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(54) **CORE UN-BLOCKING ROLLER BRUSH**

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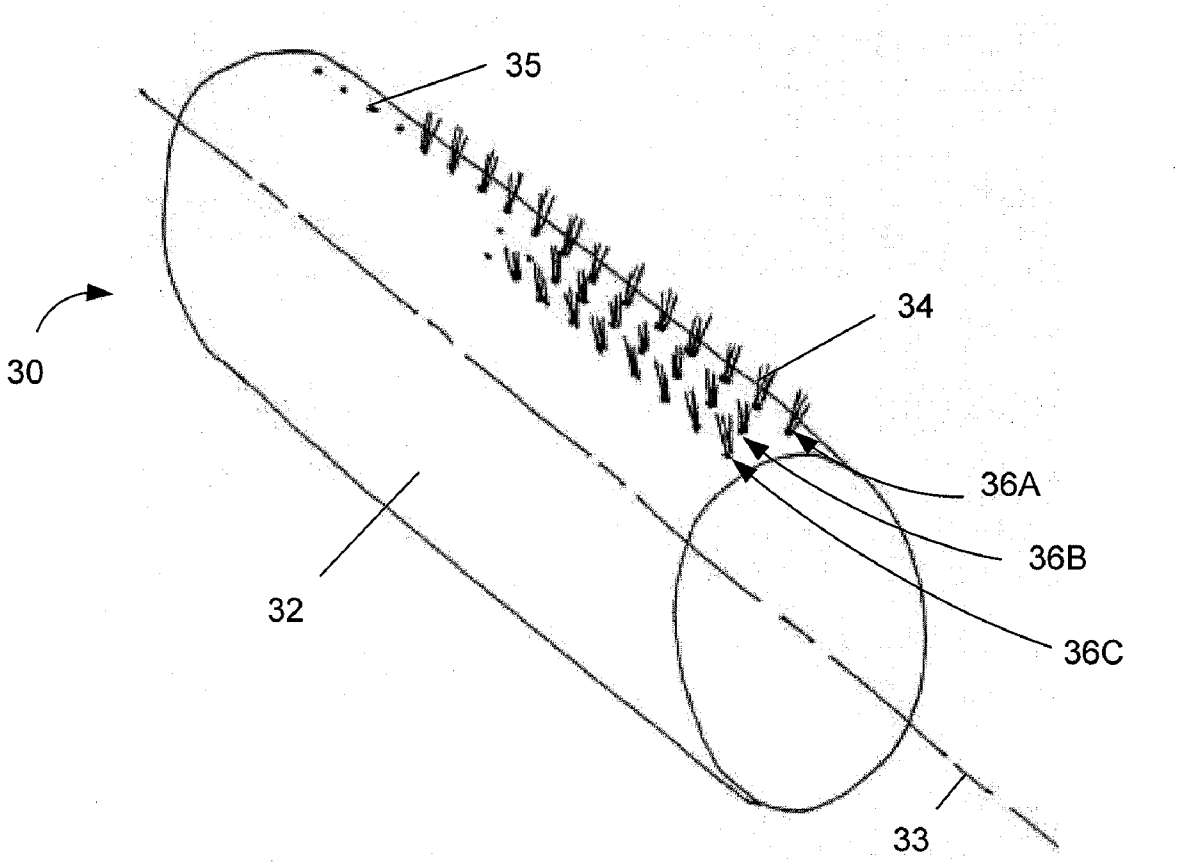
(57) **ABSTRACT**

An unblocking roller for removing excess material from the openings of cells of a honeycomb core is disclosed. The unblocking roller includes a cylindrical core having a center axis and a plurality of clusters each comprising a plurality of bristles. Each of the plurality of bristles of each cluster is coupled to the core at a first end and projecting outward from the core. Each bristle projects a minimum of a first distance from the core. Each cluster is separated from adjacent clusters by at least a second distance that is at least 20% of the first distance.



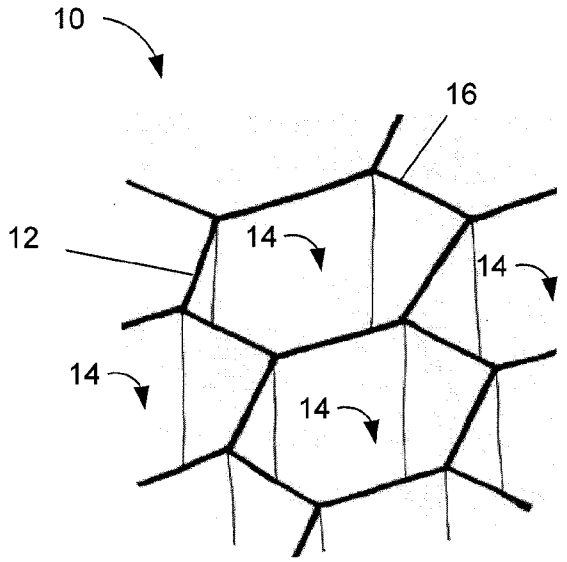


FIG. 1

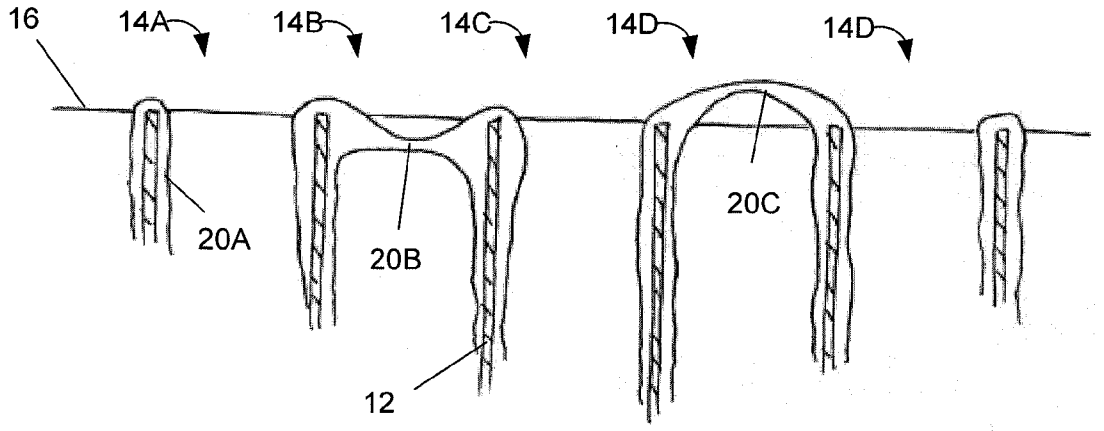


FIG. 2

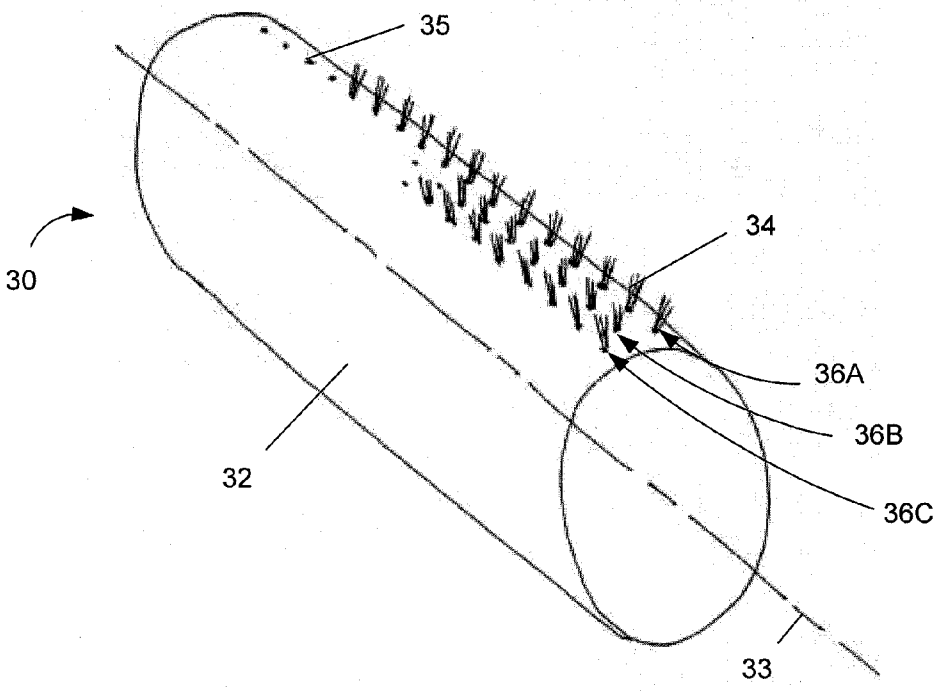


FIG. 3

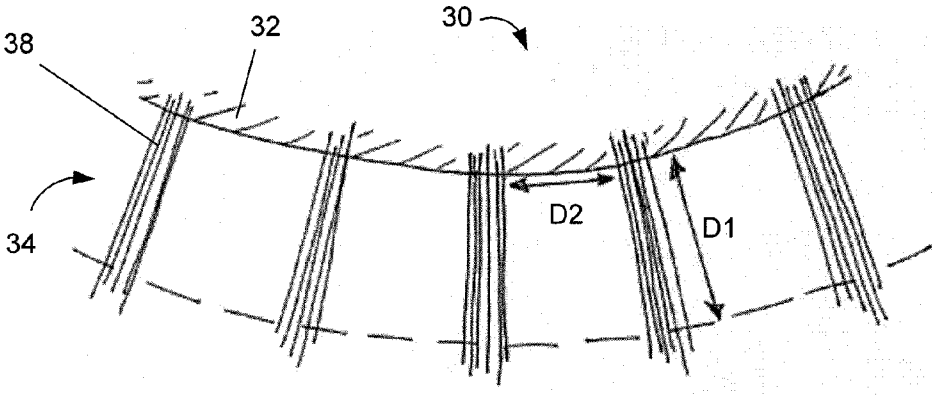


FIG. 4

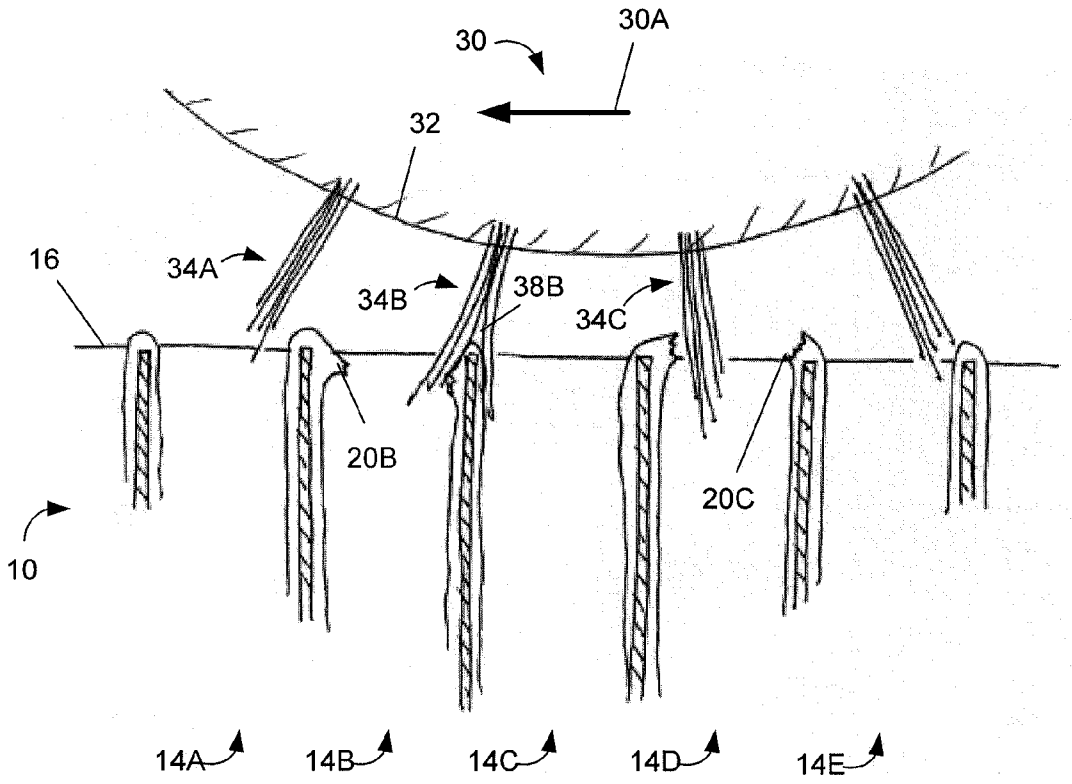

30
30A
32
16
34A
34B
38B
34C
20B
20C
10
14A
14B
14C
14D
14E

FIG. 5

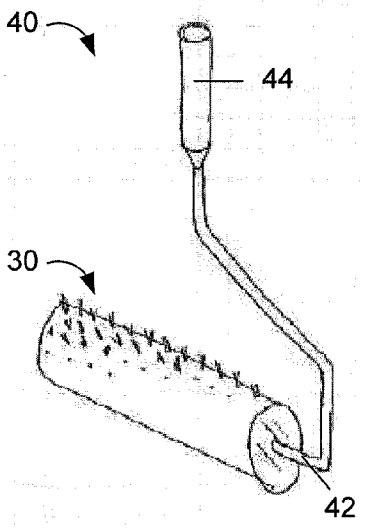

40
44
30
42

FIG. 6

CORE UN-BLOCKING ROLLER BRUSH

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] Not applicable.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] Not applicable

BACKGROUND

[0003] 1. Field

[0004] The present disclosure generally relates to fabrication of honeycomb structures and, in particular, the process of applying a coating to a honeycomb core.

[0005] 2. Description of the Related Art

[0006] Aerospace structures must meet stringent requirements for strength while also having low weight. One design approach that is utilized in structures such as aircraft wings is a composite assembly having a honeycomb core with rigid skins bonded to both faces of the core. This composite structure makes maximal utilization of the strength properties of the skin material while utilizing a lightweight interior material with adequate strength to meet the service requirements.

[0007] A typical step in the fabrication of a composite structure with a honeycomb core is to apply a coating to the walls of the cells of the honeycomb core. A common problem is that the applied coating accumulates disproportionately at the cell entrances and exits, i.e. the openings of the cells at the two faces of the honeycomb core. In some cases, the coating blocks the opening of the cell.

[0008] Current methods of unblocking the openings of the honeycomb core cells are to manually strike each opening with a brush to remove the excess coating. This is a slow process and leaves the operator susceptible to repetitive stress injuries.

SUMMARY

[0009] There is a need to provide a system and method of removing accumulated material at the opening of structures such as honeycomb cores. The disclosed system and method provide a roller brush configured to penetrate into the cells of a honeycomb core and dislodge excess material that has accumulated at the opening.

[0010] The disclosed system includes an unblocking roller having spaced clusters of bristles. The length of the bristles and the spacing of the clusters, relative to the length of the bristles, allow the bristles to penetrate through the openings of the cells of a honeycomb core rather than roll over the face of the honeycomb core without significant penetration of the bristles into the cells. Use of an unblocking roller brush to clear the openings of a honeycomb core provides a more uniform result in a much reduced period of time while reducing the risk of injury to the operator.

[0011] In certain embodiments, a roller brush for opening blocked cells in a honeycomb core is disclosed. The roller brush includes a cylindrical core having a center axis and a plurality of clusters each comprising a plurality of bristles. Each of the plurality of bristles of each cluster is coupled to the core at a first end and projects radially outward from the core. Each bristle projects a minimum of a first distance from the core. Each cluster is separated from adjacent clusters by a second distance that is at least 40% of the first distance.

[0012] In certain embodiments, a method of opening blocked cells in a honeycomb core is disclosed. The method includes the step of causing a roller having a plurality of bristle clusters each having a plurality of bristles that project a minimum of a first distance from a core wherein each cluster is separated from adjacent clusters by a second distance that is at least 40% of the first distance to pass across a face of the honeycomb core such that the bristles that are proximate to the face at least partially penetrate one or more cells of the honeycomb core.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] The accompanying drawings, which are included to provide further understanding and are incorporated in and constitute a part of this specification, illustrate disclosed embodiments and together with the description serve to explain the principles of the disclosed embodiments. In the drawings:

[0014] FIG. **1** depicts a face of a honeycomb core.

[0015] FIG. **2** is a cross-section of a honeycomb core having excess coating material accumulated at the openings of the cells.

[0016] FIG. **3** is a perspective view of an unblocking roller according to certain aspects of this disclosure.

[0017] FIG. **4** is an enlarged side view cross-section of the unblocking roller of FIG. **3** according to certain aspects of this disclosure.

[0018] FIG. **5** depicts the operation of an unblocking roller dislodging excess material from a honeycomb core according to certain aspects of this disclosure.

[0019] FIG. **6** depicts an unblocking roller assembly according to certain aspects of this disclosure.

DETAILED DESCRIPTION

[0020] Fabrication of honeycomb structures requires a significant amount of manual handling. Honeycomb core, prior to being bonded to skins or other structures, is very flexible. Honeycomb cores used in aerospace structures may have cells with a width of less than a 0.25 inch. Coatings must often be applied to the surfaces of the honeycomb core to provide protection or improved adhesion.

[0021] In the following detailed description, numerous specific details are set forth to provide a full understanding of the present disclosure. It will be apparent, however, to one ordinarily skilled in the art that embodiments of the present disclosure may be practiced without some of the specific details. In other instances, well-known structures and techniques have not been shown in detail so as not to obscure the disclosure.

[0022] The methods and systems disclosed herein are presented in terms of removal of an excess of a dried coating from the cell openings of a honeycomb core. These same methods and systems can be applied to other structures, such as perforated metal sheets or woven mesh, and other materials, such as paint or adhesive. Nothing in this disclosure should be interpreted, unless specifically stated as such, to limit the application of any claimed method or system disclosed herein to honeycomb structures or dried coatings.

[0023] FIG. **1** depicts a face of a honeycomb core **10**. In this example, the honeycomb core **10** is a series of adjacent hexagonal cells **14** separated by walls **12**. The cut surface of the honeycomb core **10** forms a face. Honeycomb cores **10** are typically provided as sheets of a uniform thickness with the

cells **14** running from a top face **16** to a bottom face (not visible in FIG. **1**) through the thickness of the honeycomb core **10**. Honeycomb cores used in aerospace structures can have cells with a width, defined as the distance between opposite flat surfaces, of 0.25 inches or less. Honeycomb cores used in other products, for example doors, may have cell widths of an inch or greater.

[0024] FIG. **2** is a cross-section of a honeycomb core **10** having excess coating material **20** accumulated at the openings of the cells **14**. In this example, the material **20**A has coated the wall **12** of the honeycomb core **10** as intended. Material **20**B has bridged the opening of cell **14**B. Material **20**C has formed a bubble over the opening of cell **14**D. It is necessary, in some processes, to remove a sufficient quantity of the material **20**B and **20**C to open the cells **14**B and **14**D.

[0025] FIG. **3** is a perspective view of an unblocking roller **30** according to certain aspects of this disclosure. In this embodiment, the roller includes a cylindrical core **32** having a center axis **33** along the axis of symmetry of the cylinder. There are bristle clusters **34** arranged in rows **36** that are, in this embodiment, aligned with the axis **33**. Only a portion of a few representative rows **32**A, **32**B, and **32**C are depicted to simplify the illustration. In certain embodiments, the rows **36** are configured as spirals around the cylindrical core **32**. In certain embodiments, the bristle clusters **34** are generally evenly spaced but are not arranged in rows.

[0026] FIG. **4** is an enlarged side view cross-section of the unblocking roller **30** of FIG. **3** according to certain aspects of this disclosure. Bristle clusters **34** comprise a plurality of bristles **38**. The length of the bristles **38**, the number of bristles **38** in a bristle cluster **34**, and the spacing of the bristle cluster **34** are important aspects of the design that control whether the unblocking roller **30** effectively penetrates the openings of the cells **14** of the honeycomb core **10**. Selection of a combination of roller **32** diameter, bristle **38** length, number of bristles **38** in a bristle cluster **34**, and the spacing and arrangement of the bristle clusters **34** is not an obvious extrapolation from existing roller products, such as paint rollers. If the bristles **38** are too short or the bristle clusters **34** are too close together, the unblocking roller **30** tends to roll over the face **16** of the honeycomb core **10** without the bristles **38** removing the excess material **20**. If the roller core **32** diameter is too small, the bristle clusters **34** miss some of the cells **14** as the unblocking roller **10** passes across the face **16** of the honeycomb core **10**. If the roller core **32** diameter is too large, too many bristle clusters **34** are in contact with the face at the same time and the unblocking roller **30** tends to pass over the face **16** without the bristles **38** penetrating the openings of the cells **14** of the honeycomb core **10** If the bristles **38** are too long, the bristles **38** tend to bend and lay flat over the face **16**, therefore not penetrating the cells **14**. If there are too many bristles **38** in a bristle cluster **34**, the bristle cluster **34** covers too much of the opening of a single cell **14** and therefore rides on the surface **16** and does not penetrate the opening of the cell **14**. If there are too few bristles **38** in a bristle cluster **34**, then there may be too little stiffness of the bristle cluster to penetrate the dried material **20**. If the bristle clusters **34** are too far apart, the unblocking roller **30** unblocks only a portion of the cells **14** as it passes over the face **16**, therefore failing to provide a benefit over the prior manual process. It can be seen, from the long list of design choices that lead to failure, that finding the proper combination of multiple design variables of an unblocking roller **30** requires a careful review of the particular features of the problem and an inventive selection of design parameter values to produce an operative unblocking roller **30**.

[0027] The bristles **38** have a minimum projection distance D**1**, with additional bristle length to allow the bristles to be coupled to the core **32**. In the exemplary embodiment of FIG. **4**, the bristles **38** have lengths that are a minimum of D**1** with some bristles **38** of each bristle cluster **34** being longer than D**1**. In certain embodiments, the bristles **38** project a distance within a range of 100% to 150% of D**1**. In certain embodiments, the bristles **38** project a distance within a range of 100% to 125% of D**1**. In certain embodiments, the bristles **38** project a distance within a range of 100% to 115% of D**1**. In certain embodiments, the bristles **38** project a distance within a range of ½ to 1 inch. In certain embodiments, the bristles **38** project a distance within a range of ¾ to ⅞ inch.

[0028] In certain embodiments, the bristles **38** are bonded into a cluster **34** with an adhesive, and the clusters **34** are then bonded into holes **35** (as seen in FIG. **1**) in the core **32**. In certain embodiments, the clusters **34** are bonded to the surface of the core **32**. In certain embodiments, the bristles **38** are bonded directly to the core **32**.

[0029] In certain embodiments, each cluster includes 10-50 bristles **38**. In certain embodiments, each cluster includes 18-24 bristles **38**.

[0030] The bristle clusters **34** are spaced apart, in this embodiment, in rows **36** (seen edge-on in the view of FIG. **4**) with a separation distance D**2**. In certain embodiments, the spacing of bristle clusters **34** along the rows **36** is at the same separation distance D**2**. In certain embodiments, the bristle clusters **34** are separated along the rows at different distances than D**2**. In certain embodiments, the bristle clusters are spaced at a plurality of spacings along a row **36**. In certain embodiments, the bristle clusters **34** of adjacent rows **36** are offset along the respective rows **36** with respect to the bristle clusters **34** of the adjacent rows **36**. In certain embodiments, the bristle clusters **34** are separated by a distance that is at least a determined percentage of the length D**1**. In certain embodiments, the bristle clusters **34** are separated by a distance that is at least 20% of the length D**1**. In certain embodiments, the bristle clusters **34** are separated by a distance that is at least 30% of the length D**1**. In certain embodiments, the bristle clusters **34** are separated by a distance that is at least 40% of the length D**1**. In certain embodiments, D**1** is at least ½ inch. In certain embodiments, D**1** is at least ¾ inch. In certain embodiments, D**2** is at least 5/16 inch.

[0031] In certain embodiments, the diameter of the cylindrical core **32** is less than 5× the length D**1**. In certain embodiments, the diameter of the cylindrical core **32** is less than 4× the length D**1**. In certain embodiments, the diameter of the cylindrical core **32** is between 3× and **4**× the length D**1**. In certain embodiments, D**1** is ¾ inch and the diameter of the cylindrical core **32** is 2.5 inches.

[0032] In certain embodiments, the bristles **38** have a diameter in the range of 0.001-0.050 inch. In certain embodiments, the bristles **38** have a diameter in the range of 0.005-0.020 inch. In certain embodiments, the bristles **38** have a diameter in the range of 0.009-0.011 inch. In certain embodiments, the bristles **38** have a nominal diameter of 0.010 inch. In certain embodiments, the bristles **38** are of a constant thickness over the length D**1**. In certain embodiments, the bristles **38** taper in thickness over the length D**1**.

[0033] In certain embodiments, the bristles **38** comprise a polymer. In certain embodiments, the bristles **38** comprise a

metal. In certain embodiments, the bristles **38** comprise natural fibers, for example horse hair.

[0034] FIG. **5** depicts the operation of an unblocking roller **30** dislodging excess material **20** from a honeycomb core **10** according to certain aspects of this disclosure. Unblocking roller **30** is moving to the left, in the view of FIG. **5**, as indicated by arrow **30**A and therefore rotating counterclockwise. The bristles **38**B of bristle cluster **34**B are depicted as penetrating into cells **14**B and **14**C and have broken away the material **20**B that bridged the opening of cell **14**B in FIG. **2**. Similarly, bristle cluster **34**C has broken away the material **20**C that was bubbled over cell **14**D. Bristle cluster **34**A is approaching the opening of cell **14**A, although there is no material **20** that needs to be removed from this cell **14**A.

[0035] In certain embodiments, the material **20** is a liquid with sufficient viscosity to bridge the openings of cells **14** and the unblocking brush displaces the material **20** while it is a liquid.

[0036] FIG. **6** depicts an unblocking roller assembly **40** according to certain aspects of this disclosure. Unblocking roller **30** is coupled to a shaft **42** such that roller **30** can freely rotate about the shaft **42**. Shaft **42** is configured with a portion that is over the roller **30**, in the view of FIG. **6**. A handle **44** is attached to shaft **42**. The handle, in this embodiment, is configured to be gripped by the hand of a user (not shown).

[0037] In use, the handle **44** of roller assembly **40** is gripped by a user and the roller **30** is brought into contact with the top face **16** of a honeycomb core **10**. The roller **30** is then rolled across the face **16** such that the bristles **38** penetrate into the openings of cells **14** under the area covered by the rolling motion. The roller assembly **40** may be moved back and forth several times over the same area. The roller **30** is then raised off the face **16** and repositioned on another portion of the honeycomb core **10** and the rolling process repeated over a new region of cells **14**.

[0038] In certain embodiments, the roller assembly **40** is rolled over the honeycomb core **10** after a coating material **20** has been applied and allowed to dry. In certain embodiments, the roller assembly **40** is used to apply the coating material **20**. In certain embodiments, the roller assembly **40** is used to spread or redistribute the applied coating material **20** while the material **20** is still wet. In certain embodiments, the roller assembly **40** is used to open the cells **14** without redistributing the applied coating material **20** while the coating material **20** is still wet. In certain embodiments, the coating is applied to only the face **16** or a limited depth into the openings of cells **14** and the roller assembly **40** is used to remove material **20** that covers or blocks the openings of the cells **14**.

[0039] While FIG. **6** depicts an embodiment of a roller assembly **40** for manual use, other embodiments may have shafts **42** or handles **44** of different configurations. For example, the handle may be a long, such as 48 inch, rod (not shown) attached at one end to the shaft **42** such that a user can roll the roller **30** across an area of a honeycomb core **10** farther than one arm's length from an edge of the honeycomb core **10**. As a second example, the handle **44** may be replaced with a machine-adapter (not shown) such that the roller **30** can be manipulated by a robotic system (not shown).

[0040] The concepts disclosed herein provide an apparatus and method for unblocking the openings of the cells of a honeycomb core when the openings are fully or partially blocked by an applied material. The disclosed unblocking roller has a range of roller core diameter, bristle length, bristle cluster separation and arrangement, and bristle types that are effective at penetrating the openings of the cells of the honeycomb structure.

[0041] The previous description is provided to enable a person of ordinary skill in the art to practice the various aspects described herein. While the foregoing has described what are considered to be the best mode and/or other examples, it is understood that various modifications to these aspects will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other aspects. Thus, the claims are not intended to be limited to the aspects shown herein, but is to be accorded the full scope consistent with the language claims, wherein reference to an element in the singular is not intended to mean "one and only one" unless specifically so stated, but rather "one or more." Unless specifically stated otherwise, the terms "a set" and "some" refer to one or more. Pronouns in the masculine (e.g., his) include the feminine and neuter gender (e.g., her and its) and vice versa. Headings and subheadings, if any, are used for convenience only and do not limit the invention.

[0042] It is understood that the specific order or hierarchy of steps in the processes disclosed is an illustration of exemplary approaches. Based upon design preferences, it is understood that the specific order or hierarchy of steps in the processes may be rearranged. Some of the steps may be performed simultaneously. The accompanying method claims present elements of the various steps in a sample order, and are not meant to be limited to the specific order or hierarchy presented.

[0043] Terms such as "top," "bottom," "front," "rear" and the like as used in this disclosure should be understood as referring to an arbitrary frame of reference, rather than to the ordinary gravitational frame of reference. Thus, a top surface, a bottom surface, a front surface, and a rear surface may extend upwardly, downwardly, diagonally, or horizontally in a gravitational frame of reference.

[0044] A phrase such as an "aspect" does not imply that such aspect is essential to the subject technology or that such aspect applies to all configurations of the subject technology. A disclosure relating to an aspect may apply to all configurations, or one or more configurations. A phrase such as an aspect may refer to one or more aspects and vice versa. A phrase such as an "embodiment" does not imply that such embodiment is essential to the subject technology or that such embodiment applies to all configurations of the subject technology. A disclosure relating to an embodiment may apply to all embodiments, or one or more embodiments. A phrase such an embodiment may refer to one or more embodiments and vice versa.

[0045] The word "exemplary" is used herein to mean "serving as an example or illustration." Any aspect or design described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other aspects or designs.

[0046] All structural and functional equivalents to the elements of the various aspects described throughout this disclosure that are known or later come to be known to those of ordinary skill in the art are expressly incorporated herein by reference and are intended to be encompassed by the claims. Moreover, nothing disclosed herein is intended to be dedicated to the public regardless of whether such disclosure is explicitly recited in the claims. No claim element is to be construed under the provisions of 35 U.S.C. §112, sixth paragraph, unless the element is expressly recited using the phrase

"means for" or, in the case of a method claim, the element is recited using the phrase "step for." Furthermore, to the extent that the term "include," "have," or the like is used in the description or the claims, such term is intended to be inclusive in a manner similar to the term "comprise" as "comprise" is interpreted when employed as a transitional word in a claim.

1. An unblocking roller for removing excess material from the openings of cells in a honeycomb core, the unblocking roller comprising:

a cylindrical core having a center axis; and

a plurality of clusters each comprising a plurality of bristles, each of the plurality of bristles of each cluster coupled to the core at a first end and projecting outward from the core; each bristle projecting a minimum of a first distance from the core;

wherein each cluster is separated from adjacent clusters by at least a second distance that is at least 20% of the first distance.

2. The unblocking roller of claim **1**, wherein the bristles project radially from the center axis.

3. The unblocking roller of claim **1**, wherein the first distance is at least 0.5 inch.

4. The unblocking roller of claim **3**, wherein the first distance is at least 0.75 inch.

5. The unblocking roller of claim **1**, wherein the second distance is at least 30% of the first distance.

6. The unblocking roller of claim **5**, wherein the second distance is at least 40% of the first distance

7. The unblocking roller of claim **1**, wherein the core has a diameter that is less than five times the first distance.

8. The unblocking roller of claim **7**, wherein the core has a diameter that is at least three times the first distance.

9. The unblocking roller of claim **1**, wherein:

the clusters are arranged in evenly spaced rows;

the clusters along each row are evenly spaced at the second distance; and

the clusters of adjacent rows are offset along the respective rows by a third distance that is less than the second distance.

10. The unblocking roller of claim **1**, wherein:

the bristles of each cluster project a plurality of distances from the core;

the shortest bristle projects the first distance from the core; and

the longest bristle projects a fourth distance from the core, the fourth distance at least 115% of the first distance.

11. The unblocking roller of claim **10**, wherein the first distance is 0.75 inches and the fourth distance is 0.875 inches.

12. The unblocking roller of claim **1**, wherein each cluster comprises 16-24 bristles.

13. The unblocking roller of claim **1**, further comprising:

a shaft coupled to the core such that the core freely rotates about a first portion of the shaft; and

a handle coupled to a second portion of the shaft, the handle configured to be gripped by a hand of a user.

14. A method of opening blocked cells in a honeycomb core, the method including the step of:

causing a roller having a plurality of bristle clusters each having a plurality of bristles that project a minimum of a first distance from a core wherein each bristle cluster is separated from adjacent bristle clusters by a second distance that is at least 20% of the first distance to pass across a face of the honeycomb core such that the bristles that are proximate to the face at least partially penetrate one or more cells of the honeycomb core.

15. The method of claim **14**, wherein the core has a diameter that is between three and five times the first distance.

16. The method of claim **14**, wherein the bristle clusters are arranged in staggered, evenly spaced rows of evenly spaced bristle clusters.

17. The method of claim **14**, wherein the bristles of each cluster project a plurality of distances from the core, the shortest bristle projecting the first distance from the core and the longest bristle projecting a fourth distance from the core, the fourth distance at least 115% of the first distance.

18. The method of claim **17**, wherein the first distance is 0.75 inches and the fourth distance is 0.875 inches.

19. The method of claim **14**, wherein each cluster comprises 16-24 bristles.

* * * * *