of the liquid introduced into the blast nozzle 8 being 0.06 cc/min to 150 cc/min.

**[0034]** Examples of the liquid may include pure water or hard water which contains a scale remover added for scale removal or contains a paint or fluorescent paint added for marking to identify the processed region in addition to what are called "waters" such as tap water, pure water, purified water and alkali ion water.

**[0035]** In a blasting apparatus 1 according to the present invention for use in the bla sting method as described above, the blasting apparatus 1 for ejecting a stream of co mpressed gas supplied from a compressed gas supply source (not shown) and an abras ive from a blast nozzle 8 as a mixed fluid comprises the features defined in claim 2, namely among other:

a liquid introduction path 88 provided in the blast nozzle 8, having one end communicable with a liquid supply source (not shown) and an other end opened in a compressed gas flow path in the blast nozzle 8 or at an ejection port of the blast nozzle 8, the liquid introduction path 88 being configured to cause a liquid introduced from the liquid supply source to strike with a stream of compressed gas flowing through the blast nozzle 8 or a stream of compressed gas ejected from the blast nozzle 8 to atomize the liquid, and
a flow rate control means such as a flow control valve 7 or a pump provided between the liquid introduction path 88 and the liquid supply source.

**[0036]** In the blasting apparatus 1 configured as described above, the blast nozzle 8 is a suction-type blast nozzle having a nozzle tip 82 directed in the ejection direction of a rear nozzle 83 communicated with a compressed gas supply source (not shown), and an abrasive introduction chamber 85 communicated with an abrasive supply source between the rear nozzle 83 and the nozzle, the blast nozzle 8 being configured to create a negative pressure in the abrasive introduction chamber 85 by ejection of a stream of compressed gas from the rear nozzle 83 to suck an abrasive in the abrasive supply source, and eject the compressed gas and the abrasive as a mixed fluid, and

the other end (distal end 88a) of the liquid introduction path 88 is opened in a compressed gas flow path 86 formed in the rear nozzle 83 or in front of an ejection port of the rear nozzle 83.

**[0037]** In the blasting apparatus 1 configured as above, the liquid introduction path 88 may be formed by a conduit inserted concentrically in the compressed gas flow path 86 provided in the rear nozzle 83, and the other end (distal end 88a) of the liquid introduction path 88 may be opened at the ejection port of the rear nozzle 83.

**[0038]** The blasting apparatus 1 may further comprise a fixed quantity liquid supply means such as a pump for supplying the liquid in the liquid supply source to the liquid introduction path 88 in a fixed quantity.

EFFECT OF THE INVENTION

**[0039]** According to the blasting method and blasting apparatus of the present invention having the configuration of the present invention as described above, the following remarkable effects can be obtained.

**[0040]** Because a liquid such as water is atomized by causing it to strike with the compressed gas flowing through the blast nozzle 8 or the compressed gas ejected from the blast nozzle 8, and because the amount of liquid that is introduced into the blast nozzle is limited to 0.06 to 150 cc/min, the atomized liquid is quickly evaporated into water vapor in the space between the blast nozzle 8 and the workpiece W or on the surface of the workpiece W because of the pressure drop after the ejection from the blast nozzle 8 and the heat that is produced when the abrasive strikes with the workpiece W. This increases the humidity in the processing chamber 21 to prevent the generation of static electricity.

**[0041]** In addition, the blasting method of the present invention, which does not wet the workpiece W or even if the method wets the workplace W, however, wet degrees are small compared to known wet blasting in spite of the prevention of the generation of static electricity as described above, is applicable to a workpiece made of a material that should avoid contact with water by adjusting the water supply conditions, and does not require additional steps such as washing and drying after the processing.

**[0042]** Further, in addition to the effect of preventing the generation of static electricity as described above, the blasting method of the present invention has new unexpected effects including the improvement of the processing amount (cutting speed or rate) that is greater than that obtainable by a known dry blasting method, prevention of sticking or lodging of the abrasive into the surface of the workpiece, reduction of consumption of the abrasive, improvement of cutting speed or rate and efficiency of removal of a coated film and burrs, reduction of elongation and warpage of the workpiece, and prevention of temperature rise of the workpiece and the resulting reduction of burning of the product.

**[0043]** Although the reason for the effects, such as the increase in the cutting speed or rate, is not known, it seems probable that the effects result from the fact that the liquid which is sprayed in an atomized state as a result of the strike with a stream of compressed gas and turns into microdroplets because of the rapid decrease in pressure after the ejection from the blast nozzle, evaporates quickly in the space in front of the workpiece or on the surface of the workpiece upon contact with the workpiece heated by the strike with the abrasive, and absorbs a large amount of vaporization heat from the surrounding air and the surface of the workpiece during evaporation (spray cooling).

**[0044]** When consideration is given to the improvement in the processing amount (cutting speed or rate) among the effects described above as one example, it is concluded that one possible reason for the smaller processing amount (cutting speed or rate) in wet blasting than in dry blasting is that the water ejected together with the abrasive forms a water film on the surface of the workpiece and the water film absorbs the strike energy of the abrasive just about being struck with the surface of the workpiece.

**[0045]** However, in the method of the present invention, because the liquid ejected in an atomize state evaporates immediately after exiting the blast nozzle 8 as described above, the workpiece W does not get wet or even if it gets wet, however, wet degrees are small compared to known wet blasting. It is therefore believed that the strike energy can be maintained at the same level as in dry blasting, and, consequently, a large processing amount can be maintained even when a liquid is ejected.

**[0046]** On the other hand, one reason for the lower cutting speed or rate in dry blasting is believed to be that the surface temperature of the workpiece increases as a result of the strike with the abrasive and the temperature rise makes the surface of the workpiece soft enough to absorb the strike energy of the abrasive.

**[0047]** In contrast to this, in the method of the present invention, the spray cooling as described above prevents the increase in surface temperature of the workpiece and enables the processing to be carried out with the surface hardness of the workpiece maintained. This is believed to be the reason why the processing amount (cutting speed or rate) is improved compared even to dry blasting.

**[0048]** The blasting method of the present invention described above can be achieved by making relatively simple structural changes in the configuration of an existing dry blasting apparatus, i.e., by replacing the blast nozzle with a blast nozzle 8 that can eject a liquid as described above, and adding a liquid supply source for supplying the liquid to the blast nozzle 8 and a flow rate control means such as a flow control valve 7 or a pump for controlling the amount of the liquid to be supplied to the blast nozzle 8.

**[0049]** In the configuration in which a conduit is concentrically inserted as the liquid introduction path 88 in the compressed gas flow path 86 of the rear nozzle 83 of the blast nozzle 8 with an other end (distal end 88a) opened at the ejection port of the rear nozzle 83, the negative pressure resulting from the ejection of the compressed gas from the rear nozzle 83 can be used to introduce the liquid through the liquid introduction path 88, and there is no need to provide an additional means for supplying the liquid such as a pump, furthermore, the introduction of the liquid is started and stopped in synchronization with the start and stop of the introduction of the compressed gas into the blast nozzle 8. Consequently, there is no need to provide an additional means for starting and stopping the supply of the liquid. Further, existing facilities can be used as long as the rear nozzle 83 of the blast nozzle 8 is replaced.

**[0050]** However, a fixed quantity supply means such as a pump for supplying a fixed quantity of liquid from the liquid supply source to the liquid introduction path 88 may be provided. In this case, the design latitude for the position at which the liquid is introduced into the blast nozzle 8 increases and the liquid can be supplied more stably and reliably.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0051]**

FIG. 1 is an explanatory diagram illustrating one configuration example of a blasting apparatus of the present invention;

FIGS. 2A and 2B are explanatory diagrams of a blast nozzle provided in the blasting apparatus of the present invention. FIG. 2A is a cross-sectional view of the entire blast nozzle and FIG. 2B is an explanatory diagram illustrating modifications of a nozzle tip;

FIGS. 3A and 3B are explanatory diagrams of the position at which a liquid is introduced into a non-claimed embodiment of the blast nozzle (suction-type). FIG. 3A is an explanatory diagram of the position at which a liquid is introduced into a blast nozzle having an ordinary nozzle tip and FIG. 3B is an explanatory diagram of the position at which a liquid is introduced into a blast nozzle having a divided-continuous nozzle tips (822, 821);

FIGS. 4A and 4B are explanatory diagrams of the position at which a liquid is introduced into a non-claimed embodiment of the blast nozzle (direct-pressure type). FIG. 4A is an explanatory diagram of the position at which a liquid is introduced into a blast nozzle having an ordinary nozzle tip and FIG. 4B is an explanatory diagram of the position at which a liquid is introduced into a blast nozzle having a divided-continuous nozzle tips (822', 821');

FIG. 5 is a cross-sectional view of a blast nozzle provided in the blasting apparatus <u>used in the test of "Confirmation of effect of different abrasives on processing amount"</u>;

FIG. 6 is a graph showing the changes in processing amount with changes in water supply amount (boron plate);

FIG. 7 is a graph showing the changes in processing amount with changes in water supply amount (carbide plate);

FIG. 8 is a graph showing the changes in processing amount with changes in water supply amount (urethane rubber plate);

FIG. 9 is a graph showing the changes in processing amount with changes in water supply amount (aluminum plate);

FIG. 10 is a graph showing the changes in processing amount with changes in water supply amount (stainless plate);

FIG. 11 is a graph showing the changes in processing amount with changes in water supply amount (iron plate);

FIG. 12 is a graph showing the changes in processing amount with changes in water supply amount (acrylic plate);

FIG. 13 is a graph showing the changes in processing amount with changes in water supply amount (epoxy glass plate);

FIG. 14 is a graph showing the changes in processing amount with changes in water supply amount (granite);

FIG. 15 is a graph showing the changes in the amount of abrasive stuck with changes in water supply amount (urethane rubber);

FIG. 16 is a graph showing the changes in the amount of abrasive stuck with changes in water supply amount (stainless);

FIG. 17 is a graph showing the changes in the amount of abrasive stuck with changes in water supply amount (iron);

FIG. 18 is a graph showing the changes in the amount of abrasive stuck with changes in water supply amount (acrylic);

FIG. 19 is a graph showing the changes in the amount of abrasive stuck with changes in water supply amount (epoxy glass);

FIG. 20 shows photographs showing the particle structures of an abrasive after use in a blasting method of the present invention (example) and an abrasive used in a dry blasting method (comparative example);

FIGS. 21A and 21B show surface roughness data of polycarbonate products after stripping paint by blasting. FIG.

21A shows the data of a product treated by a method of the present invention (example) and FIG. 21B shows the data of a product treated by dry blasting (comparative example);

FIGS. 22A and 22B show surface roughness data of polyphenylene sulfide products after deburring by blasting. FIG. 22A shows the data of a product treated by a method of the present invention (example) and FIG.22B shows the data of a product treated by dry blasting (comparative example);

FIG. 23 is a correlation diagram showing the changes in time until the coverage reaches 100% with changes in nozzle distance; and

FIG. 24 is a correlation diagram showing the changes in time until the coverage reaches 100% with changes in particle size of the abrasive.

MODE FOR CARRYING OUT THE INVENTION

**[0052]** An embodiment of the present invention is next described below with reference to the accompanying drawings.

1. Blasting apparatus

(1) General configuration

**[0053]** A configuration example of a blasting apparatus 1 of the present invention is shown in FIG. 1.

**[0054]** As shown in FIG. 1, the blasting apparatus 1 includes a compressed gas supply source (not shown), an abrasive tank 3 as an abrasive supply source, and a blast nozzle 8 for merging a compressed gas introduced from the compressed gas supply source with an abrasive from the abrasive tank 3 and ejecting the mixture. In the illustrated embodiment, the blasting apparatus 1 is constituted as what is called a "suction-type" blasting apparatus in which the abrasive from the abrasive tank 3 which is sucked by a negative pressure created in the blast nozzle 8 by the introduction of the compressed gas from the compressed gas supply source, is merged with a stream of the compressed gas and ejected onto a workpiece W. In this embodiment, the gas is compressed air.

**[0055]** In the illustrated embodiment, the blasting apparatus 1 includes a processing chamber 21 formed in a cabinet 2 accommodating the blast nozzle 8, the abrasive tank 3 which is a cyclone communicated with a hopper formed at a lower end of the processing chamber 21 via an abrasive recovery pipe 91, and a dust collector 5 for sucking the inside of the abrasive tank 3. When the abrasive is ejected from the blast nozzle 8 accommodated in the processing chamber 21 with an exhauster 6 in the dust collector 5 being actuated to suck the inside of the abrasive tank 3 as a cyclone, the ejected abrasive is introduced into the abrasive tank 3 through the abrasive recovery pipe 91 together with swarf and other objects. As a result of air classification in the abrasive tank 3, reusable abrasive is recovered to the bottom of the abrasive tank 3 and crushed abrasive and dust are sucked and removed by the dust collector 5. The recovered abrasive can be cyclically used.

**[0056]** The basic configuration of the blasting apparatus 1 is not limited to the circulation type configuration in which the abrasive is cyclically used as described above. For example, the blasting apparatus 1 may have a batch-type configuration in which the abrasive after use is not reused but is disposed of after each use. In this case, the configuration provided for air classification of the dust including swarf and the abrasive may be omitted and the dust collector 5 may be used to remove or collect the abrasive after use and dust in the processing chamber 21 together.

**[0057]** While the description is made based on the assumption that the blasting apparatus is constituted as a suction-type in the illustrated example, non-claimed embodiments may containa direct-pressure type blasting apparatus in which a compressed gas in a pressurized tank and an abrasive are introduced together into a blast nozzle and ejected therefrom, for example. Any of various structures employed in known blasting apparatuses can be employed as a basic configuration of the blasting apparatus.

**[0058]** In the blasting apparatus 1 of the present invention, a liquid, in this embodiment, water, is introduced into the blast nozzle 8. The water is caused to strike with a stream of compressed gas flowing through the blast nozzle 8 to atomize it into droplets with an average particle diameter of 1 mm or less, preferably 300 $\mu$m or less, more preferably 100 $\mu$m or less, and the atomized liquid is incorporated into the compressed gas immediately before it is ejected onto the workpiece W. In this way, the atomized liquid can be sprayed onto the workpiece W together with the abrasive.

**[0059]** In order to make it possible to incorporate the atomized liquid into the compressed gas ejected toward the workpiece W as described above, the blasting apparatus 1 of the present invention is provided with a liquid supply source (not shown) for supplying a liquid (water) to the blast nozzle 8, and has a liquid introduction path 88 in the blast nozzle 8 through which the water supplied from the liquid supply source is introduced into the blast nozzle 8, and a flow rate control means constituted of a flow control valve 7 or a pump in a conduit communicating the liquid supply source and the liquid introduction path 88 of the blast nozzle 8.

(2) Blast nozzle

**[0060]** An example of a configuration of the blast nozzle 8 provided in the blasting apparatus 1 of the present invention is shown in FIG. 2.

**[0061]** The blast nozzle 8 shown in FIG. 2 has the basic structure of an existing suction-type blast nozzle, and is constituted of a body 81 forming a primary part of the blast nozzle 8, and a nozzle tip 82 and a rear nozzle 83 attached to the body 81.

**[0062]** The body 81 is provided with an abrasive introduction port 84 through which the abrasive supplied from the abrasive tank 3 as an abrasive supply source is introduced, and an abrasive introduction chamber 85 formed therein in communication with the abrasive introduction port 84 and having the shape of a generally cylindrical container.

**[0063]** The nozzle tip 82 attached to the body 81 has a conical inner surface 82a tapered conically, and is configured such that the abrasive introduction chamber 85 formed in the body 81 and a flow path in the nozzle tip having the conical inner surface 82a are communicated with each other when the nozzle tip 82 is attached to a front end side of the body 81.

**[0064]** As shown in FIG. 2B, the nozzle tip 82 may be either one having a circular opening (round type) or one having a slit-like opening (slit type), and the flow path formed therein may have a venturi-type shape with a cross-section that first narrows from its entrance and then widens again toward the exit.

**[0065]** The rear nozzle 83 is attached to a rear end side of the body 81 with its distal end pointing toward the center of the conical inner surface 82a of the nozzle tip 82. The blast nozzle 8 is the same in configuration as a known suction-type blast nozzle 8 in that when the compressed gas from the compressed gas supply source (not shown) is ejected from the rear nozzle 83, the abrasive from the abrasive tank 3, which is sucked into the abrasive introduction chamber 85 by a negative pressure created by the ejection of the compressed gas from the rear nozzle 83, is merged into the compressed gas ejected from the rear nozzle 83 and ejected from the distal end of the nozzle tip 82.

**[0066]** The blast nozzle 8 for use in the blasting apparatus 1 of the present invention is provided with a liquid introduction path 88 through which the liquid from the liquid supply source (not shown) is introduced into the blast nozzle 8 so that the liquid can be atomized and sprayed as described above. The liquid introduction path 88 has a distal end 88a opening in a compressed gas flow path formed in the blast nozzle 8, for example, in a compressed gas flow path 86 formed in the rear nozzle 83, in front of the delivery port of the rear nozzle 83, in the flow path in the nozzle tip 82, or at the ejection port of the blast nozzle 8, so that the liquid can be atomized by causing it to strike with a high-speed stream of compressed gas flowing through the blast nozzle 8 or a high-speed stream of compressed gas ejected from the blast nozzle 8 and sprayed.

**[0067]** In the present invention, a mesh material may be provided in the opening at the distal end 88a of the liquid introduction path 88 so that the liquid can be atomized in a more preferred manner when the liquid ejected from the distal end 88a of the liquid introduction path 88 is atomized by causing it to strike with a high-speed stream of compressed gas. In this case, the liquid is atomized in a more preferred manner because the liquid supplied through the liquid introduction path 88 is preliminarily atomized through the mesh material before it is caused to strike with the high-speed stream of compressed gas.

**[0068]** The mesh material for use in the present invention is not particularly limited. For example, various types of mesh materials, such as one obtained by weaving wires made of a metal or a resin into a flat mesh or one formed by creating fine pores through a plate, can be used.

**[0069]** In the embodiment shown in FIG. 2, the conduit as the liquid introduction path 88 is arranged concentrically in the compressed gas flow path 86 formed through the rear nozzle 83 so that the compressed gas can flow between the interior wall of the compressed gas flow path 86 and the exterior wall of the liquid introduction path 88, and the distal end 88a of the liquid introduction path 88 is opened at the same position as the opening of the rear nozzle 83 in order to cause the liquid ejected from the distal end 88a of the liquid introduction path 88 to strike with the high-speed high-pressure stream of compressed gas flowing along the outer periphery of the liquid to atomize it.

**[0070]** In the blasting apparatus 1 of this embodiment constituted as described above, because the liquid is sucked out of the distal end 88a of the liquid introduction path 88 by the effect of a negative pressure created in the abrasive introduction chamber 85 and merged with the stream of compressed gas, the liquid can be atomized in the blast nozzle 8 without a fixed quantity liquid supply device such as a pump for supplying the liquid from a liquid supply source (not shown) such as a liquid tank into the blast nozzle 8. In addition, because the introduction of the liquid from the liquid supply source automatically starts and stops in synchronization with the start and stop of the introduction of the compressed gas into the blast nozzle 8, dripping and other troubles caused by failure to start or stop the supply of the liquid does not occur.

**[0071]** The configuration for causing the liquid to strike with the stream of compressed gas is not limited to the configuration shown in FIG. 2, and the configuration of any of various known gas-blast type two-fluid nozzles (atomizers) may be applied to that of the rear nozzle 83. As described above, the introduction of the liquid into the blast nozzle may be achieved by fixed quantity liquid introduction means, such as a pump, provided in the tank as a liquid supply source or in the pipe between the liquid supply source and the blast nozzle instead of the configuration that uses a negative pressure in the abrasive introduction chamber.

**[0072]** The position at which the liquid is supplied into the blast nozzle 8 may be different from the position shown in FIG. 2. For example, the liquid may be introduced into the suction-type blast nozzle through a space formed around the outer periphery of a distal portion of the rear nozzle 83 of the blast nozzle 8 as the liquid introduction path 88 and opening toward the distal end of the rear nozzle 83 as shown in FIG. 5. When the liquid is introduced into the liquid introduction path 88, it is ejected to surround the outer periphery of the compressed gas ejected from the rear nozzle 83 and atomized upon strike with the high-speed, high-pressure stream of compressed gas.

**[0073]** Further, as shown in FIG. 3A, the distal end 88a of the liquid introduction path 88 may be opened in the abrasive introduction chamber 85 or at the position where the ejection port of the blast nozzle 8 is formed so that the liquid in the liquid introduction path 88 can be sucked out by a negative pressure created by the stream of compressed gas and caused to strike with the stream of compressed gas flowing through the blast nozzle 8 or the stream of compressed gas ejected from the blast nozzle 8. Alternatively, the liquid in the liquid supply source may be supplied in a fixed quantity by a pump into a compressed gas flow path formed through the rear nozzle 83 or into a compressed gas flow path formed through the nozzle tip 82. In place of or in addition to introducing the liquid at the position described with reference to FIG. 2A or FIG. 5, the liquid may be introduced at one or more of the positions shown in FIG. 3A.

**[0074]** The nozzle tip 82 may be constituted to have two divided nozzle tips 821 and 822 coaxially and sequentially arranged in a longitudinal direction as shown in FIG. 3B so that, when a fluid is introduced from the nozzle tip 821 having a small-diameter flow path formed therethrough into the nozzle tip 822 having a large-diameter flow path formed therethrough, air is sucked in through a vent 823 formed at the interface between the nozzle tips 821 and 822 and ejected after merged water with the stream of abrasive. When a liquid is introduced into the nozzle tip 82 having such a structure, the liquid may be introduced through the vent 823 of the nozzle tip 82.

**[0075]** In a direct-pressure type blast nozzle, the distal end 88a of the liquid introduction path 88 may be opened at the position where the ejection port of the blast nozzle 8 is formed as shown in FIG. 4A so that the liquid in the liquid introduction path 88 is sucked out by the effect of a negative pressure created by the ejection of the compressed gas and caused to strike with the compressed gas ejected from the blast nozzle 8. Alternatively, the distal end 88a of the liquid introduction path 88 may be opened in a compressed gas flow path in a rear nozzle 83' provided in a blast nozzle body 81' or in a compressed gas flow path formed through a nozzle tip 82' attached to the distal end of the blast nozzle 8, and the liquid from the liquid supply source may be introduced into the blast nozzle 8 by a pump. The liquid can be introduced at any one or more of these positions.

**[0076]** A divided-continuous nozzle tip having two longitudinally-divided nozzle tips 821' and 822' arranged coaxially and sequentially in a longitudinal direction as shown in FIG. 4B can be also used as a nozzle tip 82' in the configuration of the above direct-pressure type blast nozzle. In this case again, the liquid may be introduced through a vent 823' provided at the interface between the two nozzle tips 821' and 822'.

**[0077]** A flow rate control means for controlling the flow rate of liquid that is introduced into the liquid introduction path 88 is provided in the conduit extending from the liquid supply source to the liquid introduction path 88 so that the amount of liquid that is introduced into the blast nozzle 8 can be adjusted.

**[0078]** In this embodiment, a flow control valve 7 is provided as the flow rate control means in the conduit between the liquid introduction path 88 having the distal end 88a opened at a position where a negative pressure is created and the liquid supply source. While a valve whose opening is adjustable at eight levels is used as the flow control valve 7 in this embodiment, a valve whose opening is continuously adjustable may be used. Any type of valve may be used as long as the flow rate of liquid can be adjusted.

**[0079]** A pump is provided as the flow rate control means between the liquid introduction path 88 having the distal end 88a opened at a position other than the position where a negative pressure is created and the liquid supply source so that the amount of liquid that is supplied into the blast nozzle 8 can be controlled by controlling the operating speed of the pump, such as the rotational speed of the motor for driving the pump.

**[0080]** A pump may be provided between the liquid introduction path 88 and the liquid supply source as shown as modifications in FIG. 3A and FIG. 4A even when the distal end 88a of the liquid introduction path 88 is opened at the position where a negative pressure is created, and a flow control valve may be provided on the secondary side of the pump so that the flow rate of liquid that is introduced into the blast nozzle 8 can be adjusted even when a pump is provided.

**[0081]** Further, the liquid introduction path 88 may be connected to a water intake (faucet) of the water supply system so as to use the water supply system as a liquid supply source, without providing a container such as a liquid tank as a liquid supply source. In this case, the feed-water pressure from the water supply system may be used to introduce the liquid into the liquid introduction path 88 and omit the installation of the pump.

2. Effects

**[0082]** Taking the case as an example where the blasting apparatus 1 in FIG. 1 constituted as described above is equipped with the blast nozzle 8 shown in FIGS. 2A and 2B, the explanation of its operation is given below.

**[0083]** An abrasive is placed in the abrasive tank 3 as an abrasive supply source, and the liquid tank (not shown) as a liquid supply source is filled with a liquid such as water. In this state, the introduction of a compressed gas into the blast nozzle 8 from the compressed gas supply source (not shown) is started.

**[0084]** When the introduction of the compressed gas is started in this way, a high-speed compressed gas is ejected from the distal end of the rear nozzle 83 of the blast nozzle 8. Then, in the nozzle tip 82, a high-speed gas stream toward its ejection port is generated.

**[0085]** Thus, the gas in the abrasive introduction chamber 85 is drawn into the nozzle tip 82 by the stream of compressed gas. As a result, a negative pressure is created in the abrasive introduction chamber 85, and the abrasive from the abrasive tank 3 is introduced into the abrasive introduction chamber 85 through the abrasive introduction port 84. At the same time, the liquid in the liquid introduction path 88 is sucked out of the distal end 88a of the liquid introduction path 88 by the negative pressure. The sucked-out liquid is atomized by the high-speed compressed gas ejected from the rear nozzle 83 and incorporated into the compressed gas together with the abrasive before it is sprayed from the blast nozzle 8.

**[0086]** In the blasting method of the present invention, a preferred ejection amount of the abrasive is 2 g/min to 20 kg/min, whereas the amount of liquid that is introduced into the blast nozzle 8 is as relatively small as 0.06 cc/min to 150 cc/min. In addition, the liquid ejected together with the abrasive is atomized upon strike with the high-speed compressed gas flowing through the blast nozzle 8 before being sprayed from the blast nozzle 8. Further, because the compressed gas ejected from the blast nozzle 8 undergoes a rapid decrease in pressure and because the surface of the workpiece is heated by the strike with the abrasive, the sprayed liquid evaporates in the space between the blast nozzle 8 and the workpiece W or on the surface of the workpiece W and absorbs a large amount of vaporization heat from the space and the surface of the workpiece W.

**[0087]** As a result, it is believed that, when blasting is carried out by the method of the present invention, not only the generation of static electricity is prevented by the increase in humidity resulting from the evaporation of the liquid but also several other benefits, including the improvement of the cutting speed or rate, improvement of the efficiency of removal of a coated film or burrs, prevention of sticking or lodging of the abrasive into the surface of the workpiece W, and prevention of warpage or elongation of the workpiece, can be obtained in contrast to ordinary blasting that does not involve spraying of a liquid.

**[0088]** In other words, in the method of the present invention, water is ejected but the ejected water evaporates quickly as described above. Thus, the surface of the workpiece does not get wet or even if it gets wet, however, wet degrees are small compared to known wet blasting, and the formation of a water film that absorbs the strike energy of the abrasive on the surface of the workpiece is prevented.

**[0089]** On the other hand, although the above-mentioned formation of a water film is prevented, because the sprayed water absorbs a large amount of vaporization heat when it evaporates, the surface temperature of the workpiece is prevented from increasing. As a result, the absorption of the strike energy from the abrasive due to softening of the surface of the workpiece, a coated film formed on the surface of the workpiece or burrs as the object of removal can be prevented. This is believed to be the reason why the processing amount is improved and the efficiency of removal of a coated film or burrs is improved compared to dry blasting in which such softening can occur.

**[0090]** It is believed that the sticking or lodging of abrasive as described above also occurs because the ejected abrasive sticks into the surface of the workpiece more easily as the surface of the workpiece becomes softer with increase in temperature.

**[0091]** In addition, it is believed that elongation and warpage that reduce the dimensional stability of the product occurs because of elongation of the workpiece due to temperature rise and a difference in elongation between the front and back sides of the workpiece, respectively.

**[0092]** It is, therefore, believed that the above effects can be obtained when blasting is carried out by the method of the present invention because the workpiece is protected from wetting and temperature rise.

**[0093]** It has been also observed that the abrasive recovered in the blasting method of the present invention has undergone less cracking and chipping than that of conventional blasting carried out without spraying a liquid although its principle is unknown. This means that the blasting method of the present invention can reduce the rate of consumption of the abrasive.

**[0094]** As described above, the blasting method of the present invention can effectively prevent the generation of sparks caused by accumulation of static electricity during processing and can therefore eliminate not only breakage or failure of the products themselves, in particular, items such as electronic components but also breakage of electrodes and other parts provided on the product.

**[0095]** In addition, not only the products are prevented from accumulation of static electricity but also the abrasive and the abrasive circulating system including the interior walls of the cabinet and the interior walls of the ducts are prevented from accumulation of static electricity. Several other benefits can be achieved including the prevention of the abrasive from adhering to the interior of the cabinet 2 and the abrasive tank 3, and improvement of abrasive recovery efficiency resulting from a decrease in the amount of abrasive that is not recovered but flows to a dust collector, because the abrasive in a swirling flow strikes with the abrasive adhering to the interior of the cyclone-type abrasive tank 3.

**[0096]** In addition, the blasting method of the present invention has beneficial effects that cannot be predicted from conventional arts including the improvement of processing amount as compared to ordinary dry blasting, improvement of the efficiency of removal of a coated film or burrs, reduction of surface roughness, prevention of change in color due to burning, prevention of sticking or lodging of abrasive that may cause contamination during subsequent painting or plating, and prevention of warpage and elongation of the workpiece that reduces the dimensional stability of the product in addition to the effect of preventing the generation of static electricity.

Examples

**[0097]** The results of tests conducted to confirm that the blasting method of the present invention can provide the above-mentioned benefits are shown below.

**[0098]** The dry blasting (comparative example) and the blasting of the present invention (examples) were both carried out using a suction-type blasting apparatus (see FIG. 1 for the outline of the structure) as the blasting apparatus. In the blasting example, which involves the supply of a liquid (water), either the blast nozzle of the present invention having the liquid introduction path 88 in the compressed gas flow path 86 of the rear nozzle 83 as described with reference to FIG. 2A or the non-claimed blast nozzle 8 having a chamber as the liquid introduction path 88 around a distal portion of the rear nozzle 83 as described with reference to FIG. 5 was used. On the other hand, the dry blasting (comparative example) was carried out by ejecting an abrasive from the blast nozzle 8 shown in FIG. 2A or FIG. 5 without supplying water to conduct measurement, or using a blast nozzle 8 equipped with an ordinary rear nozzle (having a structure obtained by removing the liquid introduction path 88 from the rear nozzle 83 of the blast nozzle 8 having a structure shown in FIG. 2(A)) to conduct measurement.

(1) Confirmation of antistatic effect

**[0099]** Blasting was performed on an acrylic plate (100 mm × 100 mm × 5 mm) and the accumulated amount of static electricity was measured.

**[0100]** Nylon beads (NB) #0303 (average particle diameter: 300 μm) manufactured by Fuji Manufacturing Co., Ltd. were used as the abrasives, and the abrasives were ejected at a nozzle distance of 160 mm and an ejection pressure of 0.3 MPa for 40 minutes.

**[0101]** The processing was carried out using a circulating-type blasting apparatus having a structure shown in FIG. 1 and equipped with the blast nozzle 8 described with reference to FIG. 2A. The flow control valve 7 for adjusting the amount of water introduced into the blast nozzle 8 was gradually opened from its full-closed position to increase the water supply amount. The changes in the accumulated amount of static electricity in the acrylic plate (measuring instrument: 709 STATIC SENSOR manufactured by 3M was used) and the changes in temperature and humidity in the processing chamber were measured and the condition in the processing chamber was observed. The results of measurements are shown in Table 1.

[Table 1]
Result of test for static electricity accumulation

| Ejected amount of abrasive | Water supply amount (cc/min) | Accumulated amount of static electricity (kV) | Temperature in the processing chamber (humidity) |
|---|---|---|---|
| 550 g/min | 0 | -23.4 | 21.4°C (24%) |
| | 0.06 | -14.0 | 21.3°C (24%) |
| | 0.15 | -6.4 | 21.2°C (25%) |
| | 0.50 | -5.6 | 21.3°C (24%) |
| | 1.0 | -5.8 | 22.4°C (23%) |
| | 2.0 | -8.0 | 21.5°C (24%) |
| | 3.0 | -9.3 | 18.7°C (25%) |
| | 4.0 | -7.6 | 19.1°C (24%) |
| | 5.0 | -6.2 | 19.3°C (24%) |
| | 6.0 | -7.4 | 20.6°C (24%) |
| | 7.0 | -3.9 | 20.4°C (24%) |
| | 8.1 | -5.0 | 19.7°C (24%) |
| | 8.0 | -9.9 | 20.1°C (25%) |
| | 9.1 | -7.4 | 21.6°C (25%) |
| | 10.0 | -5.2 | 21.5°C (25%) |
| 1150 g/min | 11.0 | -5.2 | 21.2°C (24%) |
| | 12.2 | -6.4 | 21.2°C (24%) |
| | 13.1 | -5.6 | 20.8°C (25%) |
| | 14.1 | -4.0 | 20.8°C (25%) |
| | 15.0 | -2.0 | 21.3°C (25%) |
| | 16.2 | -2.1 | 21.1°C (25%) |
| | 17.1 | -2.2 | 21.2°C (25%) |

**[0102]** It was confirmed from the above results that the accumulated amount of static electricity was decreased by 40% or more simply by supplying as small an amount of water as 0.06 cc/min compared to the value obtained when dry blasting was carried out without supplying water with the flow control valve 7 fully closed. It was therefore confirmed that spraying even a relatively small amount of water was highly effective in preventing the generation of static electricity.

**[0103]** After that, the accumulated amount of static electricity further decreased as the water supply amount was increased. The accumulated amount of static electricity decreased by 90% or more at 15.0 cc/min compared to the value obtained when no water was supplied.

**[0104]** The abrasive had adhered everywhere in the cabinet including the surface of the workpiece, the interior walls of the cabinet, rubber hoses and the surface of the blast nozzle after blasting was carried out without supplying water with the flow control valve 7 fully closed, whereas adhesion of abrasive due to static electricity was not observed after blasting was carried out by the method of the present invention although accumulation of abrasive was observed on uneven parts of the walls in the cabinet.

(2) Confirmation of increase in processing amount (cutting speed or rate)

**[0105]** (2-1) Measurement of changes in processing amount with changes in water supply amount The blast nozzle shown in FIG. 2A was used, and the opening of the flow control valve was adjusted to measure how the processing amount (cut amount) for the workpiece changed with changes in the water supply amount to the blast nozzle.

**[0106]** Test pieces made of the materials shown in Table 2 below were processed using an alumina abrasive ("FUJIRUNDUM A#60" manufactured by Fuji Manufacturing Co., Ltd.) at an ejection distance of 120 mm and an ejection pressure of 0.4 MPa under conditions shown again in Table 2. The weights of the test pieces before and after the processing were measured, and the decrease in weight was taken as the cut amount.

[Table 2]

Test pieces and measurement method

| Test pieces | Dimensions (mm) | Amount of abrasive used (kg) | Processing time |
|---|---|---|---|
| Boron plate (B4C) | 106×60×5.5 | 6 | 60 (min) |
| Carbide plate (D-40) | 60×45×7 | 3 | 30 (min) |
| Urethane rubber (TR100-70°) | 80×80×10 | 3 | 60 (min) |
| Aluminum plate | 80×80×10 | 3 | 30 (min) |
| Stainless plate (SUS304) | 100×100×6 | 3 | 30 (min) |
| Iron plate (SS41) | 100×100×6 | 3 | 30 (min) |
| Acrylic plate (thermoplastic) | 80×80×5 | 3 | 90 (sec) |
| Epoxy glass plate (thermosetting) | 80×80×5 | 3 | 90 (sec) |
| Granite | 80×80×10 | 3 | 30 (sec) |

**[0107]** The results of measurement on each test piece are shown in Tables 3 to 11 and FIGS. 6 to 14. The ratio of decrease in Tables 3 to 11 is the ratio of the decrease in weight to the decrease in weight obtained when processing was carried out without supplying water.

[Table 3]

Changes in processing amount with changes in water supply amount (boron plate)

| | Water supply amount (cc/min) | Weight of test piece (g) | | |
|---|---|---|---|---|
| | | Before processing | After processing | Decrease in weight (ratio of decrease) |
| Comparative example | 0 | 79.59 | 78.54 | -1.05 (1) |
| Example | 0.1 | 82.15 | 81.00 | -1.15 (1.1) |
| | 0.5 | 78.97 | 77.45 | -1.52 (1.45) |
| | 2.0 | 81.56 | 78.86 | -2.70 (2.57) |
| | 3.0 | 83.56 | 80.50 | -3.06 (2.91) |
| | 5.0 | 83.37 | 80.33 | -3.04 (2.89) |
| | 7.0 | 83.91 | 80.86 | -3.05 (2.90) |
| | 10.0 | 83.50 | 80.41 | -3.09 (2.94) |
| | 13.0 | 79.14 | 76.14 | -3.00 (2.86) |
| | 18.0 | 78.85 | 75.84 | -3.01 (2.87) |
| | 24.0 | 83.54 | 80.56 | -2.98 (2.84) |

[Table 4]

Changes in processing amount with changes in water supply amount (carbide plate)

| | Water supply amount (cc/min) | Weight of test piece (g) | | |
|---|---|---|---|---|
| | | Before processing | After processing | Decrease in weight (ratio of decrease) |
| Comparative example | 0 | 254.84 | 244.94 | -9.90 (1) |
| Example | 1.0 | 273.13 | 262.53 | -10.60 (1.07) |
| | 3.0 | 265.34 | 254.24 | -11.10 (1.12) |
| | 5.0 | 273.24 | 261.86 | -11.35 (1.15) |
| | 12.0 | 262.53 | 250.93 | -11.60 (1.17) |
| | 20.0 | 260.30 | 248.16 | -12.14 (1.22) |
| | 28.0 | 206.02 | 193.45 | -12.57 (1.27) |

[Table 5]

Changes in processing amount with changes in water supply amount (urethane rubber plate)

| | Water supply amount (cc/min) | Weight of test piece (g) | | |
|---|---|---|---|---|
| | | Before processing | After processing | Decrease in weight (ratio of decrease) |
| Comparative example | 0 | 74.61 | 74.50 | -0.11 (1) |
| Example | 3.0 | 74.78 | 74.58 | -0.20 (1.82) |
| | 8.0 | 74.75 | 73.76 | -0.99 (9.00) |
| | 16.0 | 74.81 | 72.73 | -2.08 (18.91) |
| | 28.0 | 75.19 | 72.31 | -2.88 (26.18) |
| | 40.0 | 74.57 | 71.31 | -3.26 (29.64) |
| | 50.0 | 75.13 | 71.96 | -3.17 (28.82) |
| | 60.0 | 74.43 | 71.25 | -3.18 (28.91) |

[Table 6]

Changes in processing amount with changes in water supply amount (aluminum plate)

| | Water supply amount (cc/min) | Weight of test piece (g) | | |
|---|---|---|---|---|
| | | Before processing | After processing | Decrease in weight (ratio of decrease) |
| Comparative example | 0 | 166.36 | 163.93 | -2.43 (1) |

(continued)

Changes in processing amount with changes in water supply amount (aluminum plate)

| | Water supply amount (cc/min) | Weight of test piece (g) | | |
|---|---|---|---|---|
| | | Before processing | After processing | Decrease in weight (ratio of decrease) |
| Example | 3.0 | 164.98 | 160.40 | -4.58 (1.88) |
| | 8.0 | 165.24 | 160.09 | -5.15 (2.12) |
| | 16.0 | 165.22 | 159.90 | -5.32 (2.19) |
| | 32.0 | 165.00 | 159.40 | -5.60 (2.30) |
| | 50.0 | 164.71 | 158.98 | -5.73 (2.36) |
| | 70.0 | 165.89 | 160.05 | -5.84 (2.40) |
| | 100.0 | 166.17 | 160.50 | -5.67 (2.33) |
| | 130.0 | 166.04 | 160.39 | -5.65 (2.33) |
| | 150.0 | 167.67 | 162.11 | -5.56 (2.29) |

[Table 7]

Changes in processing amount with changes in water supply amount (stainless plate)

| | Water supply amount (cc/min) | Weight of test piece (g) | | |
|---|---|---|---|---|
| | | Before processing | After processing | Decrease in weight (ratio of decrease) |
| Comparative example | 0 | 450.59 | 445.18 | -5.41 (1) |
| Example | 1.0 | 449.89 | 443.65 | -6.24 (1.15) |
| | 3.0 | 450.99 | 443.46 | -7.53 (1.39) |
| | 5.0 | 450.20 | 442.45 | -7.75 (1.43) |
| | 8.0 | 449.76 | 442.04 | -7.72 (1.43) |
| | 12.0 | 450.94 | 443.18 | -7.76 (1.43) |
| | 20.0 | 450.88 | 442.99 | -7.89 (1.46) |
| | 30.0 | 450.27 | 442.34 | -7.93 (1.47) |
| | 40.0 | 449.54 | 441.57 | -7.97 (1.47) |
| | 50.0 | 450.66 | 442.76 | -7.90 (1.46) |
| | 60.0 | 450.23 | 442.22 | -8.01 (1.48) |

[Table 8]

Changes in processing amount with changes in water supply amount (iron plate)

| | Water supply amount (cc/min) | Weight of test piece (g) | | |
|---|---|---|---|---|
| | | Before processing | After processing | Decrease in weight (ratio of decrease) |
| Comparative example | 0 | 462.72 | 457.90 | -4.82 (1) |

(continued)

Changes in processing amount with changes in water supply amount (iron plate)

| | Water supply amount (cc/min) | Weight of test piece (g) | | |
|---|---|---|---|---|
| | | Before processing | After processing | Decrease in weight (ratio of decrease) |
| Example | 1.0 | 462.86 | 456.90 | -5.96 (1.24) |
| | 3.0 | 462.20 | 455.02 | -7.18 (1.49) |
| | 5.0 | 462.40 | 455.11 | -7.29 (1.51) |
| | 8.0 | 462.46 | 455.22 | -7.24 (1.50) |
| | 12.0 | 462.94 | 455.55 | -7.39 (1.53) |
| | 20.0 | 462.20 | 454.65 | -7.55 (1.57) |
| | 30.0 | 461.73 | 454.02 | -7.71 (1.60) |
| | 40.0 | 463.07 | 455.24 | -7.83 (1.62) |
| | 50.0 | 462.63 | 454.50 | -8.13 (1.69) |
| | 60.0 | 462.38 | 454.13 | -8.25 (1.71) |

[Table 9]

Changes in processing amount with changes in water supply amount (acrylic plate)

| | Water supply amount (cc/min) | Weight of test piece (g) | | |
|---|---|---|---|---|
| | | Before processing | After processing | Decrease in weight (ratio of decrease) |
| Comparative example | 0 | 37.92 | 37.37 | -0.55 (1) |
| Example | 1.0 | 37.90 | 37.19 | -0.71 (1.29) |
| | 3.0 | 37.91 | 36.93 | -0.98 (1.78) |
| | 6.0 | 37.92 | 36.72 | -1.20 (2.18) |
| | 10.0 | 37.91 | 36.55 | -1.26 (2.29) |
| | 15.0 | 37.93 | 36.59 | -1.34 (2.44) |
| | 20.0 | 36.76 | 35.44 | -1.32 (2.40) |
| | 30.0 | 36.66 | 35.34 | -1.32 (2.40) |
| | 40.0 | 36.67 | 35.32 | -1.35 (2.45) |
| | 50.0 | 36.62 | 35.20 | -1.42 (2.58) |
| | 60.0 | 36.56 | 35.11 | -1.45 (2.64) |

[Table 10]

Changes in processing amount with changes in water supply amount (epoxy glass plate)

| | Water supply amount (cc/min) | Weight of test piece (g) | | |
|---|---|---|---|---|
| | | Before processing | After processing | Decrease in weight (ratio of decrease) |
| Comparative example | 0 | 61.90 | 60.04 | -1.86 (1) |

(continued)

Changes in processing amount with changes in water supply amount (epoxy glass plate)

| | Water supply amount (cc/min) | Weight of test piece (g) | | |
|---|---|---|---|---|
| | | Before processing | After processing | Decrease in weight (ratio of decrease) |
| Example | 1.0 | 61.81 | 60.00 | -1.81 (0.97) |
| | 3.0 | 61.83 | 59.38 | -2.45 (1.32) |
| | 6.0 | 61.91 | 59.00 | -2.91 (1.56) |
| | 10.0 | 61.78 | 59.00 | -3.06 (1.65) |
| | 15.0 | 61.83 | 58.64 | -3.19 (1.72) |
| | 20.0 | 61.77 | 58.58 | -3.19 (1.72) |
| | 30.0 | 61.74 | 58.51 | -3.23 (1.74) |
| | 40.0 | 61.85 | 58.44 | -3.41 (1.83) |
| | 50.0 | 61.92 | 58.49 | -3.43 (1.84) |
| | 60.0 | 61.91 | 58.47 | -3.44 (1.85) |

[Table 11]

Changes in processing amount with changes in water supply amount (granite)

| | Water supply amount (cc/min) | Weight of test piece (g) | | |
|---|---|---|---|---|
| | | Before processing | After processing | Decrease in weight (ratio of decrease) |
| Comparative example | 0 | 185.22 | 182.34 | -2.88 (1) |
| Example | 1.0 | 180.55 | 177.12 | -3.43 (1.19) |
| | 5.0 | 191.26 | 187.67 | -3.59 (1.25) |
| | 10.0 | 187.87 | 184.35 | -3.52 (1.22) |
| | 25.0 | 187.06 | 183.47 | -3.59 (1.25) |
| | 40.0 | 192.97 | 189.34 | -3.63 (1.26) |

**[0108]** According to the above results, it was confirmed that the cut amount could be increased compared to the value obtained when blasting was carried out without supplying water (comparative example) regardless of the material of the test piece processed.

**[0109]** While the cut amount increased as the water supply amount was increased, the cut mount did not further increase but remained constant even if the water supply amount was increased after the cut amount had increased to a certain level.

**[0110]** This indicates that ejecting a relatively small amount of liquid together with an abrasive as in the blasting method of the present invention has the unexpected effect of increasing the processing amount in addition to the above-mentioned antistatic effect.

**[0111]** In addition, it was confirmed that this effect could be obtained regardless of the material of the workpiece.

(2-2) Confirmation of effect of different abrasives on processing amount

**[0112]** The results of processing performed on stainless test pieces (SUS304) by ejecting zircon grid ("FZG 60" manufactured by Fuji Manufacturing Co., Ltd., particle diameter: 0.125 to 0.250 mm) using the blast nozzle shown in FIG. 5 and the results of processing performed on test pieces by ejecting an alumina abrasive ("FUJIRUNDUM A #60" manufactured by Fuji Manufacturing Co., Ltd., average particle diameter: 230 μm) are shown in Tables 12 and 13, respectively.

[Table 12]

Changes in processing amount depending on whether water is supplied (FZG-60)

| | Comparative example | Example |
|---|---|---|
| Valve opening | 0/8 (Full closed) | 3/8 |
| Water supply amount (cc/min) | 0 | 3.0 |
| Decrease in weight of test piece (g/20 min) | (1)-2.9<br>(2)-3.4<br>(Average: -3.15) | (1)-4.8<br>(2)-5.6<br>(Average: -5.2) |

[Table 13]

Changes in processing amount depending on whether water is supplied (FUJIRUNDUM A#60)

| | Comparative example | Example | |
|---|---|---|---|
| Water supply amount (cc/min) | 0 | 2.0 | 3.6 |
| Decrease in weight of test piece (g/1H) | -11.52 | -15.93 | -16.19 |

**[0113]** It was confirmed from the above results that the processing amount increased both when zircon grid (FZG-60) was used as the abrasive and when an alumina abrasive ("FUJIRUMDUM A #60" manufactured by Fuji Manufacturing Co., Ltd., particle diameter: 250 to 212 μm) was used. It was therefore confirmed that the processing amount increasing effect of the present invention could be still obtained even when the type of abrasive used was different.

**[0114]** The increase in processing amount was more than 1.5 times for the zircon grid (FZG-60) and 1.3 to 1.4 times for the alumina abrasive ("FUJIRUNDUM A #60" manufactured by Fuji Manufacturing Co., Ltd.). It was therefore confirmed that a significant increase in processing amount could be achieved.

(3) Confirmation of abrasive sticking or lodging state

**[0115]** The components at the center of the processed region of the urethane rubber plate, stainless plate, iron plate, acrylic plate and epoxy glass plate of the test pieces processed as described in "(2)(2-1) Measurement of changes in processing amount with changes in water supply amount" were measured with an EDX (energy dispersive X-ray analysis) device (INCA Energy manufactured by Oxford Instruments), and the mass concentration of aluminum as a primary component of the alumina abrasive used ("FUJIRUNDUM A #60" manufactured by Fuji Manufacturing Co., Ltd.) was evaluated as the amount of abrasive stuck in the test piece.

**[0116]** The results of measurements are shown in Tables 14 to 18 and FIGS. 15 to 19. The Al mass concentration ratio in Tables 14 to 18 is the ratio of the Al mass concentration to the Al mass concentration obtained without water supply.

[Table 14]

Changes in amount of abrasive stuck in test piece with changes in water supply amount (urethane rubber)

| | Water supply amount (cc/min) | Al mass concentration (%) | Al mass concentration ratio |
|---|---|---|---|
| Comparative example | 0 | 13.62 | 1 |
| Example | 3.0 | 7.99 | 0.59 |
| | 5.0 | 6.38 | 0.47 |
| | 12.0 | 4.09 | 0.30 |
| | 20.0 | 2.17 | 0.16 |
| | 28.0 | 2.11 | 0.15 |
| | 40.0 | 2.09 | 0.15 |
| | 50.0 | 2.19 | 0.16 |
| | 60.0 | 1.80 | 0.13 |

[Table 15]

Changes in amount of abrasive stuck in test piece with changes in water supply amount (stainless)

| | Water supply amount (cc/min) | Al mass concentration (%) | Al mass concentration ratio |
|---|---|---|---|
| Comparative example | 0 | 12.12 | 1 |
| Example | 5.0 | 11.21 | 0.92 |
| | 12.0 | 9.95 | 0.82 |
| | 20.0 | 8.36 | 0.69 |
| | 30.0 | 5.79 | 0.48 |
| | 40.0 | 6.08 | 0.50 |
| | 50.0 | 5.82 | 0.48 |
| | 60.0 | 6.04 | 0.50 |

[Table 16]

Changes in amount of abrasive stuck in test piece with changes in water supply amount (iron)

| | Water supply amount (cc/min) | Al mass concentration (%) | Al mass concentration ratio |
|---|---|---|---|
| Comparative example | 0 | 12.35 | 1 |
| Example | 3.0 | 11.57 | 0.94 |
| | 8.0 | 10.40 | 0.84 |
| | 16.0 | 10.04 | 0.81 |
| | 25.0 | 8.5 | 0.69 |
| | 40.0 | 6.82 | 0.55 |
| | 60.0 | 5.21 | 0.42 |

[Table 17]

Changes in amount of abrasive stuck in test piece with changes in water supply amount (acrylic)

| | Water supply amount (cc/min) | Al mass concentration (%) | Al mass concentration ratio |
|---|---|---|---|
| Comparative example | 0 | 2.02 | 1 |
| Example | 1.0 | 0.79 | 0.39 |
| | 6.0 | 0.71 | 0.35 |
| | 10.0 | 0.75 | 0.37 |
| | 20.0 | 0.71 | 0.35 |
| | 30.0 | 0.68 | 0.34 |
| | 40.0 | 0.69 | 0.34 |
| | 50.0 | 0.73 | 0.36 |
| | 60.0 | 0.67 | 0.33 |

[Table 18]

Changes in amount of abrasive stuck in test piece with changes in water supply amount (epoxy glass)

| | Water supply amount (cc/min) | Al mass concentration (%) | Al mass concentration ratio |
|---|---|---|---|
| Comparative example | 0 | 2.49 | 1 |
| Example | 3.0 | 1.43 | 0.57 |
| | 6.0 | 1.42 | 0.57 |
| | 10.0 | 1.54 | 0.62 |
| | 20.0 | 1.43 | 0.57 |
| | 30.0 | 1.61 | 0.65 |
| | 40.0 | 1.49 | 0.60 |
| | 50.0 | 1.59 | 0.64 |
| | 60.0 | 1.61 | 0.65 |

**[0117]** It was confirmed from the above results that sticking or lodging of abrasive decreases when a liquid was supplied compared to when blasting was carried out without supplying water.

**[0118]** Sticking or lodging of abrasive can be reduced even when processing is carried out by a known wet blasting method. However, because the cut amount decreases in known wet blasting compared to dry blasting as described before, good processing performance and the reduction of sticking or lodging of abrasive cannot be achieved by wet blasting at the same time.

**[0119]** In contrast to this, the method of the present invention has the unexpected effect of being able to improve the cut amount compared not only to conventional wet blasting but also to blasting without involving water supply as described above and prevent sticking or lodging of abrasive at the same time.

**[0120]** (4) Results of measurements of amount of consumption and particle size of abrasive Test pieces made of SUS304 were subjected to blasting at an ejection pressure of 0.5 MPa using zircon beads ("FZB-60" manufactured by Fuji Manufacturing Co., Ltd., average diameter: 200 $\mu$m) as the abrasive by the blasting method of the present invention, which used the blast nozzle shown in FIG. 2A (example) and, a dry blasting method, which used a known blast nozzle (having a structure obtained by removing the liquid introduction path 88 from the blast nozzle shown in FIG. 2A) (comparative example). The amount of consumption of abrasive was measured and the condition of particles of the abrasive was observed after the blasting.

**[0121]** The ejection was carried out in a continuous manner (in an abrasive circulating-type blasting apparatus shown in FIG. 1). The weight of the abrasive introduced into the abrasive tank of the blasting apparatus before starting the measurement and the weight of abrasive recovered were measured, and the decrease in weight was evaluated as the amount of consumption.

**[0122]** The blasting time was 45 minutes and water was introduced at a rate of 6 cc/min in the blasting method of the present invention.

**[0123]** The results of measurements of the amount of consumption of abrasive are shown in Table 19 and the conditions of the particles of the abrasive after use are shown in FIG. 20.

[Table 19]

Results of measurements of amount of consumption of abrasive

| | Example (after drying) | Comparative example |
|---|---|---|
| Water supply amount | 6cc/min | 0cc/min |
| Continuous ejection method | -130.0g | -225.3g |

**[0124]** It was confirmed from the above results that the blasting method of the present invention could reduce the amount of consumption of abrasive compared to the known dry blasting method.

**[0125]** According to the results of observation of the particle size of the recovered abrasive (see FIG. 20), the abrasive used in the dry blasting method underwent rapid crushing compared to the abrasive used in the blasting method of the present invention and therefore had a smaller particle diameter. In this respect, it was confirmed that there was a large difference in the consumption of abrasive.

(5) Measurement of surface temperature of workpiece

(5-1) Temperature measurement with thermocouple

**[0126]** Zircon beads ("FZB-400" manufactured by Fuji Manufacturing Co., Ltd., particle diameter: <0.05 mm) as an abrasive was ejected onto copper plates with a size of 15 mm × 15 mm × 0.5 mm at an ejection distance of 100 mm and an ejection pressure of 0.3 MPa or 0.5 MPa, and the changes in temperature of the copper plates were measured.
**[0127]** The temperature measurement was carried out by attaching a thermocouple-type thermometer to a backside of each copper plate so that the change in temperature could be read, and the abrasive was ejected for several seconds using the blast nozzle shown in FIG. 2A while the water supply amount was being varied. The highest temperature displayed while the abrasive was being ejected was employed as the measurement value. The results of measurements are shown in Table 20.

[Table 20]

| Processing pressure | 0.3MPa | | | 0.5MPa | | |
|---|---|---|---|---|---|---|
| | Comparative example | Example | | Comparative example | Example | |
| Water supply amount (cc/min) | 0 | 1.4 | 3.6 | 0 | 1.5 | 3.1 |
| Temperature (°C) | 54 | 36 | 26 | 56 | 42 | 29 |

**[0128]** It was confirmed from the above results that the blasting method of the present invention could significantly reduce the temperature rise of the workpiece compared to a dry blasting method.

(5-2) Confirmation of heat generating state

**[0129]** The temperature measured in the above test was the temperature of the backside of a copper plate as a processing object measured while the abrasive was being ejected for as fairly short a period as several seconds, and it is expected that the temperature of the surface where the strike with abrasive occurs instantaneously rises to a level high enough to soften the surface of the workpiece.
**[0130]** Thus, the blasting method of the present invention and a dry blasting method were applied to paint stripping from PC (polycarbonate) resin products and deburring of PPS (polyphenylene sulfide) resin products and the post-processing states were compared so that the difference in surface temperature of the workpiece between the blasting method of the present invention and the dry blasting method could be understood instinctively.
**[0131]** The paint stripping from the PC resin products was carried out by ejecting a high-purity alumina abrasive ("FUJIRUNDUM WA #600" manufactured by Fuji Manufacturing Co., Ltd.) at a processing pressure of 0.4 MPa and a nozzle distance of 70 mm using the blast nozzle shown in FIG. 2A. The processing was carried out with a water supply amount of 5 cc/min in the method of the present invention (example) and without supplying water in the comparative example.
**[0132]** The deburring of the PPS (polyphenylene sulfide) resin products was carried out by ejecting nylon beads ("FNB-0303" manufactured by Fuji Manufacturing Co., Ltd.) using the blast nozzle shown in FIG. 2A at a processing pressure of 0.4 MPa and a nozzle distance of 20 to 30 mm. The processing was carried out with a water supply amount of 3 cc/min in the method of the present invention (example) and without supplying water in the comparative example.
**[0133]** The results of measurements of surface roughness of the PC products after the paint stripping are shown in FIG. 21, and the results of measurements of surface roughness of the PPS products after the deburring are shown in FIG. 22.
**[0134]** It can be understood from the processing results that the surface roughness of the resin product processed by the method of the present invention (see FIG. 21A and FIG. 22A) was lower than that of the resin product processed by the dry method of the comparative example (see FIG. 21B and FIG. 22B) in either case. From these results, it is believed that the surfaces underwent significant deformation caused by thermal softening in the dry blasting.
**[0135]** In addition, the surfaces of the resin products processed by the dry blasting had been burnt dark whereas no burning was observed on the resin products processed by the method of the present invention. In this respect, it was confirmed that the method of the present invention could effectively prevent the workpiece from generating heat.
**[0136]** Such burning occurs not only when resin products are processed but also when products made of a metal such as aluminum are processed. The method of the present invention can also prevent occurrence of burning in the processing of such metal products.
**[0137]** In addition, it took 11 to 12 seconds to carry out the paint stripping by dry blasting whereas the method of the

present invention was able to reduce the time to 6 to 7 seconds. It was therefore confirmed that the paint stripping efficiency could be improved when blasting was carried out by the method of the present invention.

**[0138]** The same effect was observed not only in paint stripping from a surface of a resin base material but also in paint stripping from a surface of a metal base material such as aluminum alloy, magnesium alloy, zinc alloy, brass alloy or iron.

**[0139]** In the deburring, even burrs that could not be removed by dry blasting could be removed by the blasting of the present invention. It was therefore confirmed that the blasting of the present invention was also effective in deburring.

**[0140]** The differences are believed to be due to the fact that the surface temperature of the workpiece rises until the coated film or burrs become soft enough to absorb the impact of strike of the abrasive and make their stripping or removal difficult in dry blasting, whereas the surface of the workpiece is cooled and the coated film or burrs are prevented from becoming soft and remain hard (and thus brittle) enough to be easily stripped or removed by strike of the abrasive in the method of the present invention.

(6) Confirmation of warpage occurrence state

**[0141]** Almen strips (A strips) were processed using the blast nozzle shown in FIG. 2A and using a zircon shot ("FZB-425" manufactured by Fuji Manufacturing Co., Ltd. (Median particle diameter: 425μm to 600 μm, average diameter: 513 μm)) as the abrasive.

**[0142]** The processing was carried out at processing pressures of 0.3 MPa and 0.5 MPa for 20 seconds. The arc height value (the height to which the test piece was curved) was measured at various water supply amounts and evaluated as "warpage." The results of measurements are shown in Table 21.

[Table 21]

Result of confirmation of warpage occurrence state

| Ejection pressure | Water supply amount (cc/min) | Arc height |
|---|---|---|
| 0.3MPa | 0 | 0.163 mmA |
| | 1.4 | 0.158 mmA |
| | 3.6 | 0.158 mmA |
| 0.5MPA | 0 | 0.244 mmA |
| | 1.5 | 0.238 mmA |
| | 3.1 | 0.238 mmA |
| * The "A" in "mmA" indicates the use of an A strip. | | |

**[0143]** It was confirmed from the above results that warpage of the workpiece could be slightly reduced when blasting was carried out by the method of the present invention.

Descriptions of reference numerals

**[0144]**

| | | | |
|---|---|---|---|
| 1 | Blasting apparatus | 81 | Body |
| 2 | Cabinet | 82 | Nozzle tip |
| 21 | Processing chamber | 82a | Conical inner surface |
| 3 | Abrasive tank (cyclon) | 83 | Rear nozzle |
| 5 | Dust collector | 84 | Abrasive introduction port |
| 6 | Exhauster | 85 | Abrasive introduction chamber |
| 7 | Flow control valve | 86 | Compressed gas flow path |
| 8 | Blast nozzle | 88 | Liquid introduction path |
| 88a | Distal end (of Liquid introduction path) | | |
| 91 | Abrasive recovery pipe | | |

## Claims

1. A blasting method in which an abrasive is ejected together with a compressed gas onto a workpiece through a blast nozzle (8), wherein a liquid introduction path (88) is provided in the blast nozzle (8), having one end communicable with a liquid supply source and another end opened in a compressed gas flow path (86) in the blast nozzle (8), the liquid introduction path (88) being configured to cause a liquid introduced from the liquid supply source to strike with a stream of compressed gas flowing through the blast nozzle (8), and

   a flow rate control means is provided between the liquid introduction path (88) and the liquid supply source, wherein the blast nozzle (8) is a suction-type blast nozzle provided with a nozzle tip (82) directed in the ejection direction of a rear nozzle (83) communicated with a compressed gas supply source, and with an abrasive introduction chamber communicated with an abrasive supply source between the rear nozzle (83) and the nozzle tip (82), the blast nozzle (8) being configured to create a negative pressure in the abrasive introduction chamber by ejection of a stream of compressed gas from the rear nozzle (83) to suck an abrasive in the abrasive supply source, and eject the compressed gas and the abrasive as a mixed fluid,
   **characterised in that**
   the liquid introduction path (88) is formed by a conduit inserted concentrically in the compressed gas flow path (86) provided in the rear nozzle (83), and the other end of the liquid introduction path (88) is opened at the ejection port of the rear nozzle (83) the method comprising the step of:
   introducing a liquid into the blast nozzle (8) and atomizing the liquid by causing the liquid to strike with the compressed gas flowing through the blast nozzle (8), and ejecting droplets of the liquid together with the compressed gas and the abrasive, wherein an amount of the liquid introduced into the blast nozzle (8) being 0.06 cc/min to 150 cc/min and preventing the increase in surface temperature of the workpiece W by evaporating the atomized liquid in the space between the blast nozzle (8) and the workpiece W or on the surface of the workpiece W.

2. A blasting apparatus for ejecting a stream of compressed gas supplied from a compressed gas supply source and an abrasive from a blast nozzle (8) as a mixed fluid onto a workpiece W comprising:

   a liquid introduction path (88) provided in the blast nozzle (8), having one end communicable with a liquid supply source and another end opened in a compressed gas flow path (86) in the blast nozzle (8), the liquid introduction path (88) being configured to cause a liquid introduced from the liquid supply source to strike with a stream of compressed gas flowing through the blast nozzle (8), and
   a flow rate control means provided between the liquid introduction path and the liquid supply source,
   wherein the blast nozzle (8) is a suction-type blast nozzle provided with a nozzle tip (82) directed in the ejection direction of a rear nozzle (83) communicated with a compressed gas supply source, and with an abrasive introduction chamber communicated with an abrasive supply source between the rear nozzle (83) and the nozzle tip (82), the blast nozzle (8) being configured to create a negative pressure in the abrasive introduction chamber by ejection of a stream of compressed gas from the rear nozzle (83) to suck an abrasive in the abrasive supply source, and eject the compressed gas and the abrasive as a mixed fluid,
   **characterised in that**
   the liquid introduction path (88) is formed by a conduit inserted concentrically in the compressed gas flow path (86) provided in the rear nozzle (83), and the other end of the liquid introduction path (88) is opened at the ejection port of the rear nozzle (83).

3. The blasting apparatus according to claim 2 further comprising a fixed quantity liquid supply means for supplying the liquid in the liquid supply source to the liquid introduction path in a fixed quantity.

## Patentansprüche

1. Ein Strahlverfahren, bei dem ein Abrasionsmittel zusammen mit einem Druckgas durch eine Strahldüse (8) auf ein Werkstück geschleudert wird, wobei ein Flüssigkeitseinleitungsweg (88) in der Strahldüse (8) vorgesehenen ist, dessen eines Ende mit einer Flüssigkeitsversorgungsquelle kommunizierbar ist und dessen anderes Ende in ein Druckgasströmungsweg (86) in der Strahldüse offen ist, wobei der Flüssigkeitseinleitungsweg (88) konfiguriert ist um zu bewirken, dass die von der Flüssigkeitsversorgungsquelle zugeführte Flüssigkeit mit dem Druckgasstrom, der durch die Strahldüse (8) strömt, zusammenstoßt, und

ein Mittel zur Steuerung der Flussrate zwischen dem Flüssigkeitseinleitungsweg (88) und der Flüssigkeitsversorgungsquelle vorgesehen ist,

wobei die Strahldüse (8) eine Strahldüse vom Saugtyp ist, die mit einer Düsenspitze (82) versehen ist, die in der Ausstoßrichtung einer hinteren Düse (83) gerichtet ist, die mit einer Druckgas-Versorgungsquelle in Verbindung steht, und mit einer Abrasionsmittel-Einführungskammer, die mit einer Abrasionsmittelversorgungsquelle zwischen der hinteren Düse (83) und der Düsenspitze (82) in Verbindung steht, wobei die Strahldüse (8) so konfiguriert ist, dass sie durch Ausstoßen eines Druckgasstroms aus der hinteren Düse (83) einen Unterdruck in der Abrasionsmittel-Einführungskammer erzeugt, um ein Abrasionsmittel in der Abrasionsmittelversorgungsquelle anzusaugen, und das Druckgas und das Abrasionsmittel als gemischte Flüssigkeit auszustoßen,

**dadurch gekennzeichnet, dass**

der Flüssigkeitseinleitungsweg (88) durch eine Leitung gebildet ist, die konzentrisch in dem in der hinteren Düse (83) bereitgestellten Druckgasströmungsweg (86) eingesetzt ist, und das andere Ende des Flüssigkeitseinleitungswegs (88) an der Ausstoßöffnung der hinteren Düse (83) geöffnet ist,

wobei das Verfahren den folgenden Schritt umfasst

Einleiten einer Flüssigkeit in die Strahldüse (8) und Zerstäuben der Flüssigkeit durch Zusammenstossen der Flüssigkeit mit dem durch die Strahldüse (8) strömenden Druckgas und Ausstoßen von Tropfen der Flüssigkeit zusammen mit dem Druckgas und dem Abrasionsmittel, wobei die Menge der in die Strahldüse (8) eingeleiteten Flüssigkeit 0,06 $cm^3$/min bis 150 $cm^3$/min beträgt, und Verhindern eines Anstiegs der Oberflächentemperatur des Werkstücks W durch Verdampfen der zerstäubten Flüssigkeit im Raum zwischen der Strahldüse (8) und dem Werkstück oder auf der Oberfläche des Werkstücks.

**2.** Eine Strahlvorrichtung zum Ausstoßen eines Strahls von Druckgas, der von einer Druckgasversorgungsquelle geliefert wird, und Abrasionsmittels aus einer Strahldüse (8) als gemischtes Fluid auf ein Werkstück, umfassend:

ein Flüssigkeitseinleitungsweg (88), die in der Strahldüse (8) vorgesehenen ist, dessen eines Ende mit einer Flüssigkeitsversorgungsquelle verbunden werden kann und dessen anderes Ende in ein Druckgasströmungsweg (86) in der Strahldüse (8) offen ist, wobei der Flüssigkeitseinleitungsweg (88) konfiguriert ist um zu bewirken, dass die von der Flüssigkeitsversorgungsquelle zugeführte Flüssigkeit mit dem Druckgasstrom, der durch die Strahldüse (8) strömt, zusammenstosst, und

ein Mittel zur Steuerung der Flussrate zwischen dem Flüssigkeitseinleitungsweg (88) und der Flüssigkeitsversorgungsquelle vorgesehen ist,

wobei die Strahldüse (8) eine Strahldüse vom Saugtyp ist, die mit einer Düsenspitze (82) versehen ist, die in die Ausstoßrichtung einer hinteren Düse (83) gerichtet ist, die mit einer Druckgas-Versorgungsquelle in Verbindung steht, und mit einer Abrasionsmittel-Einführungskammer, die mit einer Abrasionsmittelversorgungsquelle zwischen der hinteren Düse (83) und der Düsenspitze (82) in Verbindung steht, wobei die Strahldüse (8) so konfiguriert ist, dass sie durch Ausstoßen eines Druckgasstroms aus der hinteren Düse (83) einen Unterdruck in der Abrasionsmittel-Einführungskammer erzeugt, um ein Abrasionsmittel in der Abrasionsmittelversorgungsquelle anzusaugen, und das Druckgas und das Abrasionsmittel als gemischte Flüssigkeit auszustoßen,

**dadurch gekennzeichnet, dass**

der Flüssigkeitseinleitungsweg (88) durch eine Leitung gebildet ist, die konzentrisch in dem in der hinteren Düse (83) bereitgestellten Druckgasströmungsweg (86) eingesetzt ist, und das andere Ende des Flüssigkeitseinleitungswegs (88) an der Ausstoßöffnung der hinteren Düse (83) geöffnet ist.

**3.** Eine Strahlvorrichtung nach Anspruch 2, ferner umfassend eine Einrichtung zum Zufuhr von fester Menge der Flüssigkeit, um die Flüssigkeit in der Flüssigkeitszufuhrquelle in einer festen Menge dem Flüssigkeitseinleitungswegs zuzuführen.

## Revendications

**1.** Procédé de sablage où un abrasif est éjecté avec un gaz comprimé sur une pièce par une buse (8) de soufflage, où un trajet (88) d'introduction de liquide est prévu dans la buse (8) de soufflage, comprenant une extrémité communicable avec une source d'alimentation en liquide et une autre extrémité ouverte dans un trajet (86) d'écoulement de gaz comprimé dans la buse (8) de soufflage, le trajet (88) d'introduction de liquide étant configuré pour obliger une liquide introduite de la source d'alimentation en liquide à frapper avec un courant de gaz comprimé s'écoulant à travers de la buse (8) de soufflage, et un dispositif de contrôle de taux d'écoulement est prévu entre le trajet (88) d'introduction de liquide et la source d'alimentation en liquide,

où la buse (8) de soufflage et une buse de soufflage de type d'aspiration pourvue d'un embout (82) de buse dirigé dans le sens d'éjection d'une buse (83) arrière communiquée avec une source d'alimentation en gaz comprimé, et avec une chambre d'introduction d'abrasif communiquée avec une source d'alimentation en abrasif entre la buse (83) arrière et l'embout (82) de buse, la buse (8) de soufflage étant configurée pour créer une pression négative dans la chambre d'introduction d'abrasif par éjection d'un courant de gaz comprimé de la buse (83) arrière pour aspirer un abrasif dans la source d'alimentation en abrasif, et pour éjecter du gaz comprimé et de l'abrasif en tant que fluide mélangé,

**caractérisé en ce que** le trajet (88) d'introduction de liquide est formé par un conduit concentriquement inséré dans le trajet (86) d'écoulement de gaz comprimé, prévu dans la buse (83) arrière, et l'autre extrémité du trajet (88) d'introduction de liquide est ouverte à l'orifice d'éjection de la buse (83) arrière, le procédé comprenant l'étape:

d'introduction d'un liquide dans la buse (8) de soufflage et d'atomisation du liquide en obligeant le liquide à frapper avec le gaz comprimé s'écoulant à travers la buse (8) de soufflage, et d'éjection de gouttelettes du liquide avec le gaz comprimé et l'abrasif, où la quantité du liquide introduite dans la buse (8) de soufflage et de 0.06 cc/min à 150 cc/min, et de prévention de l'augmentation de la température de surface de la pièce W par évaporation du liquide atomisé dans l'espace entre la buse (8) de soufflage et la pièce W ou sur la surface de la pièce W.

2. Appareil de sablage destiné à éjecter un courant de gaz comprimé provenant d'une source d'alimentation en gaz comprimé et d'un abrasif d'une buse (8) de soufflage en tant que fluide mélangé sur une pièce W, l'appareil de sablage comprenant :

un trajet (88) d'introduction de liquide prévu dans la buse (8) de soufflage comprenant un extrémité communicable avec une source d'alimentation en liquide et une autre extrémité ouverte dans un trajet (86) d'écoulement de gaz comprimé dans la buse (8) de soufflage, le trajet (88) d'introduction de liquide étant configuré pour obliger le liquide introduit de la source d'alimentation en liquide à frapper avec un courant de gaz comprimé s'écoulant à travers la buse (8) de soufflage, et

un dispositif de contrôle de taux d'écoulement prévu entre le trajet d'introduction de liquide et la source d'alimentation en liquide,

où la buse (8) de soufflage est une buse de soufflage de type d'aspiration pourvue d'un embout (82) de buse dirigé dans le sens d'éjection de la buse (83) arrière communiquée avec une source d'alimentation en gaz comprimé, et avec une chambre d'introduction d'abrasif communiquée avec une source d'alimentation en abrasif entre la buse (83) arrière et l'embout (82) de la buse, la buse (8) de soufflage étant configurée pour créer une pression négative dans la chambre d'introduction d'abrasif par éjection d'un courant de gaz comprimé de la buse (83) arrière pour aspirer un abrasif dans la source d'alimentation en abrasif, et pour éjecter le gaz comprimé et l'abrasif en tant que fluide mélangé,

**caractérisé en ce que** le trajet (88) d'introduction de liquide est formé par un conduit concentriquement inséré dans le trajet (86) d'écoulement de gaz comprimé prévu dans la buse (83) arrière, et l'autre extrémité du trajet (88) d'introduction de liquide est ouverte à l'orifice d'éjection de la buse (83) arrière.

3. Appareil de sablage selon la revendication 2, comprenant de plus un dispositif d'alimentation en liquide à quantité fixe pour fournir le liquide dans la source d'alimentation en liquide au trajet d'introduction de liquide dans une quantité fixe.

# FIG. 1

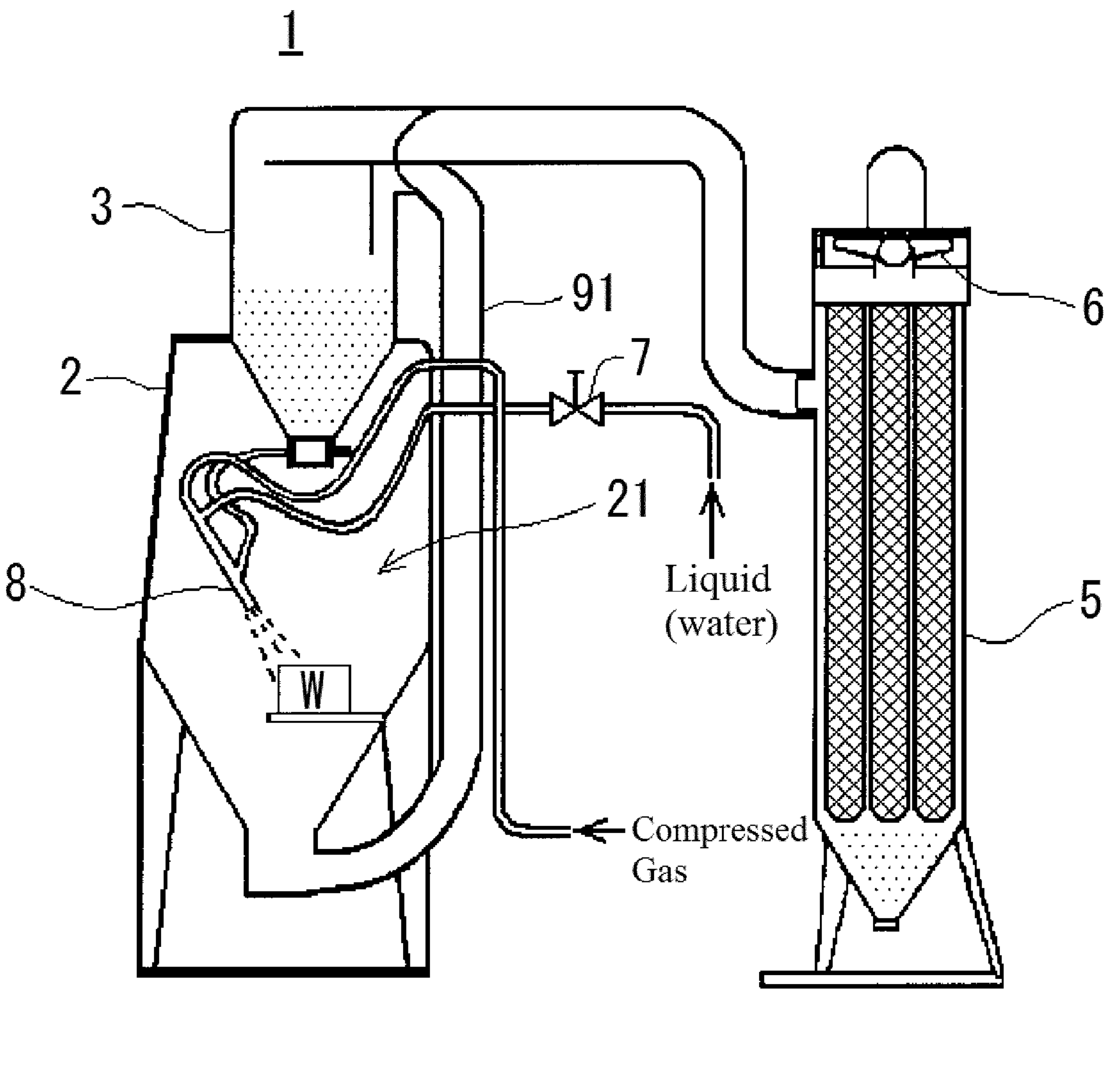


FIG. 2A

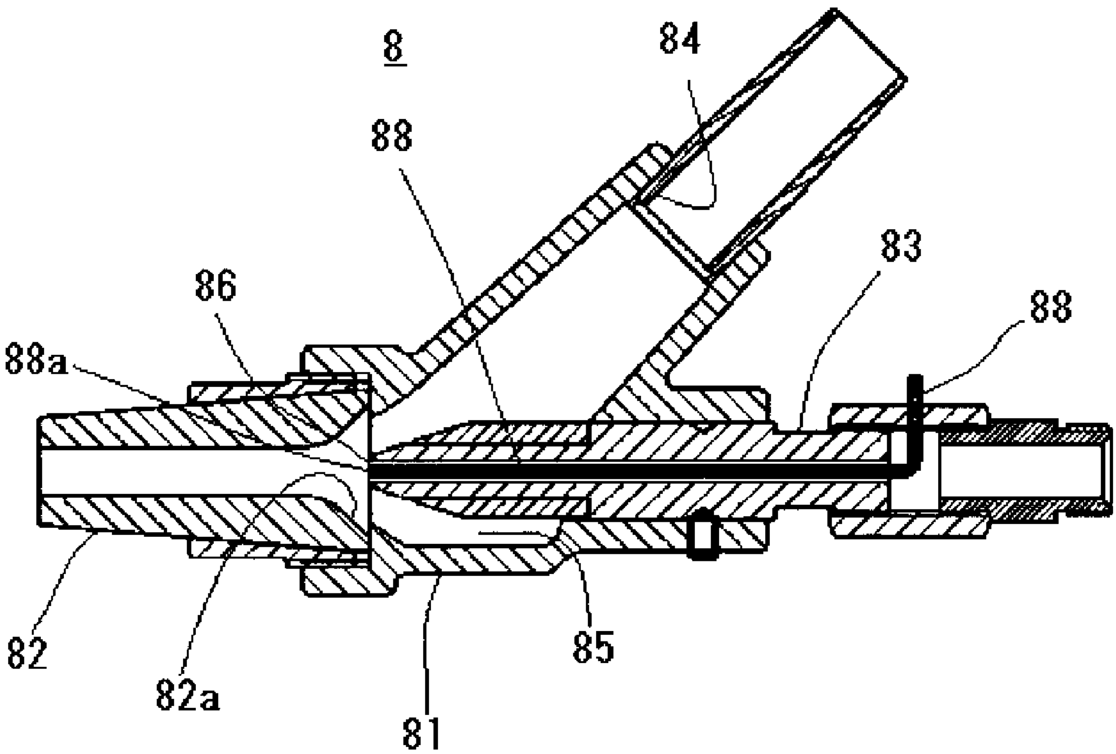
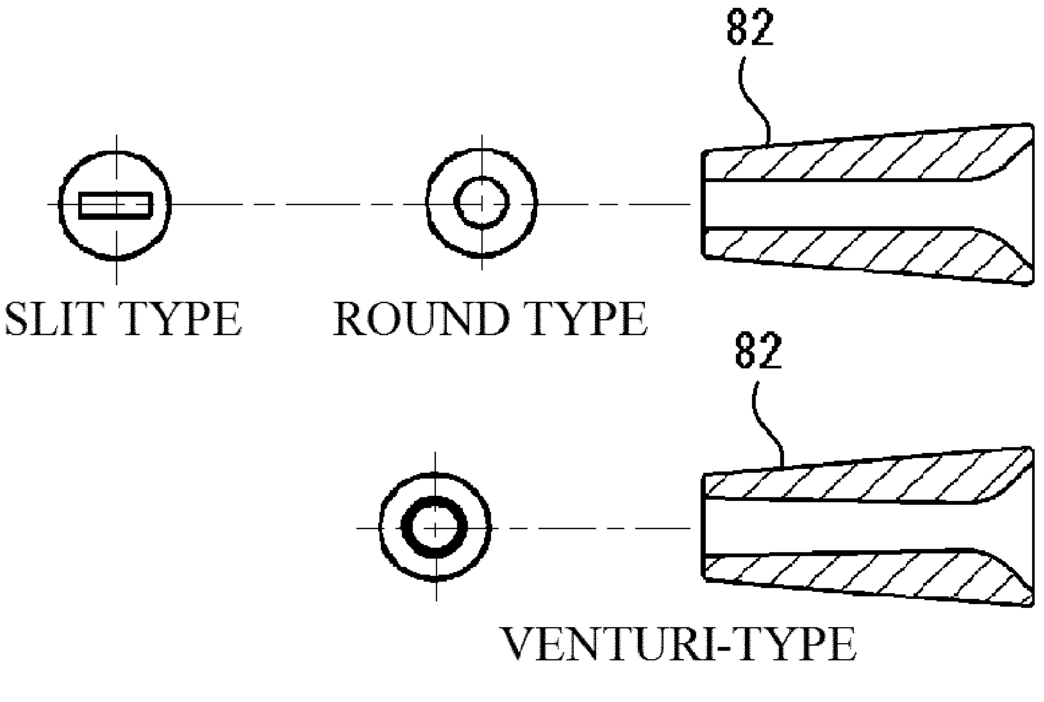
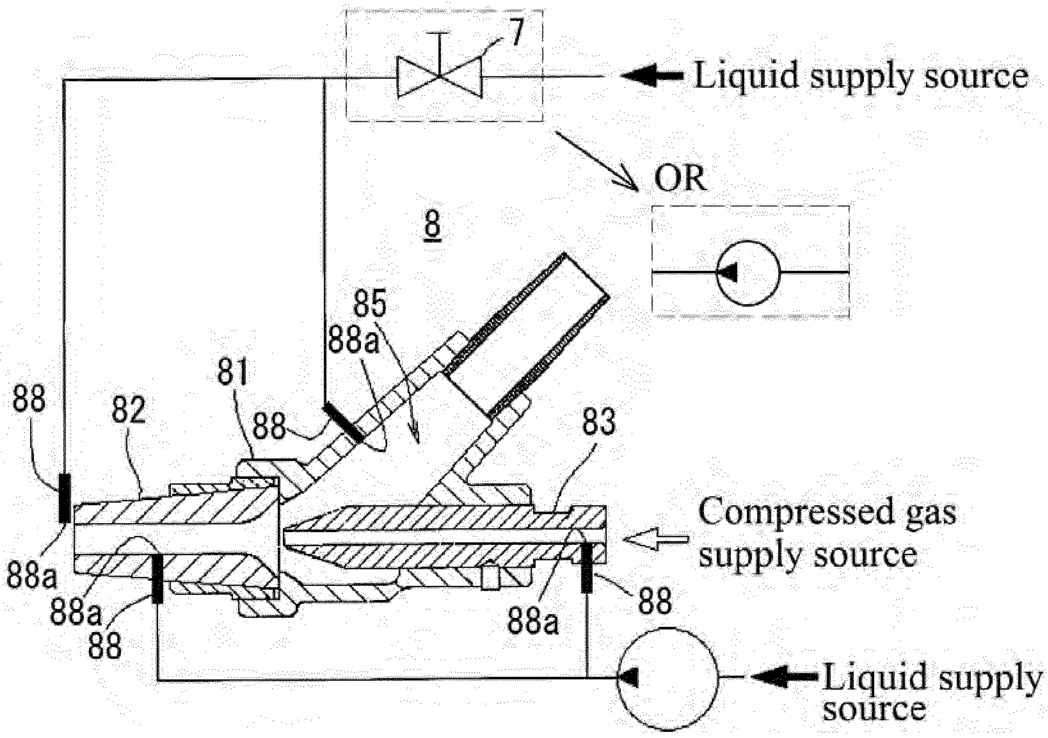

8
84
88
83
88
86
88a
82
82a
81
85

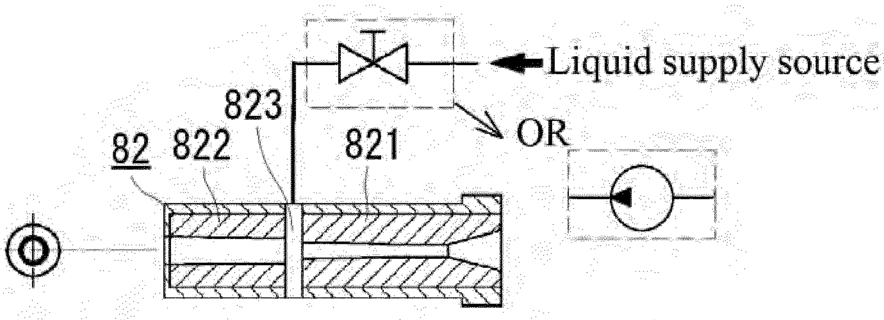
FIG. 2B


82
SLIT TYPE
ROUND TYPE
82
VENTURI-TYPE

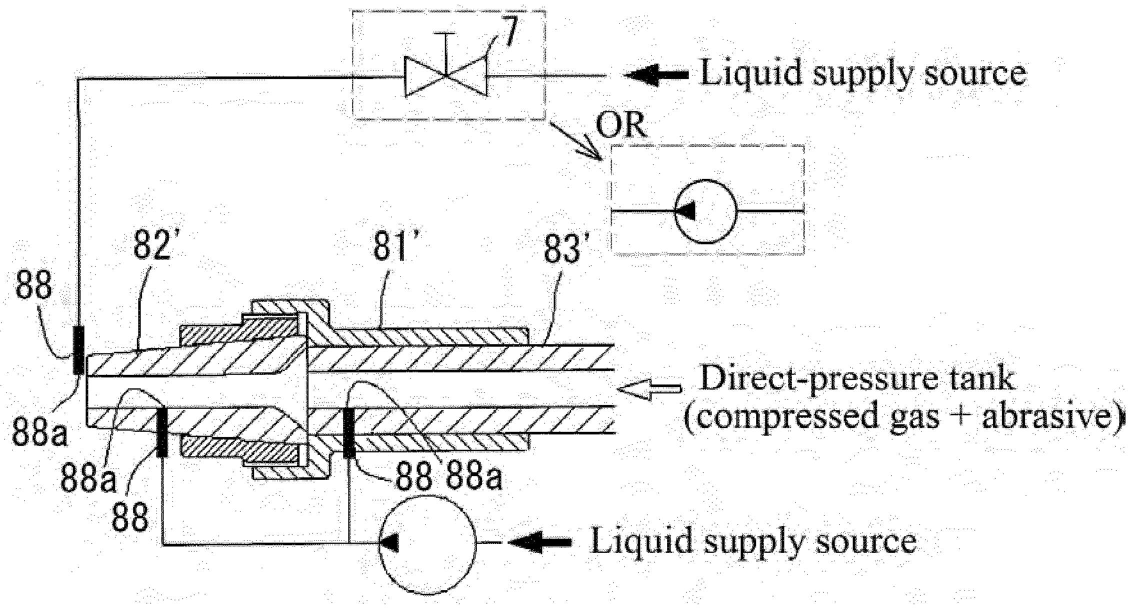
# FIG. 3A


7
Liquid supply source
OR
8
85
88a
81
88
82
88
83
Compressed gas
supply source
88a
88a
88
88
88a
Liquid supply
source

# FIG. 3B


Liquid supply source
823
OR
82
822
821

# FIG. 4A


7
Liquid supply source
OR
82'
81'
83'
88
88a
Direct-pressure tank
(compressed gas + abrasive)
88a
88
88
88a
Liquid supply source

# FIG. 4B

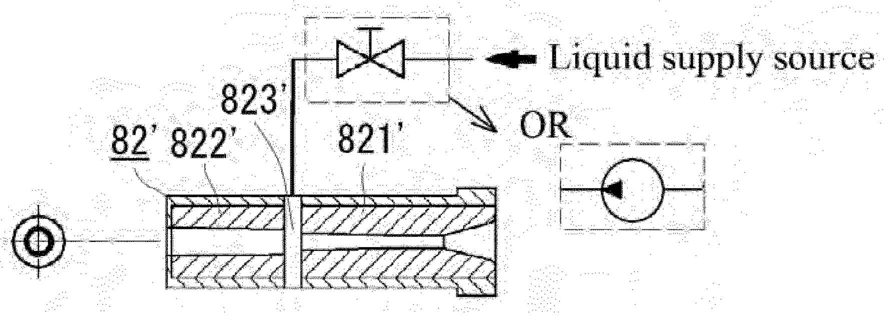
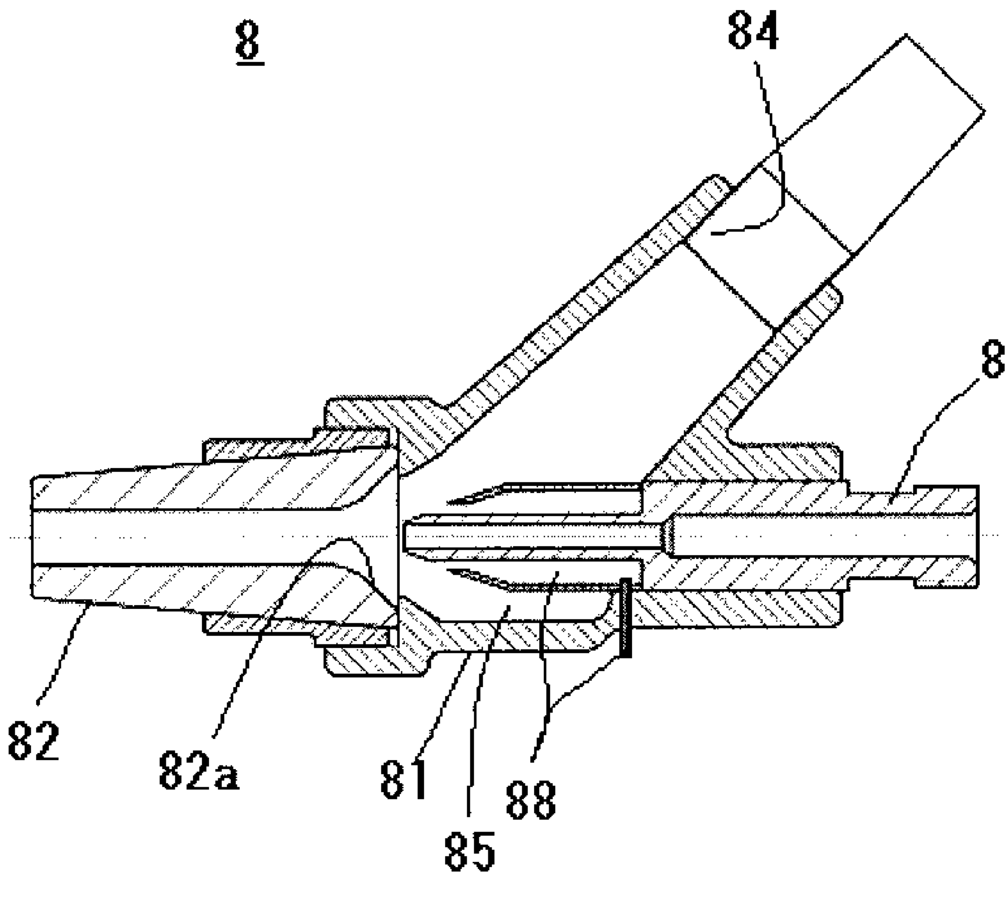
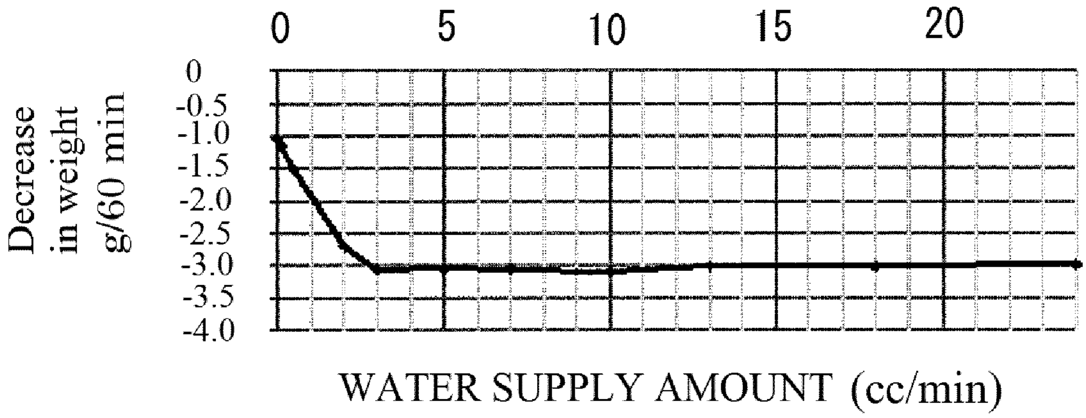

Liquid supply source
823'
OR
82' 822'
821'

FIG. 5



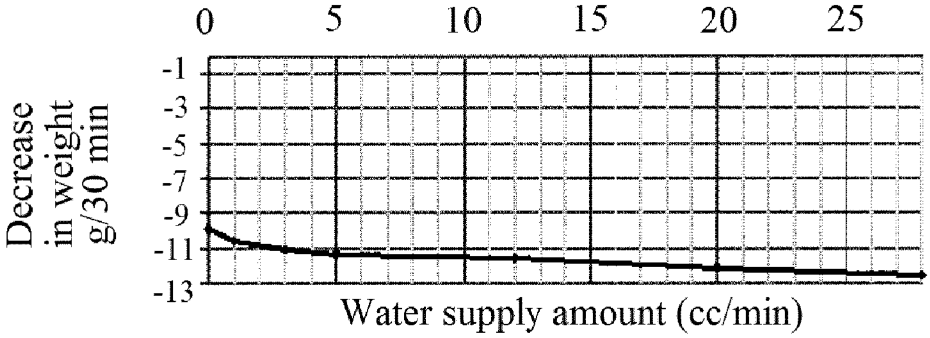
# FIG. 6

CHANGES IN PROCESSING AMOUNT WITH CHANGES IN WATER SUPPLY AMOUNT (BORON PLATE)



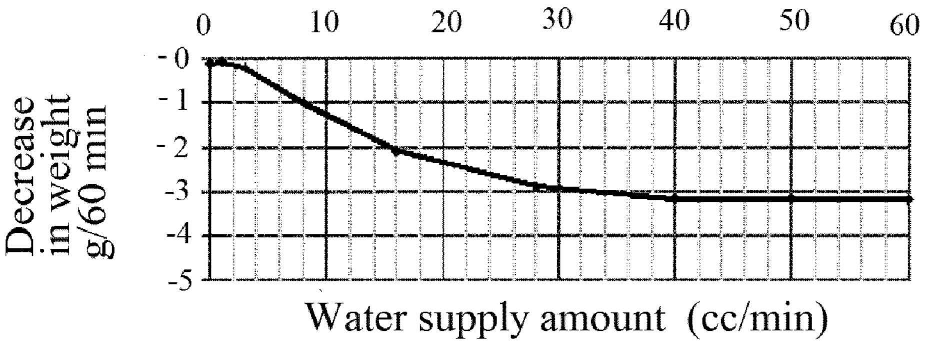

# FIG. 7

CHANGES IN PROCESSING AMOUNT WITH CHANGES IN WATER SUPPLY AMOUNT (CARBIDE PLATE)



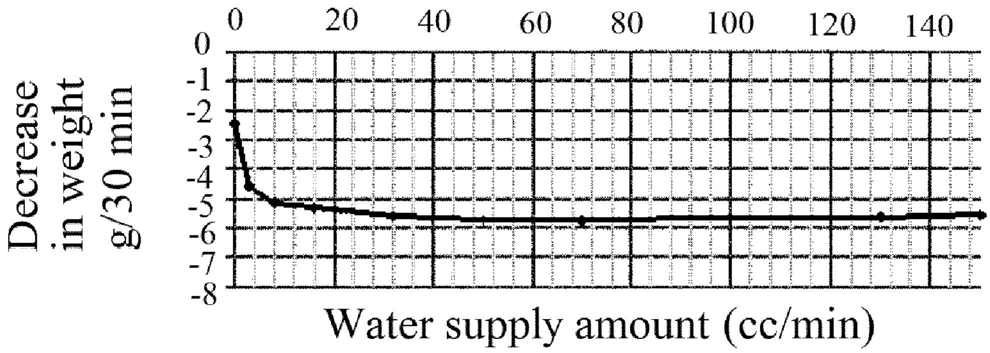
# FIG. 8

CHANGES IN PROCESSING AMOUNT WITH CHANGES IN WATER SUPPLY AMOUNT (URETHANE RUBBER PLATE)

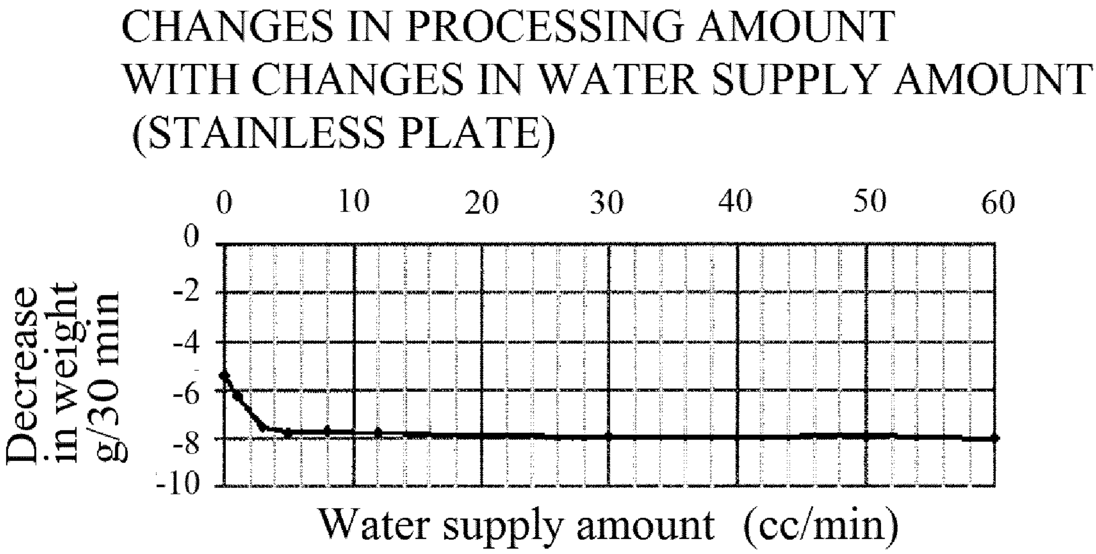



# FIG. 9

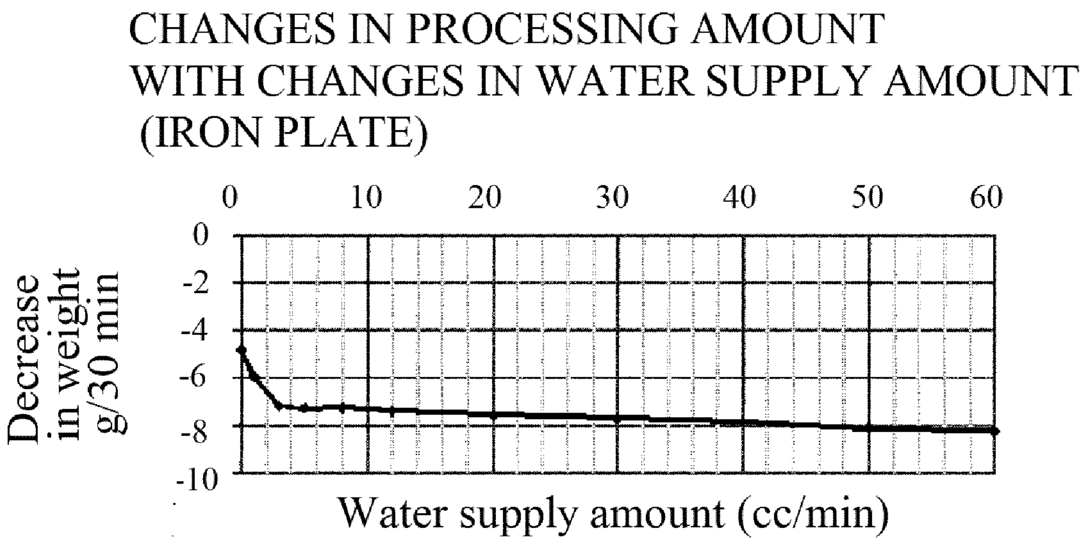
CHANGES IN PROCESSING AMOUNT WITH CHANGES IN WATER SUPPLY AMOUNT (ALUMINUM PLATE)



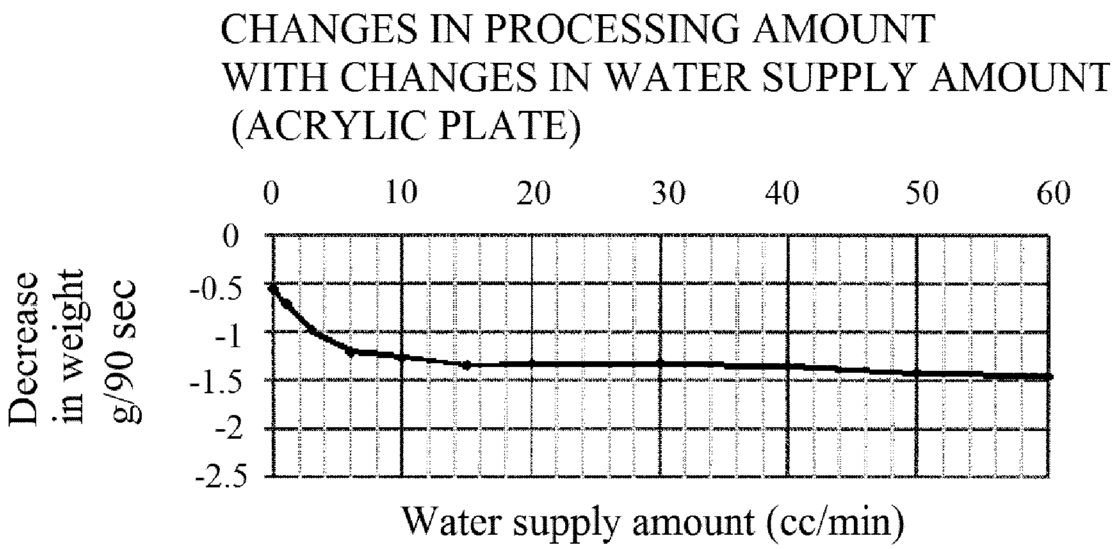
# FIG. 10


CHANGES IN PROCESSING AMOUNT
WITH CHANGES IN WATER SUPPLY AMOUNT
(STAINLESS PLATE)
0
10
20
30
40
50
60
0
-2
-4
-6
-8
-10
Decrease in weight g/30 min
Water supply amount (cc/min)

# FIG. 11


CHANGES IN PROCESSING AMOUNT
WITH CHANGES IN WATER SUPPLY AMOUNT
(IRON PLATE)
0
10
20
30
40
50
60
0
-2
-4
-6
-8
-10
Decrease in weight g/30 min
Water supply amount (cc/min)

# FIG. 12


CHANGES IN PROCESSING AMOUNT
WITH CHANGES IN WATER SUPPLY AMOUNT
(ACRYLIC PLATE)
0
10
20
30
40
50
60
0
-0.5
-1
-1.5
-2
-2.5
Decrease in weight g/90 sec
Water supply amount (cc/min)

# FIG. 13

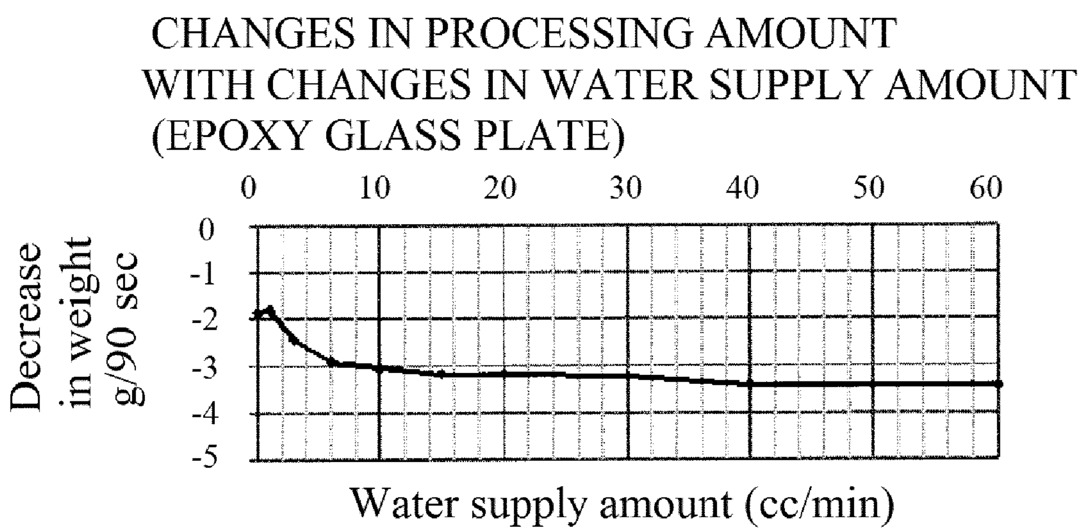

CHANGES IN PROCESSING AMOUNT
WITH CHANGES IN WATER SUPPLY AMOUNT
(EPOXY GLASS PLATE)
0
10
20
30
40
50
60
0
-1
-2
-3
-4
-5
Decrease in weight g/90 sec
Water supply amount (cc/min)

FIG. 14

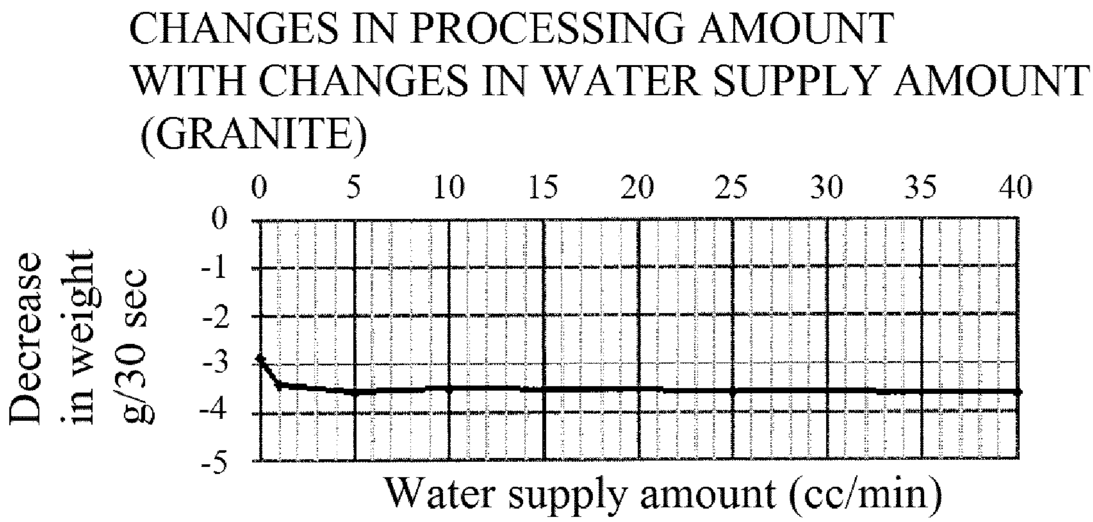
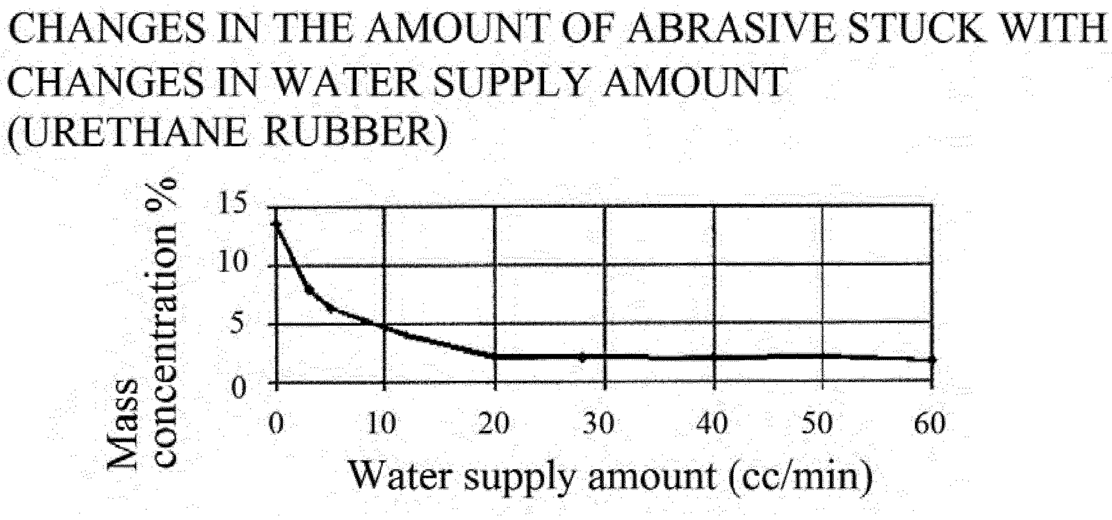
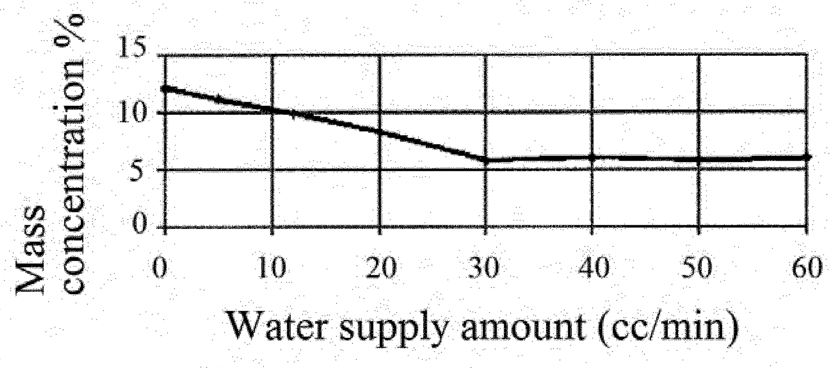

CHANGES IN PROCESSING AMOUNT
WITH CHANGES IN WATER SUPPLY AMOUNT
(GRANITE)
Decrease
in weight
g/30 sec
0
-1
-2
-3
-4
-5
0
5
10
15
20
25
30
35
40
Water supply amount (cc/min)

FIG. 15


CHANGES IN THE AMOUNT OF ABRASIVE STUCK WITH
CHANGES IN WATER SUPPLY AMOUNT
(URETHANE RUBBER)
Mass
concentration %
15
10
5
0
0
10
20
30
40
50
60
Water supply amount (cc/min)

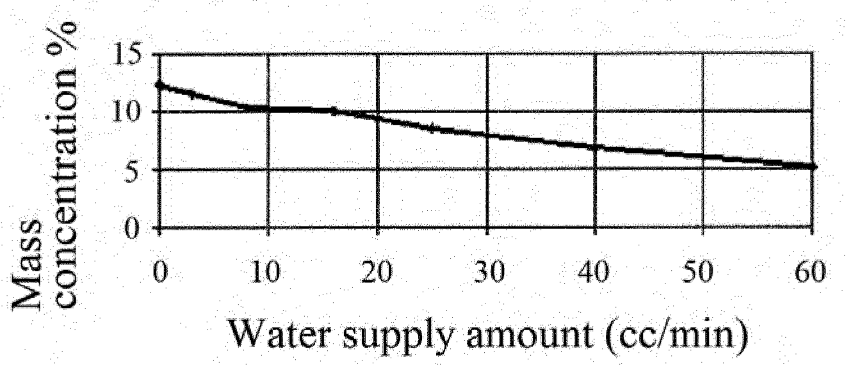
# FIG. 16

CHANGES IN THE AMOUNT OF ABRASIVE STUCK WITH CHANGES IN WATER SUPPLY AMOUNT (STAINLESS)



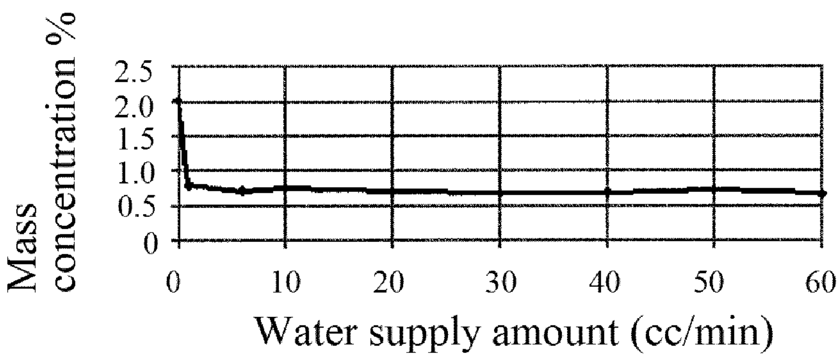

# FIG. 17

CHANGES IN THE AMOUNT OF ABRASIVE STUCK WITH CHANGES IN WATER SUPPLY AMOUNT (IRON)



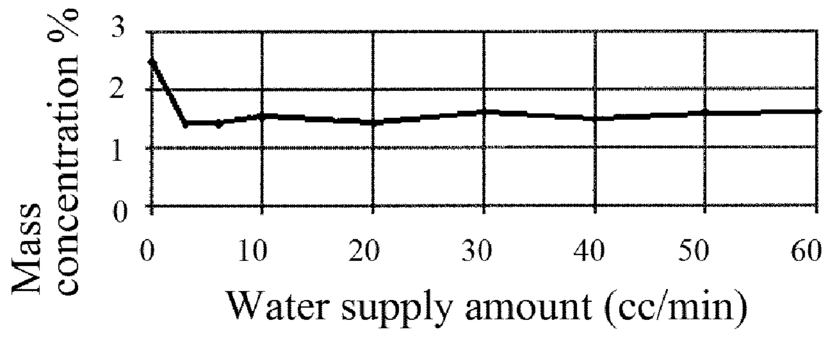
# FIG. 18

CHANGES IN THE AMOUNT OF ABRASIVE STUCK WITH CHANGES IN WATER SUPPLY AMOUNT (ACRYLIC)

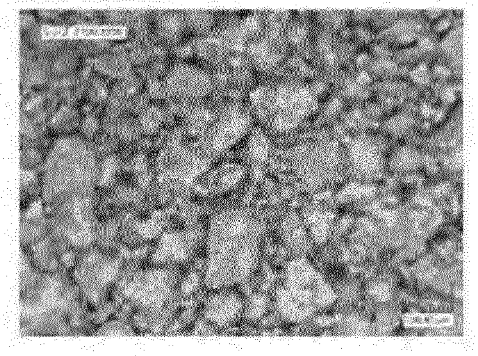
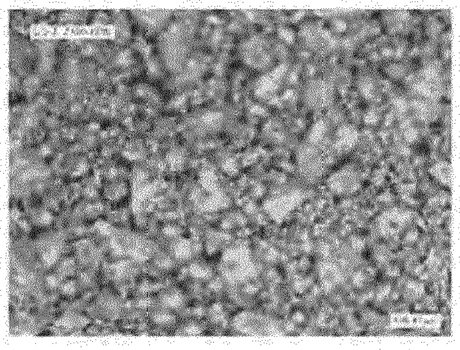



# FIG. 19

CHANGES IN THE AMOUNT OF ABRASIVE STUCK WITH CHANGES IN WATER SUPPLY AMOUNT (EPOXY GLASS)



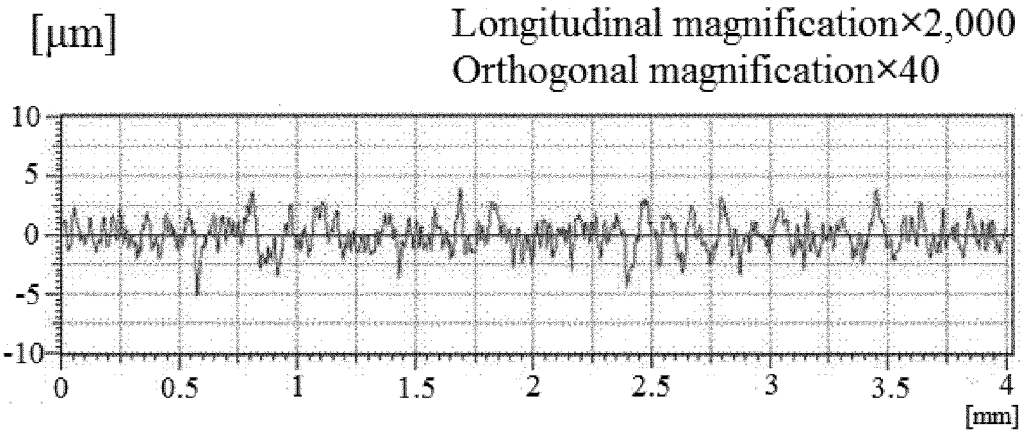
# FIG. 20

| EXAMPLE (with water supply) | COMPARATIVE EXAMPLE (by dry blasting method) |
|---|---|
|  |  |

# FIG. 21A

## EXAMPLE

CONTACT-TYPE ROUGHNESS DATA: JIS 1994

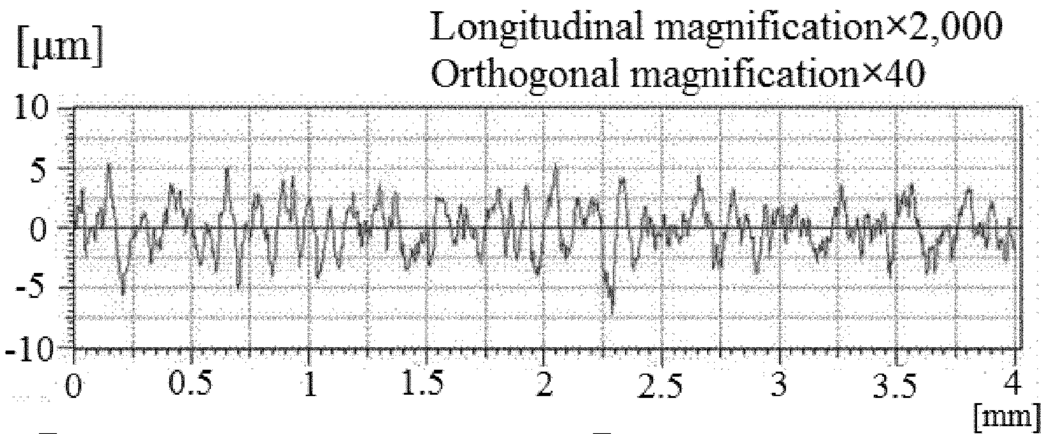



| | | | | | |
|---|---|---|---|---|---|
| Ra : | 1.055 | µm | Ry : | 7.493 | µm |
| RZ : | 5.250 | µm | Sm : | 87.568 | µm |
| S : | 32.038 | µm | Pc : | 109.0 | |

# FIG. 21B

## COMPARATIVE EXAMPLE

CONTACT-TYPE ROUGHNESS DATA: JIS 1994

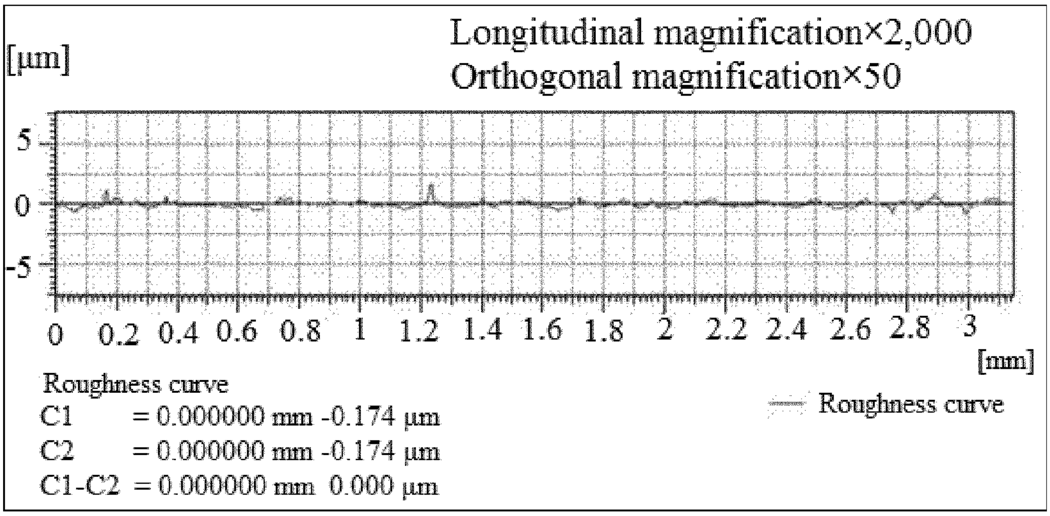



| | | | | | |
|---|---|---|---|---|---|
| Ra : | 1.593 | μm | Ry : | 9.854 | μm |
| RZ : | 7.102 | μm | Sm : | 109.454 | μm |
| S : | 40.921 | μm | Pc : | 81.0 | |

# FIG. 22A

## EXAMPLE

CONTACT-TYPE ROUGHNESS DATA: JIS 1994



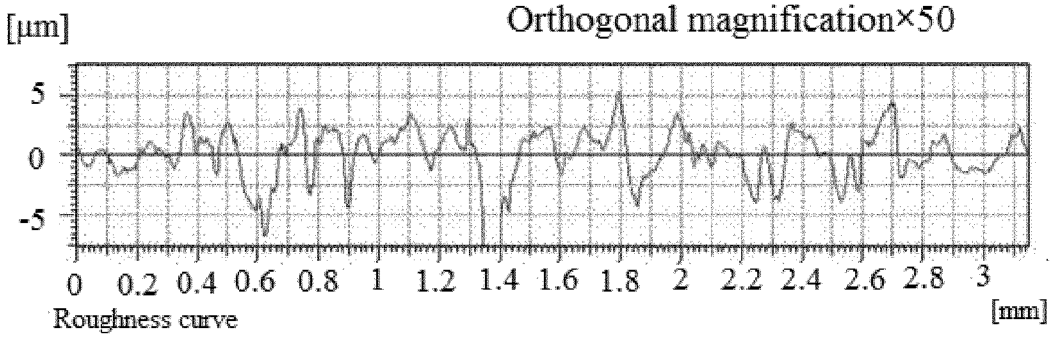

| | | | | | |
|---|---|---|---|---|---|
| Ra : | 0.177 | μm | Ry : | 1.553 | μm |
| RZ : | 0.913 | μm | Sm : | 146.34 | μm |
| S : | 31.87 | μm | Pc : | 213.00 | |

# FIG. 22B

## COMPARATIVE EXAMPLE

CONTACT-TYPE ROUGHNESS DATA: JIS 1994

Longitudinal magnification×2,000
Orthogonal magnification×50

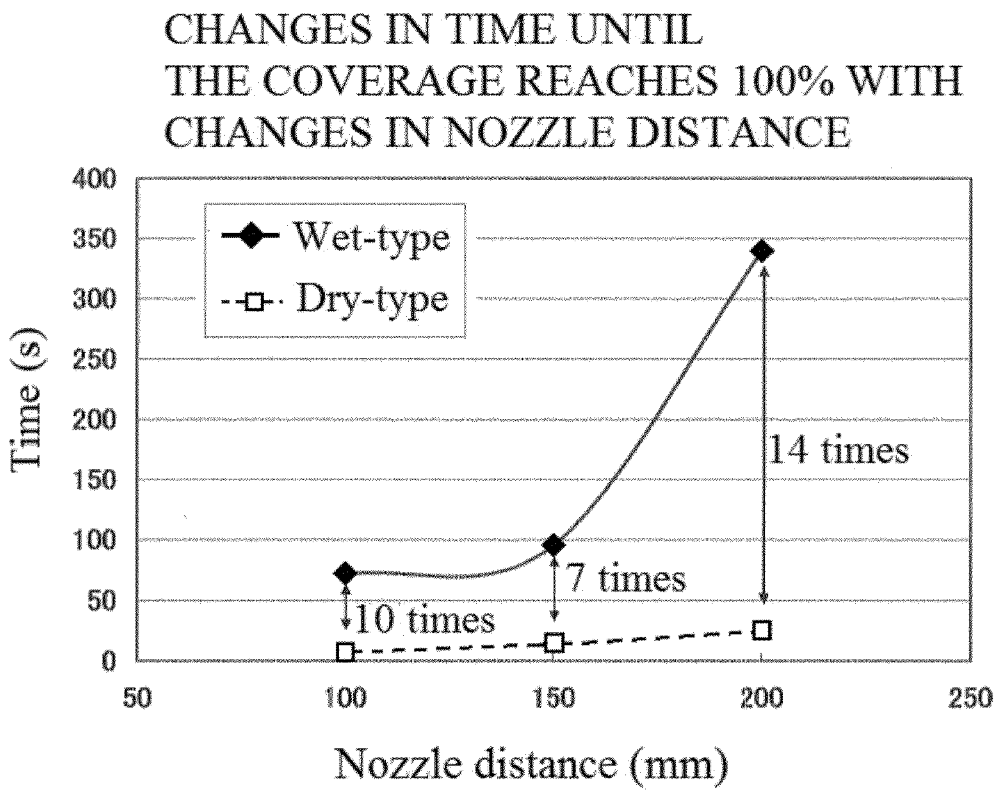



Roughness curve
C1 = 0.000000 mm -0.396 μm
C2 = 0.000000 mm -0.396 μm
C1-C2 = 0.000000 mm 0.000 μm

Roughness curve

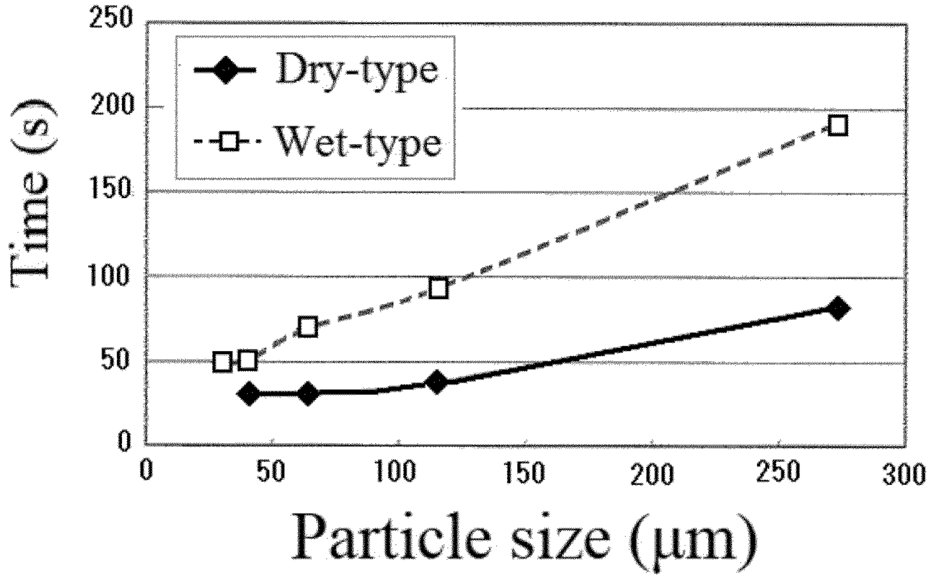
| | | | | | |
|---|---|---|---|---|---|
| Ra : | 1.737 | μm | Ry : | 10.79 | μm |
| RZ : | 6.725 | μm | Sm : | 245.54 | μm |
| S : | 93.550 | μm | Pc : | 41.00 | |

# FIG. 23


CHANGES IN TIME UNTIL
THE COVERAGE REACHES 100% WITH
CHANGES IN NOZZLE DISTANCE
Wet-type
Dry-type
Time (s)
400
350
300
250
200
150
100
50
0
50
100
150
200
250
14 times
7 times
10 times
Nozzle distance (mm)

# FIG. 24

CHANGES IN TIME UNTIL THE COVERAGE REACHES 100% WITH CHANGES IN PARTICLE SIZE OF THE ABRASIVE



## REFERENCES CITED IN THE DESCRIPTION

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### Patent documents cited in the description


- JP 2006297568 A **[0001] [0012]**
- JP 3846842 B **[0012]**
- JP 2011237378 A **[0012]**