



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
09.09.2015 Bulletin 2015/37

(51) Int Cl.:
B24B 31/06 (2006.01)

(21) Application number: **15156158.6**

(22) Date of filing: **23.02.2015**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(71) Applicant: **The Boeing Company**
Chicago, IL 60606-2016 (US)

(72) Inventor: **Hovik, Brian K.**
Renton, WA Washington 98056 (US)

(74) Representative: **Boult Wade Tennant**
Verulam Gardens
70 Gray's Inn Road
London WC1X 8BT (GB)

(30) Priority: **07.03.2014 US 201414201083**

(54) **Method and system for vibratory finishing of composite laminate parts**

(57) A method for vibratory finishing of a composite laminate part includes placing particles of a vibratory media into a trough of a vibratory finishing machine, the particles of a vibratory media comprising titanium oxide abrasive in a synthetic binder, the method further comprising placing a composite laminate part into the trough such

that the composite laminate part is substantially immersed in the vibratory media, and operating the vibratory finishing machine at a vibrational frequency of 40 Hz to 50 Hz with the vibratory media and composite laminate part disposed in the trough.

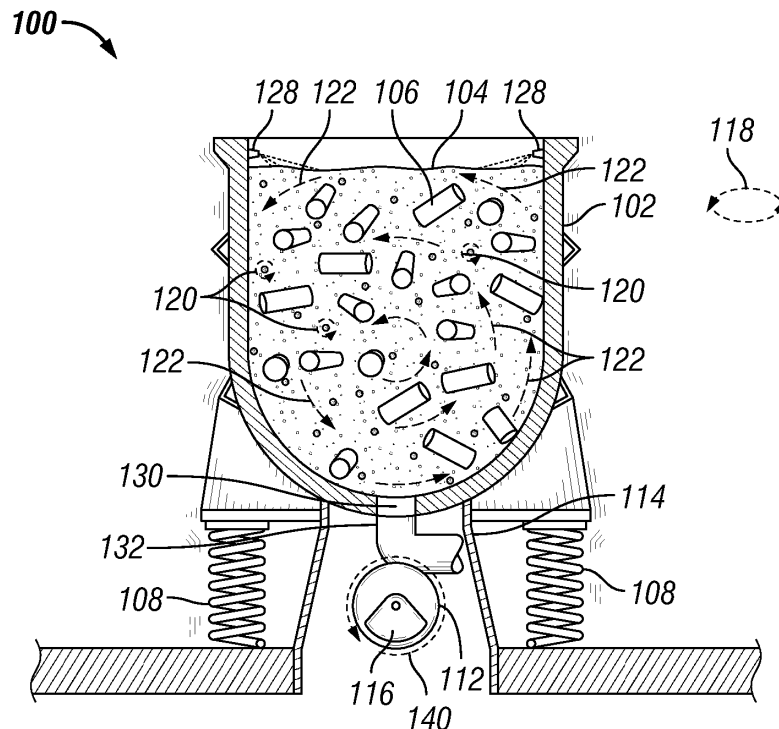


FIG. 2

Description

BACKGROUND

[0001] In a variety of manufacturing processes, it is desirable to deburr manufactured parts after they have been machined or subjected to other processing steps. Parts that have been produced by casting, machining, laminating and other fabrication techniques frequently have burrs and surface roughness that are not considered acceptable in the final product. Finishing of such an article can include the removal of burrs and modification of the surface finish. Deburring is the general term given to various processes for rounding or smoothing the edges of parts and removing burrs from them, in order to provide a part with the desired finish characteristics.

[0002] Traditionally, deburring of manufactured parts has involved significant manual labor, using grinders and other tools to smooth the edges and surfaces of parts. More recently, vibratory deburring processes have been developed for removing burrs and smoothing the surfaces of mass-produced articles. In these processes, articles to be finished are typically placed in a vibratory finishing apparatus such as a vibratory trough or bowl, together with particles of a finishing medium, which can be an abrasive material. The finishing medium is agitated in the trough, causing the particles of the finishing medium to repeatedly contact the edges and surfaces of the articles to be finished. The finishing medium can include particles having relatively sharp points or corners, which can work their way into grooves and crevices of the article, thereby smoothing the article and removing burrs and sharp edges. In some cases, the finishing medium can have a cleaning or surface polishing effect. In many cases, the vibratory deburring process produces a slightly sanded looking surface.

[0003] While vibratory deburring of manufactured parts reduces manual labor involved in deburring and can provide more consistent results, it has primarily been applied to metal parts, and is not believed to have been applied to laminated composite parts for a variety of reasons. Consequently, deburring of advanced composite laminated parts that have been machined or fabricated is still generally performed using manual deburring tools and methods. Unfortunately, these manual processes tend to be very labor intensive, and can produce irregular results - leading to over-burring of some parts and providing parts that do not meet specifications for edge-break and surface finish.

[0004] The present disclosure is directed toward one or more of the above issues.

SUMMARY

[0005] In accordance with one aspect thereof, the present disclosure provides a method for vibratory finishing of a composite laminate part. The method includes placing particles of a vibratory media, comprising titanium

oxide abrasive in a synthetic binder, into a trough of a vibratory finishing machine, placing a composite laminate part into the trough and substantially immersed in the vibratory media, and operating the vibratory finishing machine at a vibrational frequency of 40 Hz to 50 Hz with the vibratory media and composite laminate part disposed in the trough.

[0006] In accordance with another aspect thereof, the present disclosure provides a method for deburring composite laminate parts. The method includes placing particles of a vibratory media, comprising titanium oxide abrasive in a synthetic acrylic binder, into a trough of a vibratory finishing machine, placing a composite laminate part into the trough and substantially immersed in the particles of vibratory media, applying flush water to the vibratory media at a rate of about 0.35 to 0.50 gallons per hour per cubic foot of volume of the finishing media, and operating the vibratory finishing machine, with the vibratory media and composite laminate part disposed in the trough, at a vibrational frequency of 40 Hz to 50 Hz via a rotating shaft having an approximately 10% eccentric rotation, for a period of 45 to 60 minutes.

[0007] In accordance with yet another aspect thereof, the present disclosure provides a system for finishing composite laminate parts, including a vibratory finishing machine, having a trough of suitable volume to contain a composite laminate part, a volume of vibratory media particles, disposed in the trough, and a water inlet. The trough is configured to vibrate at a frequency of 40 Hz to 50 Hz. The vibratory media particles are titanium oxide abrasive in a synthetic binder. The water inlet is configured to provide process water into the trough while the vibratory finishing machine is vibrating with the composite laminate part substantially immersed in the vibratory media particles, whereby the composite laminate part is substantially deburred through contact with the vibratory media particles.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Additional features and advantages of the invention will be apparent from the detailed description which follows, taken in conjunction with the accompanying drawings, which together illustrate, by way of example, features of the invention.

FIG. 1 is a perspective view of a tub- or trough-type vibratory finishing machine.

FIG. 2 is a cross-sectional view of a trough of a vibratory finishing machine showing the drive shaft and offset counterweights.

FIG. 3 is a close-up view of a trough-type vibratory finishing machine loaded with finishing media and having parts being finished therein.

FIGs. 4A and 4B are perspective views of media particles of various sizes and shapes that can be used in a deburring process in accordance with the present disclosure.

FIG. 5 is a partial sectional view showing the edge break of a piece of composite material that has been subjected to a vibratory deburring process in accordance with the present disclosure.

FIG. 6 is a logic flowchart outlining the steps in an embodiment of a process of deburring laminated composite parts in accordance with the present disclosure.

[0009] While the disclosure is susceptible to various modifications and alternative forms, specific embodiments have been shown by way of example in the drawings and will be described in detail herein. However, it should be understood that the disclosure is not intended to be limited to the particular forms disclosed. Rather, the intention is to cover all modifications, equivalents and alternatives falling within the scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION

[0010] As noted above, mass finishing or "vibratory finishing" is a mechanical and/or chemical process that is applied to finish component parts. Vibratory finishing processes can remove burrs and smooth the surfaces of mass-produced articles. However, while vibratory deburring reduces manual labor and can provide more consistent results than manual deburring, it has primarily been applied only to metal parts. For example, manufacturers of vibratory finishing equipment acknowledge that metal parts are the major field of application for this technology, and that mass finishing technologies are also used for wood, rubber, stone and plastic. Notably, vibratory finishing is not believed to have been applied to laminated composite parts. One reason is that typical vibratory finishing media is not compatible with composite materials. Another reason is that composite laminated parts tend to "float" atop vibratory media, and do not naturally immerse themselves in the media. Additionally, vibratory finishing machines that are commercially available operate at a fixed frequency and magnitude of vibration that is not suitable to finishing laminated composite parts. Thus, known vibratory finishing systems and methods not only teach away from finishing laminated composite parts, but teach away from systems that are adjustable in a way that they could be made suitable for finishing laminated composite parts.

[0011] Advantageously, as disclosed herein, a system and method have been developed for applying vibratory deburring processes to laminated composite parts. This process utilizes automated vibratory deburring machines with specific deburring media, specific RPM and processing times to deburr these parts, which eliminates the need for manual single-part deburring of many composite parts. This saves time, money and eliminates many ergonomic issues that can arise with manual deburring. Preliminary testing with certain media has shown excellent results that meet exacting specifications.

[0012] Shown in FIGs. 1 and 2 is a trough-type vibratory finishing apparatus 100, such as are commercially available from Rosler America, of Battle Creek Michigan and other manufacturers. Another commercially available vibratory finishing machine that has been used in this type of process is the model SVP-5 made by Hammond Roto Finish of Kalamazoo Michigan. The vibratory finishing machine 100 includes a large tub or trough 102 that receives finishing media, indicated generally at 104, and the article to be treated 106. The trough 102 is supported on springs 108 and is attached to a motor 110 that drives a drive shaft 112 that is positioned below the trough 102. The drive shaft 112 is attached to the spring-mounted trough 102 with bearings 114 and is provided with offset or off-center counterweights 116, so that the drive shaft 112 vibrates as it rotates, and thus transmits this vibration through the bearings 114 to the trough 102. This configuration causes the trough 102 to vibrate at a frequency that depends on the rotational speed of the drive shaft 112, and a magnitude that depends on the weight and offset position (i.e. how much the counterweights are off-center) of the counterweights 116.

[0013] As shown in FIG. 2, rotation and vibration of the drive shaft 112 causes the trough 102 to vibrate in a generally elliptical motion, as indicated by arrow 118. This vibration of the trough 102 causes the individual particles (136 in FIGs. 4A, 4B) of the finishing media 104 and the part(s) 106 that are being finished to rotate individually within the trough 102 in a small circular motion, as indicated by arrows 120, and the whole mass of the media 104 to rotate or churn in a "rolling" motion simultaneously in one direction about a horizontal axis, as indicated by arrows 122.

[0014] Previously, vibratory finishing machines of the general type shown in FIGs. 1 and 2 have typically had a fixed vibrational speed. Indeed, it does not appear that vibratory finishing machines of this type having an adjustable speed are commercially available at all, and those that are commercially available all operate at a speed of 2100 RPM. Unfortunately, vibratory finishing machines of this type that operate at that speed are largely ineffective with composite materials, for reasons discussed above.

[0015] Advantageously, the vibratory finishing system depicted herein is compatible with composite materials, and its operational parameters, specifically the vibrational frequency and magnitude of vibration, have been developed and optimized for them. In one embodiment, the vibratory finishing machine 100 includes both a motor RPM controller 124 and a tachometer 126 to allow a user to adjust and verify the RPM of the motor 110, which determines the vibrational frequency. This speed adjustment mechanism allows a user to change the RPM to find an optimum RPM for the parts 106 that are to be finished, whether composite parts or other types of parts. This not only allows a user to find a suitable speed for finishing composite parts, but can also allow a single vibratory finishing machine to be selectively adjusted for

use with metal parts, composite parts, and other types of parts, if desired.

[0016] In one embodiment, it has been found that a motor frequency of around 2700 RPM, with the offset counterweights 116 provided on the drive shaft 112, will vibrate the trough at a frequency in the range of 40-50 Hz, such as a specific frequency of 45 Hz. Frequencies in this range have been found to be effective for composite materials, while the typical 35 Hz frequency of prior vibratory finishing machines is not.

[0017] As shown in FIGs. 1 and 2, the vibratory finishing machine 100 can be configured to allow for the addition or subtraction of counterweights 116 to allow a user to create a desired offset so that the vibration has a desired magnitude (combined with the selected RPM). Those of skill in the art will recognize that the frequency of vibration is a function of the rotational speed of the drive shaft 112, while the magnitude of vibration is a function of the mass of the counterweights 116 in relation to the combined mass of the trough 102, vibratory media 104 and part(s) 106. These latter characteristics are, in turn, affected by the size and volume of the trough 102. In one test embodiment, a Hammond SVP-5 vibratory finishing machine was modified according to the present disclosure and used to finish composite parts. The modified machine included a trough having a volume of 5 cubic feet, and was modified to run at 2700 RPM, as discussed above. This machine included four, 4½ pound counterweights 116. These weights were each increased by 1½ pounds, providing four 6-pound counterweights (24 pounds total) positioned eccentrically on the drive shaft, as shown in FIG. 2. Imposing this additional weight on the weighting mechanism helped provide a satisfactory magnitude for the deburring motion with the lighter weight deburring media.

[0018] Using the modified counterweight system described, it has been found that with the drive shaft rotating at a speed of 2700 RPM, the shaft demonstrates an eccentric rotation of about 10% (relative to the diameter of the shaft), as indicated by the dashed line circle 140 in FIG. 2. For example, a 3" diameter drive shaft 112 that is provided with suitable counterweights 116 will describe an eccentric rotational motion that is about 3.3" (i.e. 10% larger than the shaft diameter) when rotating. This magnitude of vibration, at the frequency of 40-50 Hz, produces a vibration of about 0.001" in the individual abrasive media particles 136. It is believed that this magnitude of vibration can be suitable for any size of part and any size of vibratory finishing machine. It will thus be apparent that as the size, volume and mass of the vibratory finishing machine 100 increases or decreases, the mass of the counterweights 116 can be increased or decreased to provide the desired vibrational magnitude at the same vibrational frequency.

[0019] A close-up view of the trough 102 loaded with finishing media 104 and having parts 106 being finished therein is provided in FIG. 3. Under the vibrating motion of the trough 102, the finishing media 104 is agitated in

the trough 102, and tends to behave almost like a liquid. The part 106 that is immersed in the finishing media 104 gradually rolls and tumbles within the media, as particles of the finishing medium repeatedly contact its edges and surfaces, gradually removing burrs and smoothing rough edges and surfaces, and also rounding edges of the part.

[0020] The vibratory finishing machine 100 also includes one or more water inlets 128, which provide a flow of process water to the volume of abrasive media 104. The process water, sometimes with a small amount of mild liquid soap (e.g. 30:1 water to soap ratio), is slowly metered into the media 104 to provide liquidity, some lubricity, and washing action to wash away and remove the media swarf and abraded particles of substrate. As shown in FIG. 2, the trough 102 includes an outlet or drain 130 at its lower extremity and drain conduit 132, which allows the process water to drain away. Strainers, filters, etc. (not shown) can be placed in or associated with the drain conduit 132 to remove the media swarf and particles of substrate that are washed away by the process water. The machine 100 can be configured to deposit these particles into a waste tub (not shown) before the waste water is discharged. The system for adding the process water and the associated waste tub can be standard components that are commonly included with commercially available vibratory finishing systems.

[0021] As shown in FIG. 3, an individual trough 102 can be provided with dividers 134, so that multiple parts 106 can be simultaneously finished in separate portions of a single trough 102. A divider 134 is also shown in the trough 102 of the finishing machine 100 in FIG. 1. Depending on the part size, shape and whether or to what extent incidental contact of multiple parts 106 with each other during the finishing process can be tolerated, multiple parts 106 can be simultaneously placed in a single or undivided portion or region of a vibratory finishing trough 102, and finished together.

[0022] As described above, the finishing media 104 comprises individual abrasive particles 136. Perspective views of individual finishing media particles 136, which can be used in a deburring process in accordance with the present disclosure, are shown in FIGs. 4A and 4B. The finishing media 104 can include particles 136 having various shapes and sizes. For example, the particles 136a shown in FIG. 4A have a tetrahedral shape, while the particles 136b shown in FIG. 4B have a conical shape. Other shapes can also be used. These particles 136 can range in size from about ¼" to about 2½" in their maximum dimension. Other sizes can also be used. As illustrated in FIGs. 4A and 4B, the particles 136 can have relatively sharp points or corners 138, which tend to work their way into grooves and crevices of the part 106 that is being finished, thereby smoothing the article and removing burrs and sharp edges on the outer part surface.

[0023] The particles 136 of finishing media 104 are made of two parts: an abrasive and a binder. In one embodiment, the abrasive includes titanium oxide, and the binder is synthetic acrylic. In a more specific embodiment

the media is about 10%-20% titanium oxide, held in a binder of synthetic urea-resin that constitutes 80% -90% of the volume of the particle 104. Vibratory finishing media having this general formulation is commercially available under the product designation SY from Vibra-Finish Co. of Los Angeles, California, for example.

[0024] For the vibratory finishing of composite parts, as disclosed herein, it is considered desirable that the specific gravity of the finishing media be from about 1.5 to 2.0, so that the sectional density of the total volume of the particles 136 is approximately equal to the sectional density of the composite laminate parts 106 that are to be finished. This aspect of the vibratory finishing media 104 allows the composite part 106 to naturally "sink" in the media, rather than "float" atop it, thus allowing the part to become substantially immersed in the media.

[0025] This media formulation is different than the standard media commonly used for finishing metal and other parts. Specifically, many vibratory finishing media formulations use aluminum oxide as an abrasive, which is generally incompatible with composite materials. On the other hand, it has been found that titanium oxide abrasive works well with composite parts. However, it is believed that the suitability of this type of abrasive media for composite materials has not previously been known. Additionally, the binder, being a synthetic, does not require any processing compound (e.g. soap) for the finishing process. Instead, the processing fluid can be ordinary water, leaving the parts soap-free, receiving only a water rinse and towel dry at the end of the process.

[0026] The abrasive particles 136 of the media 104 are of a generally constant make-up throughout their volume, such that as each particle 136 gradually wears down with use, its surface retains the same abrasive quality, even as it changes shape and size. That is, during use, the surface of the abrasive particles 136 will gradually wear away, exposing the underlying material, which has substantially the same abrasive quality and characteristics. In this way, the abrasive particles 136 retain their operational characteristics as they gradually wear down during use, until they are of a size where it is considered desirable to replace them with new, full sized particles. Replacing the worn particles 136 can be effectively accomplished by adding new particles 136 periodically, so as to maintain a given percentage of larger full-sized particles.

[0027] The vibratory deburring process with this finishing media produces a slightly sanded looking surface on composite materials. One additional aspect of vibrational deburring of parts using the apparatus and method disclosed herein is the provision of an edge break or edge relief on parts. It is well known in manufacturing that sharp edges on mechanical parts are undesirable in many instances, but are the natural byproduct of various fabrication and/or machining processes. Shown in FIG. 5 is a partial sectional view of an end portion 202 of a composite part 200. Prior to deburring, the end 202 of the part 200 includes sharp edges 204. After vibratory finish-

ing in accordance with the present disclosure, the sharp edges 204 are smoothed to a rounded profile 206. The degree of edge break or edge relief that is desired will vary from one situation to another. Using the present system and method, an edge break or round-over of about 0.005" can be provided on the exposed edges of a composite part. It will be apparent that the magnitude of the edge break will depend at least in part on the length of vibratory processing and the grit level of the abrasive media 104.

[0028] A logic flowchart outlining the steps in an embodiment of a method 500 for deburring and finishing laminated composite parts in accordance with the present disclosure is provided in FIG. 6. First, the trough of the vibratory machine is filled with finishing media particles (step 502). It is considered desirable to fill the trough no more than about 80% full, but not less than about 50% full, by volume. Next, the process water flow is turned on (step 504). The process water can be ordinary water, without any additives, such as soap or the like. The process water washes debris out of the volume of finishing media particles, enhancing the finishing process by removing residue that has been worn off of the part, and removing abrasive dust that has been worn off of the finishing media particles. The process water flow that is used in this process is about double the amount of flow water that is typically used in vibratory finishing of metal parts. In general, it is believed that a process water flow of 0.35-0.50 gallons per hour per cubic foot of volume of finishing media can be used. In one embodiment, using a trough having a volume of 5 cubic feet, a process water flow of 2 gallons per hour has been used.

[0029] After the process water is flowing, the machine can be started (step 506) - that is, the vibration can be initiated at the desired frequency. Next, the parts to be deburred can be placed into the trough of the finishing machine (step 508), with the parts being immersed in the finishing media. It has been found desirable that the volume of parts placed into the trough not exceed about 10% of the total trough volume, in order to avoid damage from the parts contacting each other, and/or to avoid the parts being inadequately finished. The parts are then left in the vibrating trough for a set time (step 510), while the process goes forward. In one embodiment, it has been found that parts can be processed for about 60 minutes with good results. In general, it is believed that vibratory finishing for about 45-60 minutes is likely to be sufficient. Those of skill in the art will be able to determine optimal settings for any given part and media combination to provide the desired edge-break and surface treatment.

[0030] After sufficient processing of the parts, the finished parts can be removed from the machine (step 512). Advantageously, parts can be removed from the trough while the machine is running, which can help to speed up the batch processing flow. Alternatively, the machine and the process water flow can be shut off (step 514) either before or after removal of the parts. After processing, the parts can be rinsed with fresh water (step 516)

and dried, making them ready for use. The entire composite laminate part will show signs of deburring, which leaves a slightly dull, sanded appearance on the part, and is especially noticeable on the "tool-side" of the parts (i.e., the side of the composite part that was held against a form or "tool" while being cured). An un-deburred tool-side of a composite part will appear shiny compared to parts processed in the manner disclosed herein. After a part or a batch of parts have been finished in this manner, the process can be repeated by placing more parts into the trough (step 508), or returning to one of the prior steps, if needed.

[0031] As noted above, the finishing media particles 136 gradually wear away with use. Consequently, it is desirable to periodically refresh the vibratory media (step 518) by removing particles below a certain lower threshold size and replacing the removed particles with a comparable volume of new particles, so that the particle size distribution is kept within a desired range. This can be done by dumping all of the particles from the trough into a vibratory sieve mechanism (not shown), which sorts out all particles below a certain size, depending on the size of sieve that is used, thus removing the smallest particles. The remaining particles, which are greater in size than the sieve that was used, can be returned to the trough for continued use, and a volume of new particles (or particles of suitable size) can be placed into the trough to bring the particle volume back up to a desired "full" level (step 502). In one embodiment, refreshing of the vibratory media particles involves removing particles below about 1/2" in size, and replacing them with a comparable volume of particles of 1" to 2 1/2" size.

[0032] The process disclosed herein is made possible by combining specifically developed machine operational parameters and processing time with a specific and unique vibratory finishing media formulation, to allow the special deburring media to be applied to a composite substrate. Heretofore in the composite industry it is believed that this sort of process had not been attempted because the technical understanding of how to use abrasive media upon a composite substrate had not been developed.

[0033] The apparatus and method provides for the automated batch processing of composite parts, removing burrs occurring on the outer part surface. The use of automated finishing allows for batching of many parts, eliminates the human-error of over-burring, and reduces or eliminates the possibility of ergonomic issues that are often associated with manual deburring, such as carpal-tunnel syndrome. The process disclosed herein has the potential to save a tremendous amount of time and money by providing a much more cost effective and safe way to deburr the large number of composite parts that are and will be made. Labor cost will be highly reduced by transferring the labor-intensive manual deburring to automated equipment.

[0034] Although various embodiments have been shown and described, the present disclosure is not so

limited and will be understood to include all such modifications and variations that would be apparent to one skilled in the art. Further the disclosure comprises embodiments according to the following clauses:

Clause A. A method for vibratory finishing of a composite laminate part, comprising: placing particles of a vibratory media, comprising titanium oxide abrasive in a synthetic binder, into a trough of a vibratory finishing machine; placing a composite laminate part into the trough and substantially immersed in the vibratory media; and operating the vibratory finishing machine at a vibrational frequency of 40 Hz to 50 Hz with the vibratory media and composite laminate part disposed in the trough.

Clause B. A method in accordance with clause A, wherein the binder of the vibratory media comprises synthetic acrylic.

Clause C. A method in accordance with clause A, wherein the particles of vibratory media range in size from about 1/4" to about 2 1/2" and have a specific gravity of about 1.5 to about 2.0.

Clause D. A method in accordance with clause A, wherein a total volume of the particles of vibratory media in the trough have a sectional density approximately equal to a sectional density of the composite laminate part.

Clause E. A method in accordance with clause A, wherein the particles of vibratory media comprise about 10% to 20% titanium oxide abrasive in a binder of synthetic urea-resin.

Clause F. A method in accordance with clause A, further comprising operating the vibratory finishing machine for a period of 45 to 60 minutes.

Clause G. A method in accordance with clause A, further comprising applying flush water to the vibratory media at a rate of about 0.35-0.50 gallons per hour per cubic foot of volume of the finishing media.

Clause H. A method in accordance with clause A, wherein operating the vibratory finishing machine comprises rotating a drive shaft, coupled to the trough, the drive shaft having offset counterweights that cause an approximately 10% eccentric rotation of the drive shaft.

Clause I. A method in accordance with clause A, further comprising adjusting the vibrational frequency of the vibratory finishing machine.

Clause J. A method in accordance with clause A, further comprising refreshing the vibratory media by removing worn particles below about 1/2" in size and replacing the worn particles with a comparable volume of particles of 1" to 2 1/2" in size.

Clause K. A method for finishing composite laminate parts, comprising: placing particles of a vibratory media, comprising titanium oxide abrasive in a synthetic acrylic binder, into a trough of a vibratory finishing machine; placing a composite laminate part into the trough and substantially immersed in the particles of

vibratory media; applying flush water to the vibratory media at a rate of about 0.35-0.50 gallons per hour per cubic foot of volume of the finishing media; and operating the vibratory finishing machine, with the vibratory media and composite laminate part disposed in the trough, at a vibrational frequency of 40 Hz to 50 Hz via a rotating shaft having an approximately 10% eccentric rotation, for a period of 45 to 60 minutes.

Clause L. A method in accordance with clause K, wherein the particles of vibratory media range in size from about ¼" to about 2½" and have a specific gravity of about 1.5 to about 2.0.

Clause M. A method in accordance with clause K, wherein the particles of vibratory media have a sectional density approximately equal to a sectional density of the composite laminate part.

Clause N. A method in accordance with clause K, further comprising refreshing the vibratory media by removing particles below about ½" in size and replacing a comparable volume of particles of 1" to 2½" in size.

Clause O. A method in accordance with clause K, further comprising removing the part from the trough and rinsing the part with water.

Clause P. A system for finishing composite laminate parts, comprising: a vibratory finishing machine, having a trough of suitable volume to contain a composite laminate part, configured to vibrate at a frequency of 40 Hz to 50 Hz; a volume of vibratory media particles, disposed in the trough, comprising titanium oxide abrasive in a synthetic binder; and a water inlet, configured to provide process water into the trough while the vibratory finishing machine is vibrating with the composite laminate part substantially immersed in the vibratory media particles, whereby the composite laminate part is substantially deburred through contact with the vibratory media particles.

Clause Q. A system in accordance with clause P, wherein the vibratory media particles range in size from ¼" to about 2½" and have a specific gravity of about 1.5 to about 2.0.

Clause R. A system in accordance with clause P, further comprising a speed adjustment mechanism, configured to allow adjustment of the vibrational frequency of the vibratory finishing machine.

Clause S. A system in accordance with clause P, further comprising a rotating a drive shaft, coupled to the trough, rotatable at about 2700 RPM, having offset counterweights that cause an approximately 10% eccentric rotation of the drive shaft.

Clause T. A system in accordance with clause P, wherein the water inlet is configured to apply flush water at a rate of up to about 0.5 gallons per hour per cubic foot of volume of the finishing media, and further comprising a water outlet, disposed in the trough, configured to drain flush water from the trough.

Claims

1. A method for vibratory finishing of a composite laminate part, comprising:

5

placing particles of a vibratory media, comprising titanium oxide abrasive in a synthetic binder, into a trough of a vibratory finishing machine; placing a composite laminate part into the trough and substantially immersed in the vibratory media; and

10

operating the vibratory finishing machine at a vibrational frequency of 40 Hz to 50 Hz with the vibratory media and composite laminate part disposed in the trough.

15

2. A method in accordance with claim 1, wherein the binder of the vibratory media comprises synthetic acrylic.

20

3. A method in accordance with claim 1, wherein the particles of vibratory media range in size from about ¼" to about 2½" and have a specific gravity of about 1.5 to about 2.0.

25

4. A method in accordance with claim 1, wherein a total volume of the particles of vibratory media in the trough have a sectional density approximately equal to a sectional density of the composite laminate part.

30

5. A method in accordance with claim 1, wherein the particles of vibratory media comprise about 10% to 20% titanium oxide abrasive in a binder of synthetic urea-resin.

35

6. A method in accordance with claim 1, further comprising operating the vibratory finishing machine for a period of 45 to 60 minutes.

40

7. A method in accordance with claim 1, further comprising applying flush water to the vibratory media at a rate of about 0.35-0.50 gallons per hour per cubic foot of volume of the finishing media.

45

8. A method in accordance with claim 1, wherein operating the vibratory finishing machine comprises rotating a drive shaft, coupled to the trough, the drive shaft having offset counterweights that cause an approximately 10% eccentric rotation of the drive shaft.

50

9. A method in accordance with claim 1, further comprising adjusting the vibrational frequency of the vibratory finishing machine.

55

10. A method in accordance with claim 1, further comprising refreshing the vibratory media by removing worn particles below about ½" in size and replacing the worn particles with a comparable volume of par-

ticles of 1" to 2½" in size.

11. A system for finishing composite laminate parts, comprising:

5

a vibratory finishing machine, having a trough of suitable volume to contain a composite laminate part, configured to vibrate at a frequency of 40 Hz to 50 Hz;

10

a volume of vibratory media particles, disposed in the trough, comprising titanium oxide abrasive in a synthetic binder; and

15

a water inlet, configured to provide process water into the trough while the vibratory finishing machine is vibrating with the composite laminate part substantially immersed in the vibratory media particles, whereby the composite laminate part is substantially deburred through contact with the vibratory media particles.

20

12. A system in accordance with claim 11, wherein the vibratory media particles range in size from ¼" to about 2½" and have a specific gravity of about 1.5 to about 2.0.

25

13. A system in accordance with claim 11, further comprising a speed adjustment mechanism, configured to allow adjustment of the vibrational frequency of the vibratory finishing machine.

30

14. A system in accordance with claim 11, further comprising a rotating drive shaft, coupled to the trough, rotatable at about 2700 RPM, having offset counterweights that cause an approximately 10% eccentric rotation of the drive shaft.

35

15. A system in accordance with claim 11, wherein the water inlet is configured to apply flush water at a rate of up to about 0.5 gallons per hour per cubic foot of volume of the finishing media, and further comprising a water outlet, disposed in the trough, configured to drain flush water from the trough.

40

45

50

55

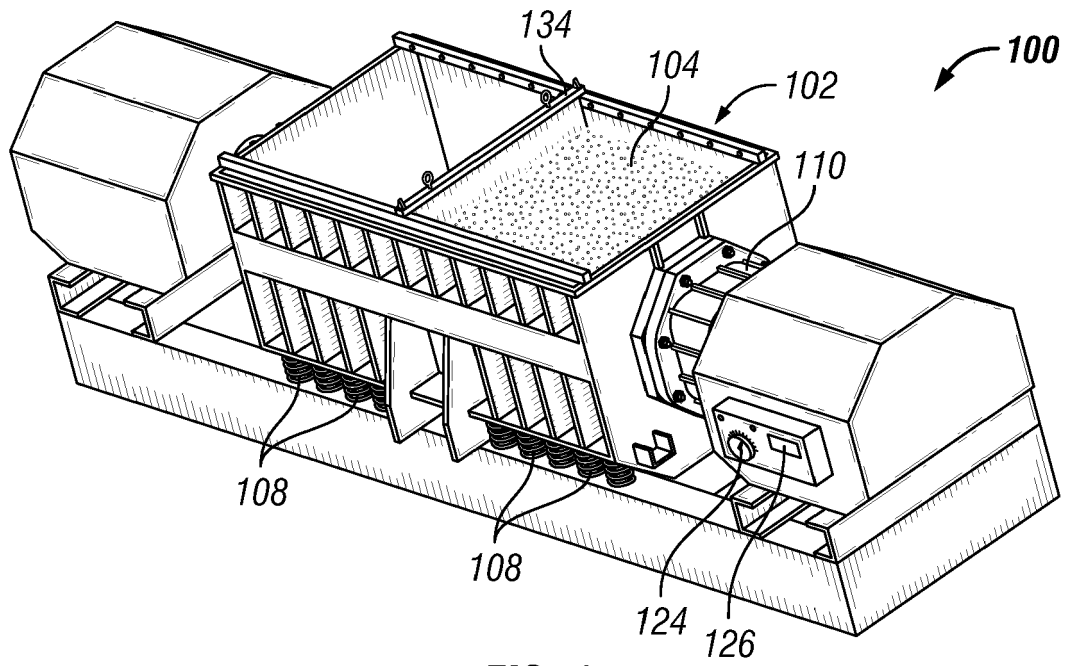


FIG. 1

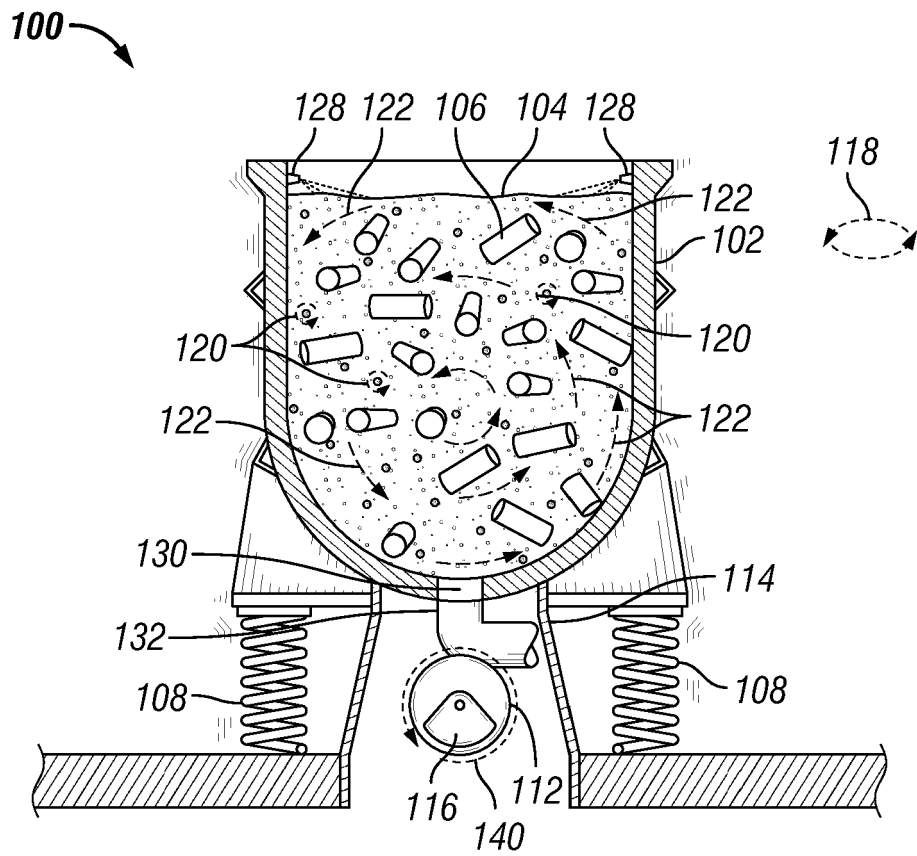


FIG. 2

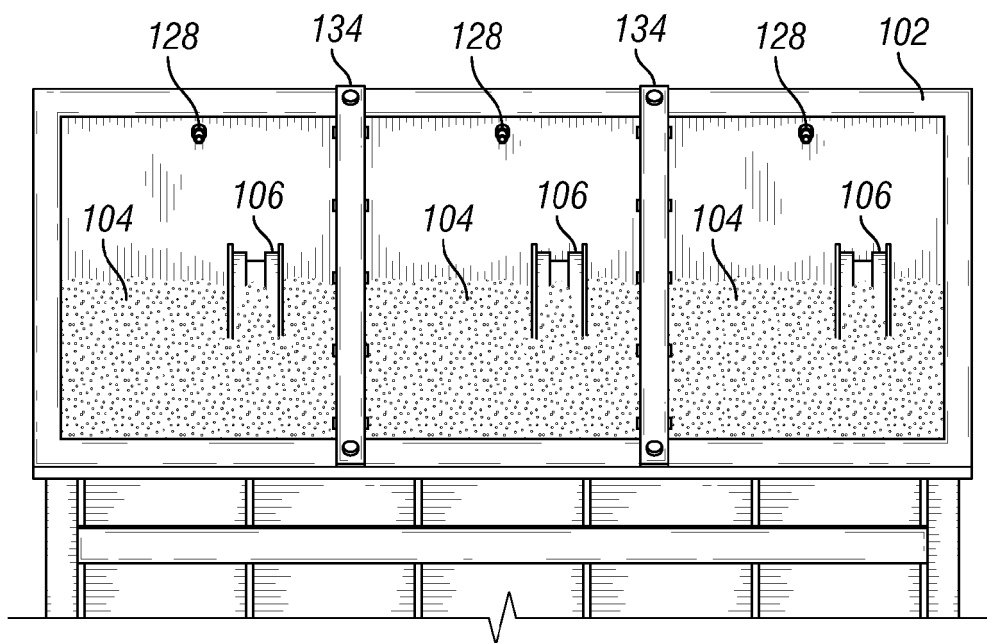


FIG. 3

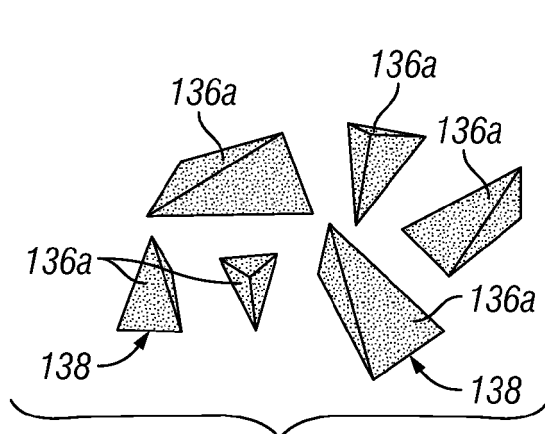


FIG. 4A

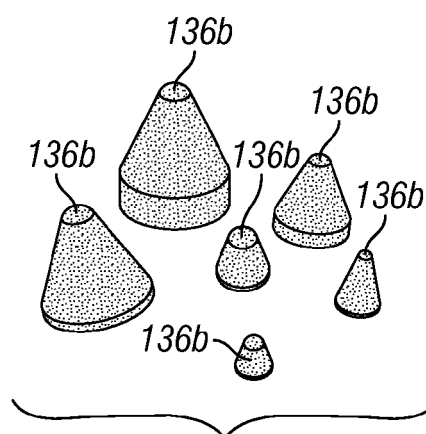


FIG. 4B

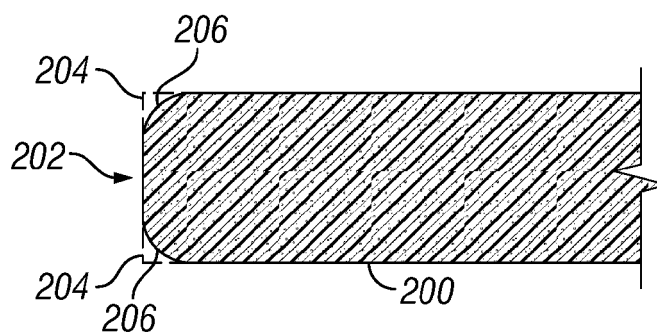
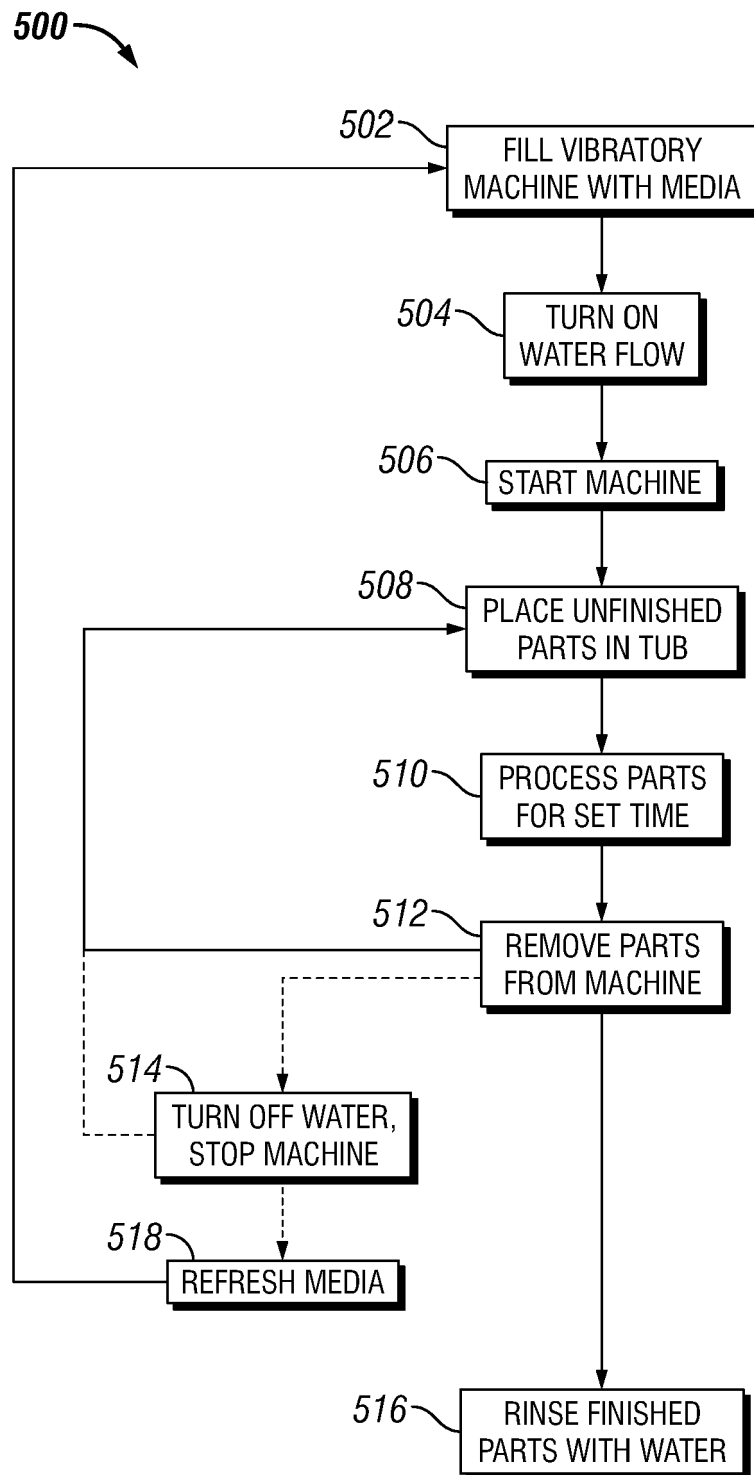


FIG. 5

**FIG. 6**



EUROPEAN SEARCH REPORT

Application Number
EP 15 15 6158

5

10

15

20

25

30

35

40

45

50

55

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	JP 2012 240156 A (ASAHI GLASS CO LTD) 10 December 2012 (2012-12-10) * abstract; figures 2,4 *	1-15	INV. B24B31/06
A	US 2009/017252 A1 (DUCWORTH LYMAN SCOTT [US]) 15 January 2009 (2009-01-15) * abstract * * paragraph [0028] *	1-15	
A	JP H04 300159 A (NEC CORP) 23 October 1992 (1992-10-23) * abstract *	1-15	
A	JP H01 234158 A (MATSUSHITA ELECTRIC IND CO LTD) 19 September 1989 (1989-09-19) * abstract *	1-15	
A	US 3 702 758 A (FUKUI SAKAE ET AL) 14 November 1972 (1972-11-14) * column 5, line 54 - line 56 *	1-15	
A	EP 0 083 250 A2 (INOUE JAPAX RES [JP]) 6 July 1983 (1983-07-06) * abstract * * page 5, line 5 - line 15 *	1-15	TECHNICAL FIELDS SEARCHED (IPC) B24B
A	US 2012/252322 A1 (ISHIGAMI HIDEKI [JP] ET AL) 4 October 2012 (2012-10-04) * abstract * * paragraph [0051] - paragraph [0053] *	1-15	
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 6 July 2015	Examiner Herrero Ramos, J
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document</p>			

2

EPO FORM 1503 03 82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 15 15 6158

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

06-07-2015

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 2012240156 A	10-12-2012	NONE	
US 2009017252 A1	15-01-2009	NONE	
JP H04300159 A	23-10-1992	NONE	
JP H01234158 A	19-09-1989	NONE	
US 3702758 A	14-11-1972	NONE	
EP 0083250 A2	06-07-1983	DE 83250 T1	14-08-1985
		EP 0083250 A2	06-07-1983
		JP S58114857 A	08-07-1983
		US 4512859 A	23-04-1985
US 2012252322 A1	04-10-2012	CN 102732212 A	17-10-2012
		JP 2012206220 A	25-10-2012
		US 2012252322 A1	04-10-2012

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82