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(54) PRESSURE FLUSH PROCESS FOR COOLED TURBINE BLADES

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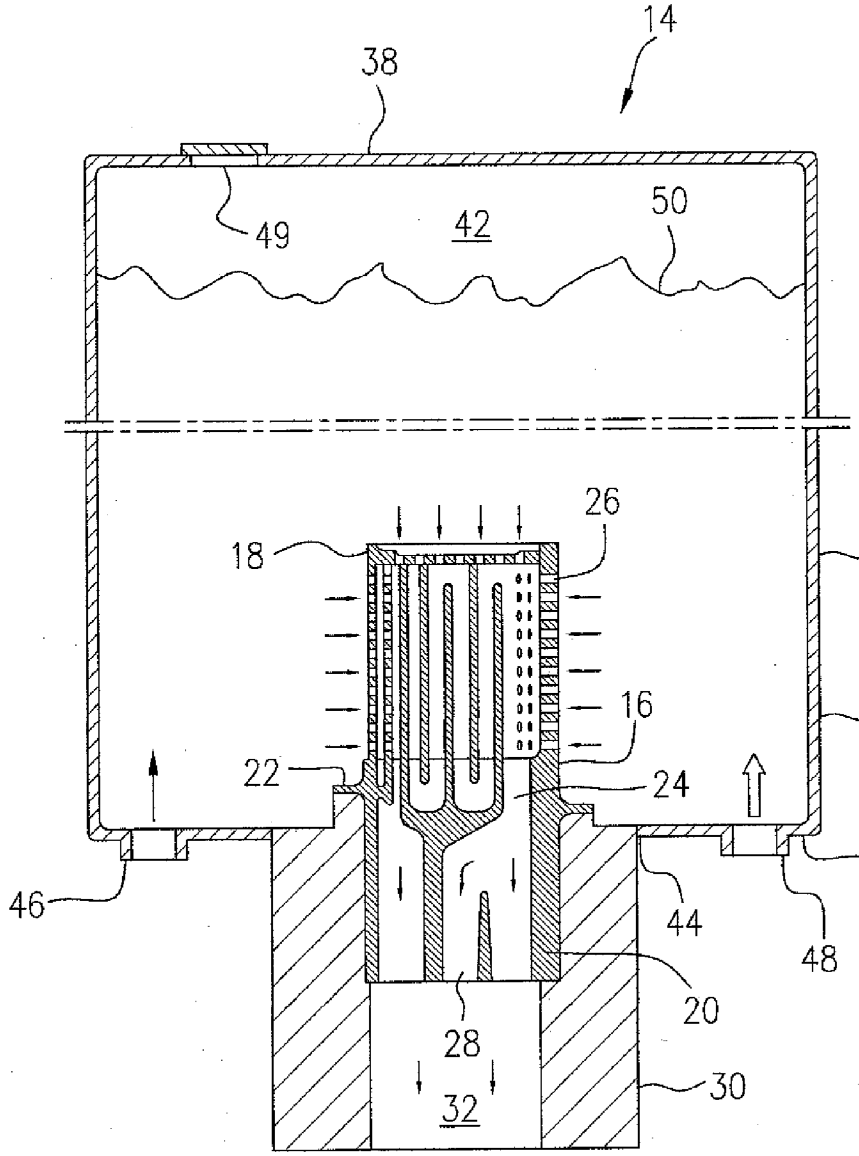
(57) **ABSTRACT**

A pressure flush process for removing debris from internal passageways of a cooled turbine blade includes a step of creating an agitated liquid/gas mixture and a step of injecting the agitated liquid/gas mixture under a positive pressure, into at least some of cooling holes in the blade to pass through the internal passageways and discharging the agitated liquid/gas mixture together with removed debris, through a larger root opening of the blade.



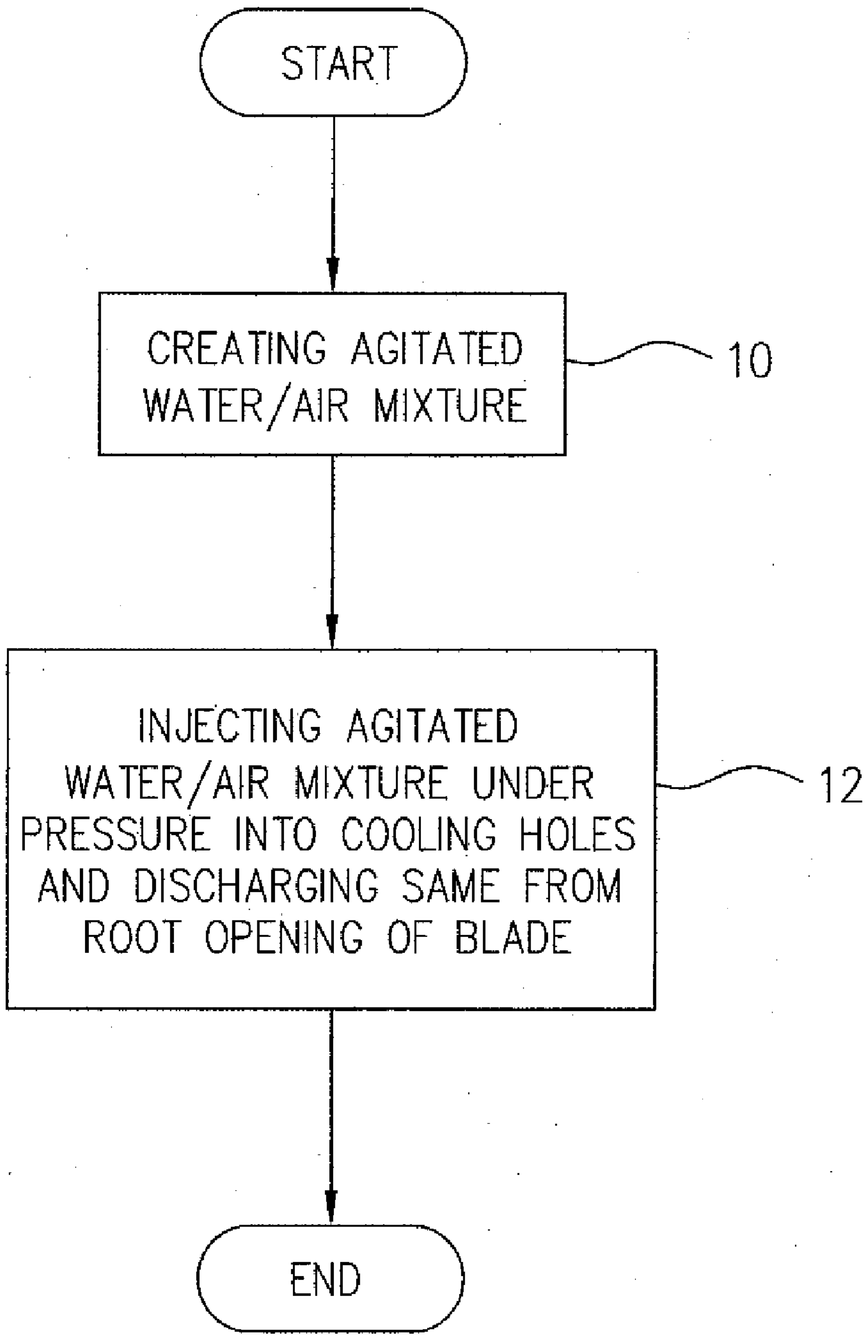

START
CREATING AGITATED WATER/AIR MIXTURE
10
INJECTING AGITATED WATER/AIR MIXTURE UNDER PRESSURE INTO COOLING HOLES AND DISCHARGING SAME FROM ROOT OPENING OF BLADE
12
END

FIG. 1

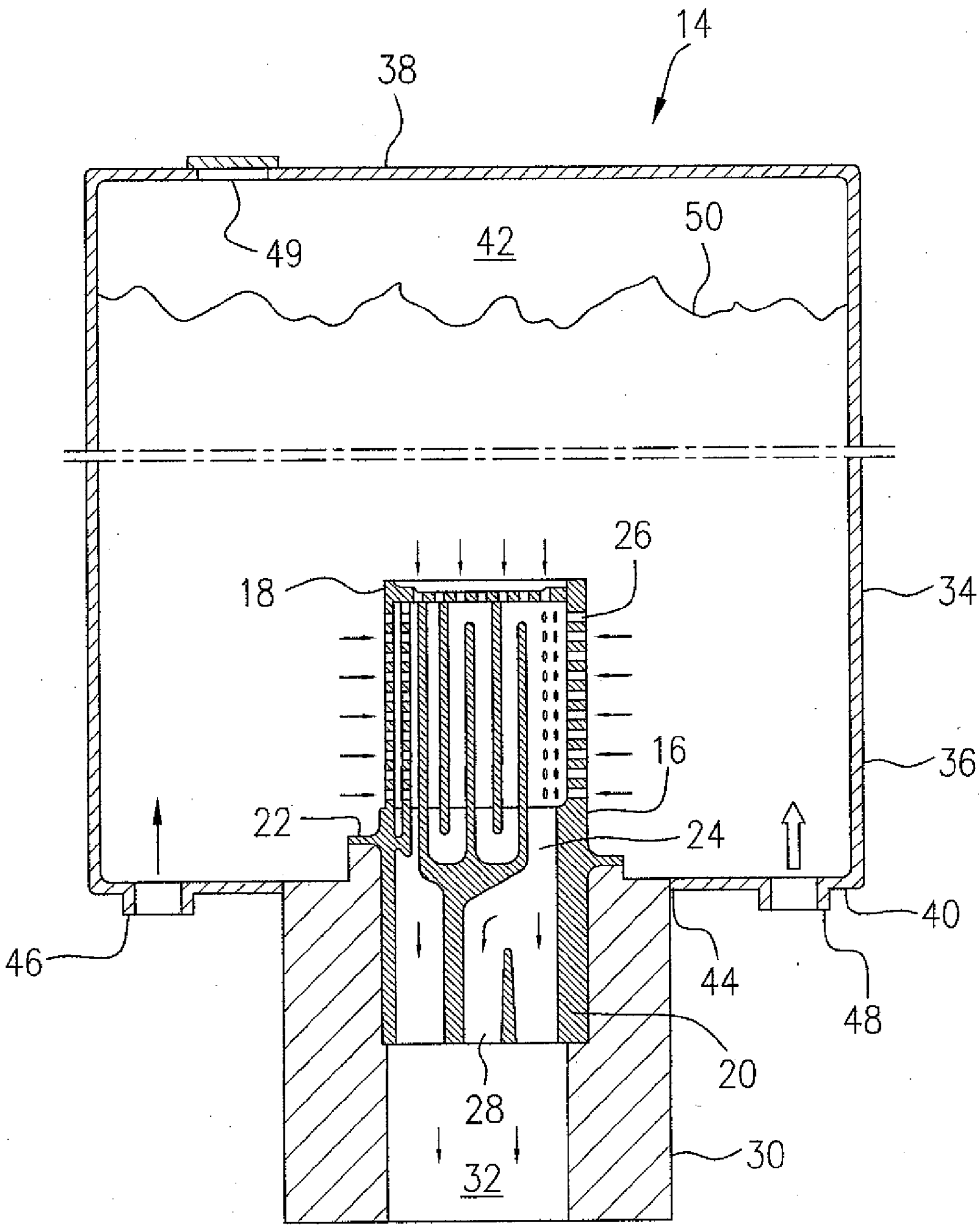


FIG. 2

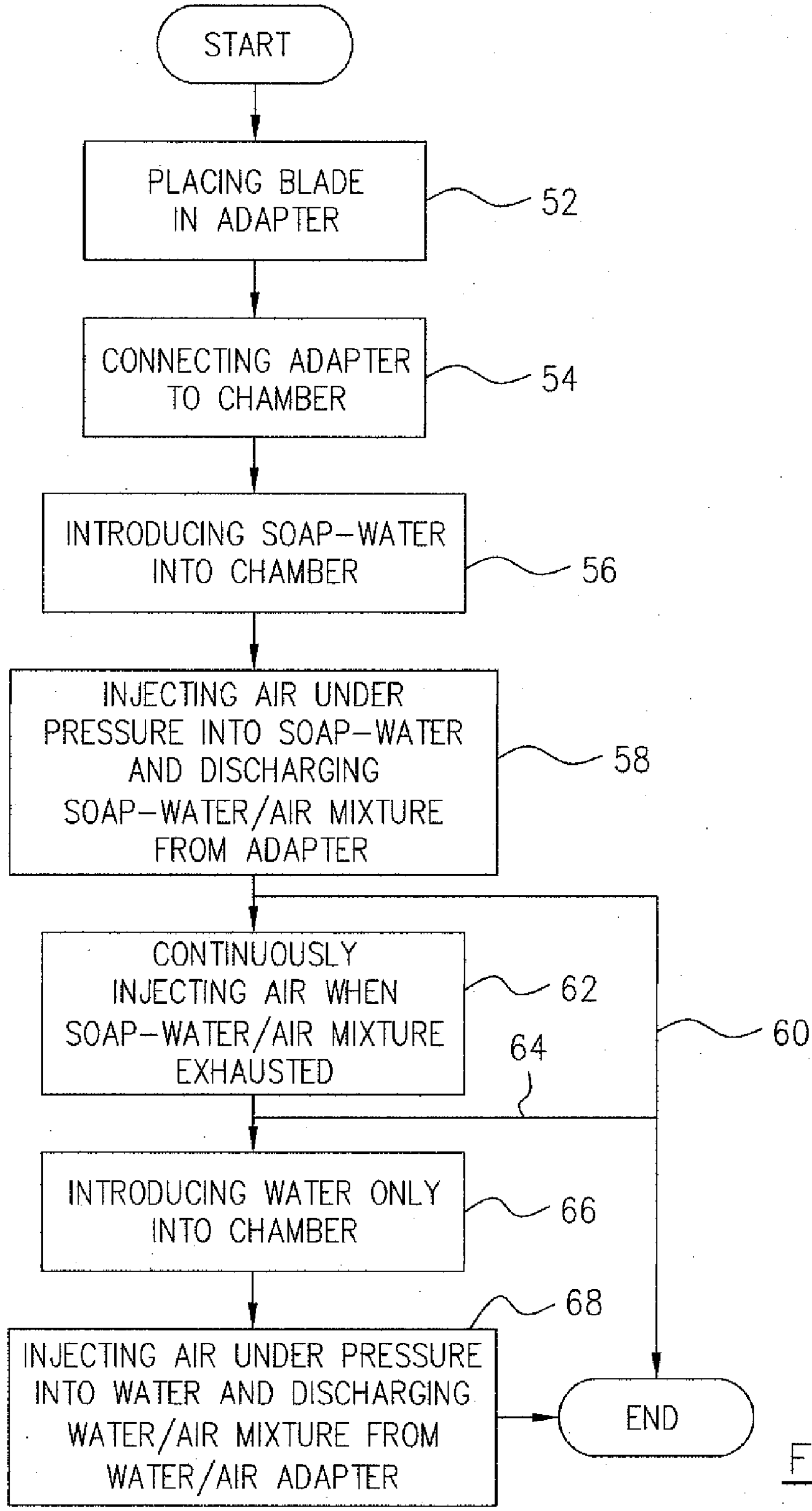

START
PLACING BLADE IN ADAPTER
52
CONNECTING ADAPTER TO CHAMBER
54
INTRODUCING SOAP-WATER INTO CHAMBER
56
INJECTING AIR UNDER PRESSURE INTO SOAP-WATER AND DISCHARGING SOAP-WATER/AIR MIXTURE FROM ADAPTER
58
CONTINUOUSLY INJECTING AIR WHEN SOAP-WATER/AIR MIXTURE EXHAUSTED
62
60
64
INTRODUCING WATER ONLY INTO CHAMBER
66
68
INJECTING AIR UNDER PRESSURE INTO WATER AND DISCHARGING WATER/AIR MIXTURE FROM WATER/AIR ADAPTER
END

FIG. 3

PRESSURE FLUSH PROCESS FOR COOLED TURBINE BLADES

TECHNICAL FIELD

[0001] The described subject matter relates generally to turbine engines and more particularly, to an improved pressure flush process for removing debris from internal passages of cooled turbine blades.

BACKGROUND OF THE ART

[0002] It is know in the prior art to direct gas streams containing a soluble blast media or a solvent flow through the internal passageways of cooled turbine blades for cleaning the internal passageways during maintenance of the cooled turbine blades. Carbon-like deposits which build up in the internal passageways of the cooled turbine blades over thousands of hours of operation can be dissolved or broken up into particulates fine enough to be flushed out of the internal passageways through very fine cooling holes defined in the airfoil of cooled turbine blades. On the other hand, in a production/manufacturing environment, debris such as grinding swarf, steel shot peen material, grinding wheel fragments, etc., should also be removed from the internal passages of the cooled blades before the blades are installed in turbine engines. However, this manufacturing debris is generally indissoluble and may not escape through those small airfoil cooling holes. Prior art methods of automated cleaning lines are not very effective in removing the debris lodged in the complex internal passageways of the cooled turbine blades.

[0003] Accordingly, there is a need to provide an improved process for cleaning indissoluble debris lodged in the internal passageways of cooled turbine blades.

SUMMARY

[0004] In accordance with one aspect, there is provided a pressure flush process for removing debris from internal passageways of a turbine blade, the internal passageways being in fluid communication with a plurality of cooling holes defined in the blade and with a root opening defined in a root section of the blade, the root opening being sized larger than the individual cooling holes, the process comprising a) creating an agitated water/air mixture; and b) injecting the agitated water/air mixture under a positive pressure into at least some of the cooling holes to pass through the internal passageways and discharging the agitated water/air mixture together with removed debris through the root opening.

[0005] In accordance with another aspect, there is provided a pressure flush process for removing indissoluble debris from internal passageways of a blade of a turbine engine, the internal passageways being in fluid communication with a plurality of cooling holes defined in the blade and with a root opening defined in a root section of the blade, the root opening being sized larger than the individual cooling holes, the process comprising a) placing the blade in an adapter such that the root section is sealingly received in a cavity of the adapter to allow the root opening to be connected in fluid communication with a draining passage extending through the adapter and allow a remaining part of the blade having at least some of the cooling holes, to project from the adapter; b) connecting the adapter to a sealable chamber with seals therebetween to allow the projecting part of the blade to be accommodated within the chamber; c) introducing a selected amount of a soap-water into the chamber, the soap-water including water with a soap solution; and d) injecting air under a positive pressure into the soap-water in the chamber to cause an agitation of the soap-water/air mixture under the positive pressure within the chamber, and allowing the agitated soap-water/air mixture to inject into the at least some of the cooling holes and further to pass through the internal passageways, and discharging the soap-water/air mixture together with debris which has been removed from the internal passageways through the draining passage in the adapter.

[0006] In accordance with a further aspect, there is provided a pressure flush process for removing debris from internal passageways of a turbine blade, the internal passageways being in fluid communication with a plurality of cooling holes defined in the blade and with a root opening defined in a root section of the blade, the root opening being sized larger than the individual cooling holes, the process comprising: a) creating an agitated liquid/gas mixture; and b) injecting the agitated liquid/gas mixture under a positive pressure into at least some of the cooling holes to pass through the internal passageways and discharging the agitated liquid/gas mixture together with removed debris through the root opening.

[0007] Further details of these and other aspects of the described subject matter will be apparent from the detailed description and figures included below.

DESCRIPTION OF THE DRAWINGS

[0008] Reference is now made to the accompanying figures depicting aspects of the present invention, in which:

[0009] FIG. **1** is a simplified flowchart of the steps involved in one embodiment of a pressure flush process for removing indissoluble debris from internal passageways of a turbine blade;

[0010] FIG. **2** is a cross-sectional view of a turbine blade seated within a pressure flush apparatus; and

[0011] FIG. **3** is a flowchart of the steps of the pressure flush process used with the apparatus of FIG. **2**, according to another embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0012] Referring to the drawings, a general principle of a pressure flush process for removing debris, particular indissoluble debris such as grinding swarf, steel shot peen material, grinding wheel fragments, etc., from internal passageways of cooled turbine blades in FIG. **1**, as a simple example including step **10** of creating an agitated water/air mixture, and a step **12** of injecting the agitated water/air mixture under a pressure differential (such as applying a positive pressure to the water/air mixture) into at least some cooling holes defined in the turbine blades, to pass through the internal passageways and discharge the agitated water/air mixture with removed debris through a root opening of the blade.

[0013] FIG. **2** illustrates an apparatus **14** used with a cooled turbine blade **16** to conduct the pressure flush process as illustrated in FIG. **1**. The cooled turbine blade **16** includes an airfoil section **18**, a root section **20** and a platform **22** located intermediate therebetween and transversely outwardly extending away from the blade **16**. The blade **16** is of a hollow configuration to define internal passageways **24** which are in fluid communication with a plurality of very small cooling holes **26** defined, for example in the airfoil section **18**. The internal passageways **24** are also in fluid communication with one or more root openings **28** which are sized much larger than the individual cooling holes **26**. Therefore, cooling air (not shown) can be introduced through the root openings **28** into the internal passageways **24** to cool the blade **16** and then exit through the cooling holes **26** when the blade **16** is installed in a turbine engine for operation.

[0014] However, the manufacturing process of the blades **16** may result in debris being lodged in the internal passageways **24** of the blade **16**. This debris created in the manufacturing process may include, for example, grinding swarf, steel shot peen material, grinding wheel fragments, etc. which are not dissoluble and may be too large to escape through the small cooling holes **26** defined in the airfoil section **18**. This debris must be removed from the internal passageways **24** of the blade **16** prior to installation of the blade **16** in a turbine engine (not shown).

[0015] In this embodiment an adapter **30** is provided for sealingly receiving the root section **20** of the blade **16** in a cavity (not numbered) of the adapter **30** to allow the root openings **28** of the blade **16** to be connected in fluid communication with a draining passage **32** extending through the adapter **30**. The remaining part of the blade **16** such as the airfoil section **18** in which the cooling holes **26** or at least some of them are defined, projects away from the adapter **30**.

[0016] A sealable chamber **42** is defined in a cylinder **34** having a cylindrical wall **36** extending between a top end wall **38** and a bottom end wall **40**. The cylinder **34** defines an opening **44** in the bottom end wall **40**, to allow the projecting part (the airfoil section **18**) of the blade **16** to be accommodated within the sealable chamber **42** when the cylinder **34** is sealingly connected to the adapter **30**. A seal (not shown) may be provided in the opening **44** and around the adapter **30**. The cylinder **34** further includes inlets **46** and **48**, for example, defined in the bottom end wall **40**, which are adapted to be sealingly connected to a source of water supply (not shown) and a source of pressurized air (not shown), respectively. The cylinder **34** may further include a closable vent opening **49** defined in the top end wall **38** or in an upper location of the cylindrical side wall **36**. The sealable vent opening **49** is usually closed.

[0017] The blade **16** is placed within the apparatus **14** as shown in FIG. **2**, in order to begin a pressure flush process for the blade **16** according to, for example, the embodiment shown in FIG. **1**. Step **10** of creating agitated water/air mixture is achieved by first introducing water into the chamber **42** through, for example inlet **46** while inlet **48** and draining passage **32** are closed. The vent opening **49** may be open to facilitate the water intake procedure. A selected amount of water is introduced into the chamber **42** such that the entire airfoil section **18** of the blade **16**, which projects from the adapter **30** and is accommodated within the chamber **42**, is submerged in the water, leaving a space between a surface **50** of the water and the top end wall **38** of the chamber **42**. Then inlet **46** and the vent opening **49** are closed while inlet **48** is opened to inject an air flow through inlet **48** under a positive pressure into the water contained in the chamber **42**, resulting in severe agitation of the water/air mixture within the chamber **42**.

[0018] Almost simultaneously to the injection of the pressurized air flow through the inlet **48**, the draining passage **32** of the adapter **30** is opened, for example to the ambient pressure, such that an agitated water/air mixture is formed and is injected under that positive pressure, through the small cooling holes **26** and into the internal passageways **24** of the blade **16**. Under the force of the agitated water/air mixture, the debris remaining in the internal passageways **24** is dislodged and discharged together with the exhausted water/air mixture, through the larger root opening **28** of the blade **16** and into the draining passage **32** of the adapter **30**.

[0019] It is optional to supply water which is warmer than the ambient temperature for the agitated water/air mixture in this process. The water supplied for this process may not contain any solvents or solid particles which would compromise the integrity of any internal coatings (not shown) the internal passageways **24** of the blade **16** may have. Therefore, if the exhausted water/air mixture from the draining passage **32** of the adapter **30** in this process, is to be re-used as part of the water supply, an adequate filtration system (not shown) may be needed.

[0020] In accordance with another embodiment as illustrated in FIG. **3** in which steps **52** (placing the blade **16** in the adapter **30**) and **54** (connecting the adapter **30** to the sealable chamber **42**) are completed as described above with reference to FIG. **2**, a selected amount of a soap-water which includes water with a soap solution, is introduced into the chamber **42** as indicated in step **56**, instead of water only as shown in the embodiment of FIG. **1**. The soap-water supplied for this process may have an ambient temperature or may be much warmer than the ambient temperature, if desired. Step **58** (injecting air under pressure into soap-water and discharging same from the adapter) is similar to the procedures described above with reference to steps **10** and **12** of the embodiment shown in FIG. **1**. The agitated soap-water mixture under pressure of step **58**, provides better lubrication than the agitated water/air mixture of step **12** of FIG. **1**, when the debris in the internal passageways **24** of the blade **16** is removed and discharged.

[0021] The process according to this embodiment may end after step **58** is completed, as indicated by link **60**, similar to the embodiment of FIG. **1**.

[0022] Optionally, the process of this embodiment may further include a step **62** of continuously injecting air under positive pressure into the chamber **42** after the soap-water in the chamber **42** is substantially exhausted (residual soap-water may remain on the bottom end wall **40** of the cylinder **34**, at a level lower than the locations of all the cooling holes **26** in the airfoil section **18** of the blade **16**). Optionally, inlet **46** may be opened to drain the residual soap-water and empty the chamber **42** before step **62** is conducted. The air flow under pressure continuously injected into the internal passageways **24** of the blade **16**, dries the internal passageways **24** and further removes residual debris therefrom. The process of this embodiment may end at the completion of step **62**, as indicated by link **64**.

[0023] Optionally, the process of this embodiment may further include step **66** of introducing only water into the chamber **42** and then a step **68** of injecting an air flow under pressure into the water within the chamber **42** and then discharging the exhausted water/air mixture from the draining passage **32** of the adapter **30**.

[0024] It should be noted that in steps **66** and **68** all operational details and the resulting water/air mixture in a severe agitation, are similar, as above described with reference to the process shown in FIG. **1** and will not be repeated herein. This secondary water/air mixture resulting from steps **66** and **68** is used to wash any residual soap material from the internal passageways **24** of the blade **16**.

[0025] The apparatus **14** may be optionally attached to an automated pressure flush machine (not shown) to conduct the above-described process. However, the machine is not be part of the pressure flush process described above and is not part of this application.

[0026] The configuration of the adapter **30** and the cylinder **34** as shown in FIG. **2** illustrating the apparatus **14** is exemplary and any other configuration of an apparatus for a similar function to that of apparatus **14** may be used in the pressure flush process described in this application. The cylinder **34** of FIG. **2** is for illustration purposes only and is not intended to represent an accurate size relationship with respect to the size of blade **16**. The size of the cylinder **34** should define the sealable chamber **42** such that the sealable chamber **42** will contain enough water or soap-water for the flush process to substantially remove the debris in the internal passageways **24** of the blade **16**.

[0027] As an alternative embodiment, the pressure differential under which the water/air mixture is injected into the cooling holes, may be achieved by applying a negative (vacuum) pressure on the root opening **28** of the blade **16** or the draining passage **32** of the adapter **30**, while allowing atmospheric air to enter into the vent opening **49**, resulting in an atmospheric pressure on the water/air mixture. The agitation in this embodiment will be achieved when the air/liquid recedes past each cooling hole, therefore drawing in air with the liquid and thus agitating the flow.

[0028] The above description is meant to be exemplary only, and one skilled in the art will recognize that changes may be made to the embodiments described without departure from the scope of the invention disclosed. For example, the water or soap-water used in this process may be replaced by other liquids or solutions and the air may be replaced by any gases when they are desirable. Other devices may be used, such as a manifold with nozzles which may be placed within the chamber and connected to the pressurized air inlet for creating the agitation of the water/air or soap-water/air mixture in the chamber. Although an example of the described pressure flush process is described for removing debris resulting from a manufacturing process, the described process is also applicable for flushing internal passages of cooled turbine blades as part of a maintenance process. Still other modifications which fall within the scope of the present invention will be apparent to those skilled in the art, in light of a review of this disclosure, and such modifications are intended to fall within the appended claims.

1. A pressure flush process for removing debris from internal passageways of a turbine blade, the internal passageways being in fluid communication with a plurality of cooling holes defined in the blade and with a root opening defined in a root section of the blade, the root opening being sized larger than the individual cooling holes, the process comprising:

a) creating an agitated water/air mixture; and

b) injecting the agitated water/air mixture under a positive pressure into at least some of the cooling holes to pass through the internal passageways and discharging the agitated water/air mixture together with removed debris through the root opening.

2. The process as defined in claim **1** further comprising a step, prior to step (a), of preparing respective water and air supplies for the agitated water/air mixture to avoid any solvent and solid particles in the agitated water/air mixture, which cause damage to internal coatings of the internal passageways.

3. The process as defined in claim **1** further comprising supplying water warmer than the ambient temperature for the agitated water/air mixture.

4. The process as defined in claim **1** further comprising supplying water with a soap solution for the agitated water/air mixture used in step (a).

5. The process as defined in claim **4** further comprising step (c) of injecting only air under a positive pressure into said at least some of the cooling holes and discharging same from the root opening to dry the internal passageways and remove residual debris in the internal passageways after step (b).

6. The process as defined in claim **5** further comprising step (d) of injecting a secondary agitated water/air mixture under a positive pressure into the cooling holes and discharging same from the root opening, the secondary agitated water/air mixture including water and air only in order to wash away residual soap from the internal passageways.

7. A pressure flush process for removing indissoluble debris from internal passageways of a blade of a turbine engine, the internal passageways being in fluid communication with a plurality of cooling holes defined in the blade and with a root opening defined in a root section of the blade, the root opening being sized larger than the individual cooling holes, the process comprising:

a) placing the blade in an adapter such that the root section is sealingly received in a cavity of the adapter to allow the root opening to be connected in fluid communication with a draining passage extending through the adapter and allow a remaining part of the blade having at least some of the cooling holes, to project from the adapter;

b) connecting the adapter to a sealable chamber with seals therebetween to allow the projecting part of the blade to be accommodated within the chamber;

c) introducing a selected amount of a soap-water into the chamber, the soap-water including water with a soap solution; and

d) injecting air under a positive pressure into the soap-water in the chamber to cause an agitation of the soap-water/air mixture under the positive pressure within the chamber, and allowing the agitated soap-water/air mixture to inject into the at least some of the cooling holes and further to pass through the internal passageways, and discharging the soap-water/air mixture with debris which has been removed from the internal passageways through the draining passage in the adapter.

8. The process as defined in claim **7** further comprising step (e) of continuously injecting only air under the positive pressure into the chamber after step (d), in order to allow an air flow to pass through the internal passageways to dry said internal passageways and remove residual debris from the internal passageways.

9. The process as defined in claim **8** further comprising step (f) after step (e), of repeating steps (c) and (d) wherein the soap-water used in steps (c) and (d) is replaced with water only in step (f).

10. The process as defined in claim **7** wherein the selected amount of soap-water in step (c) is determined such that the remaining part of the blade projecting from the adapter is entirely submerged in the soap-water.

11. The process as defined in claim **10** wherein the selected amount of soap-water in step (c) is determined such that there is a space between the surface of the soap-water in the chamber and a top end of the chamber.

12. The process as defined in claim 7 wherein the draining passage is closed in step (c).

13. The process as defined in claim 7 wherein the soap-water is warmer than an ambient temperature.

14. The process as defined in claim 7 wherein step (d) is continuously conducted until the surface of the soap-water is at a lower level than all of the cooling holes defined in the remaining part of the blade projecting from the adapter.

15. The process as defined in claim 7 wherein the draining passage is in fluid communication with an ambient pressure when the draining passage is open.

16. A pressure flush process for removing debris from internal passageways of a turbine blade, the internal passageways being in fluid communication with a plurality of cooling holes defined in the blade and with a root opening defined in a root section of the blade, the root opening being sized larger than the individual cooling holes, the process comprising:

a) creating an agitated liquid/gas mixture; and

b) injecting the agitated liquid/gas mixture under a pressure differential into at least some of the cooling holes to pass through the internal passageways and discharging the agitated liquid/gas mixture together with removed debris through the root opening.

17. The process as defined in claim 16 wherein the pressure differential is achieved by applying a positive pressure on the liquid/gas mixture to be injected.

18. The process as defined in claim 16 wherein the pressure differential is achieved by applying an atmospheric pressure on the liquid/gas mixture to be injected, while applying a negative pressure on an outlet of the internal passageways.

19. The process as defined in claim 16 wherein the process is performed on an as-manufactured blade prior to use of the blade in a gas turbine engine.

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