Systems for cooling a heat-treated metallic part include a plurality of atomization nozzles disposed on a stage and radially disposed about the part to be cooled; and a fluid in fluid communication with the atomization nozzles. The fluid may be gas, liquid, or a combination thereof, e.g., water and gas. During use, the atomization nozzles are generally configured to rapidly cool the thicker sections of the part relative to the thinner section since the thicker sections are generally slower to cool. In some embodiments, the stage can be configured to rotate about the part during cooling.
COOLING SYSTEMS FOR HEAT-TREATED PARTS AND METHODS OF USE

BACKGROUND

[0001] The present disclosure generally relates to systems and methods for cooling heat-treated parts, such as metallic work pieces. More particularly, the present disclosure relates to systems and methods for more controlled cooling heat-treated parts of various geometries and thicknesses.

[0002] Certain metallic parts, also known as work pieces, are subjected to severe environmental stresses during use. As an example, certain components of jet aircraft turbines and turbines for power generation, particularly the rotational components, are subjected to extreme centrifugal forces and high thermal stresses during use. Such components also have complex geometries, oftentimes irregular shapes, wherein the thickness varies across the metal component.

[0003] The metal parts, usually formed of nickel and titanium superalloys, are commonly heat-treated to improve the strength and wear characteristics of the part, so that they can better withstand the rotational and thermal stresses experienced during use. The heat-treating process usually begins in a furnace, wherein the temperature is set precisely to control growth of specific strengthening microstructures. The alloy properties such as hardness, strength, toughness, ductility, elasticity, and the like of the parts can be determined by the type of microstructure, grain sizes, the heat-treatment temperature, the rate of cooling, the composition of the cooling medium, and the like.

[0004] After the alloy part is heated and held above a critical temperature for a predetermined duration, the alloy part must then be cooled. A common method of cooling the heat-treated alloy parts is by immersing the part in a fluid bath. This cooling process is commonly referred to as “quenching.” Quenching of alloy work pieces is conventionally achieved by immersing the part in a liquid coolant, such as water or oil. Immersion of the hot part in the liquid coolant rapidly cools the part at a rate that is either sufficient to maintain certain molecular characteristics of the metal that were acquired in the heat-treatment process, or to obtain different molecular characteristics that form during the cooling (quenching) process.

[0005] For heat-treated parts having complex shapes and alloys that are strain-rate sensitive, quenching through immersion in a liquid coolant typically does not provide uniform cooling throughout the part. Heat dissipates quickly from thin portions of the part, while thicker portions retain heat for much longer periods. The difference in cooling rates between the surface of the part and the inner portions of the part can result in the creation of varying material properties, varying grain structures, or, in extreme cases, cracks in the work piece. Air quenching as opposed to liquid immersion quenching has the advantage of producing a slower cooling of the part than achieved with a liquid bath quench. However, conventional air quenching methods have only a limited capability in cooling work pieces, because it is difficult to control the air quenching process aside from varying the length of time the heated part remains in the cooling air stream. As such, current air quenching processes are not as effective in providing uniform cooling rates to parts having complex geometries and varying thickness.

[0006] Thus, uniform cooling of work pieces having complex sizes and shapes is, at best, extremely difficult using current cooling/quenching techniques. As such, there is a need for systems and methods that enable uniform cooling and formation of the desirable metal grain structures in heat-treated parts having complex shapes and sizes, particularly for the rotational parts found in jet engines and turbine generators.

BRIEF SUMMARY

[0007] Disclosed herein are systems for the uniform cooling of a heat-treated alloy part. In one embodiment, the system for cooling a heat-treated metallic part includes a housing configured to hold the heat-treated metallic part; an upper shroud assembly comprising at least one sub-assembly coupled to the housing comprising an annular-shaped body, at least two annular channels disposed within the annular shaped body, a cover attached to the annular shaped body including at least two fluid inlets for receiving a fluid source, and a plurality of atomization nozzles annularly arranged on an outer surface of the annular shaped body comprising outlets oriented to discharge atomized fluid at the metallic part, wherein the at least two fluid inlets are in fluid communication with the atomization nozzles via the at least two annular channel; and a lower shroud assembly comprising at least one sub-assembly coupled to the housing comprising an annular-shaped body, at least two annular channels disposed within the annular shaped body, a cover attached to the annular shaped body including at least two fluid inlets, and a plurality of atomization nozzles annularly arranged on an outer surface of the annular shaped body comprising outlets oriented to cool the metallic part, wherein the at least two fluid inlets are in fluid communication with the atomization nozzles via the at least two annular channels; wherein the at least two inlets in the upper and lower shroud assemblies are in fluid communication with at least one liquid source and at least one gas source such that each one of the plurality of atomization nozzles are in fluid communication with the at least one liquid source and the at least one gas source produce an atomized fluid discharge when in use.

[0008] The disclosure may be understood more readily by reference to the following detailed description of the various features of the disclosure and the examples included therein.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0009] Referring now to the figures wherein the like elements are numbered alike:

[0010] FIG. (“FIG.”) 1 schematically illustrates a turbine disk in accordance with an embodiment of the present disclosure;

[0011] FIG. 2 schematically illustrates a downward perspective view of a cooling system in accordance with the present disclosure, wherein the cooling system utilizes upper and lower shroud assemblies including arrays of atomization nozzles;

[0012] FIG. 3 schematically illustrates a sectional perspective view of the upper and lower shroud assemblies of FIG. 2;

[0013] FIG. 4 illustrates a perspective bottom view of an annular manifold assembly of the upper shroud assembly;

[0014] FIG. 5 illustrates a perspective top view of the annular manifold assembly of the upper shroud assembly of FIG. 4, and
FIG. 6 illustrates a sectional view of the annular manifold assembly of FIG. 5 taken along lines 6-6.

DETAILED DESCRIPTION

Disclosed herein are systems and methods for the rapid and highly controlled cooling of a heat-treated metallic part. The heat-treated metallic part to be cooled can be any metallic material. In some embodiments, the heat-treated part is a high temperature aerospace alloy. Typically, these materials must have adequate performance characteristics for its intended use, such as tensile strength, creep resistance, oxidation resistance, and corrosion resistance, at high temperatures. More particularly, the systems and methods are configured to maintain highly controlled cooling across the surface of the metallic part being heat-treated by tailoring the heat transfer coefficient in specific areas of the part based on the cross-sectional thickness of the part in those locations. The systems and methods disclosed herein can be particularly advantageous in the production of jet engine and gas turbine generator components, such as turbine disks, and the like.

The production of metallic parts, such as turbine components, generally begins with the shaping of a billet, e.g., an alloy billet in the case of turbine components. The alloy billet is forged into the desired shape under heat and pressure. In order for the shaped part to have the desired microstructure and mechanical properties, the shaped part is then heated and held at a predetermined temperature for a predetermined duration. The part is then cooled in a separate step, commonly referred to as quenching. For most applications, uniform cooling of the heat-treated part is desired because it will promote the development of a uniform grain structure within the alloy composition and minimize distortion of the piece. The cooling method described herein rapidly produces the desired microstructure of the material and desired mechanical properties while avoiding physical defects in the part, such as cracking or distortion that may occur in other systems and processes. Advantageously, the cooling process, also referred to herein as a quenching process, provides a substantially uniform and rapid reduction in temperature.

While the cooling systems and methods disclosed herein can be useful for the rapid and controlled cooling of any heat-treated part, the systems and methods are particularly useful for heat-treated metallic parts intended to be used as components in jet turbine engines and generators. The turbine components, such as turbine disks and casings, are typically circular in shape with radial cross-sections having complex geometries and/or varying thickness across the diameter of the part. In one embodiment, the turbine components are axisymmetric. As such, for ease in discussion, further discussion of the cooling systems and methods will be with respect to the controlled cooling of a turbine disk having a complex geometry. However, it is to be understood that the systems and methods described herein are not limited to turbine disks, but are applicable to any heat-treated part where controlled cooling is highly desirable.

Referring to FIG. 1, a cross-sectional view of an exemplary turbine component is a turbine disc 10 that is representative of a heated treated part to be cooled. The illustrated cross-section of the turbine disk 10 has a complex axisymmetric geometric shape, rather than the simple rectangular shape that would be seen in the cross-section of a plain flat disc. Thus, as used herein, the term complex geometric shape is generally defined as a three-dimensional object having varying thicknesses. As shown, the turbine disk 10 is radially symmetrical, i.e., axisymmetric having a radial cross-section that is uniform about the entire circumference of the part. The turbine disk 10 includes an inner annular portion 12, which forms the disk hub. A second portion 14 of the disk 10 exists between the inner annular portion 12 and the outer portion 16, which is located about the circumference of the disk. The thickness of the second portion 14 is substantially greater than that of the inner and outer portions 12, 16. The second portion 14 includes a fin or ridge 18 that protrudes outwardly from the main body of the turbine disk 10. As seen from FIG. 1, the turbine disk 10 varies in thickness across the radius of the disk, and in this embodiment generally comprises about three distinct thicknesses.

In other embodiments of a turbine disk, the disk could include channels or grooves (not shown) cut inwardly into the part, further altering the thickness profile of the disk. These dissimilar portions will exhibit different cooling rates due to the differences in thickness. If the same amount of cooling were applied to the entire disk, the thicker portions would retain heat longer than their thinner counterparts. In other words, the thicker portions, such as defined by the second portion 14 and ridge 18 will retain heat for a longer period and thus take longer to cool than the thinner portions, such as the inner annular portion 12 and the outer portion 16. These thinner portions are capable of dissipating heat more quickly than the thicker second portion 14 and ridge 18. The cooling systems and methods disclosed herein are able to cool such turbine disks at a substantially more uniform rate than that previously known, despite the disk’s complex shape and varying thickness profile. Moreover, relative to other systems and processes, the cooling systems provides a significant reduction in the cooling rate.

Turning now to FIG. 2, there is depicted a downward perspective view of an exemplary cooling system, generally designated by reference numeral 100, in accordance with the present disclosure for substantially uniformly cooling a heat-treated part such as the turbine component 10 shown in FIG. 1. The illustrated cooling system 100 includes a housing generally defined by reference numeral 104 for supporting a shroud assembly generally designated by reference numeral 101, wherein the shroud assembly 101 includes an upper shroud assembly 150 and a lower shroud assembly 200 movably supported by the housing 104. The housing 104 is not limited to any particular shape and generally includes an access opening for inserting and removing a heat-treated part to be cooled with the cooling system 100. The illustrated housing 104 includes a plurality of horizontal 108 and vertical beams 110 to support at least the upper shroud assembly 150 and optionally, the lower shroud assembly 200. The housing 104 further includes upper and lower support brackets 105, 107, respectively, attached to stages 151, 201, respectively, wherein the brackets are movably coupled to guide and actuation rods 106 attached to the housing 104 for vertical positioning of the upper and/or lower shroud assembly during operation. In some embodiments, the guide and actuation rods 106 are coupled to an actuator to effect automated movement, e.g., a hydraulic telescopic rod or the like. The heated part, to be
cooled, e.g., turbine disc 10 shown in FIG. 1, would be seated intermediate the upper and lower shroud assemblies 150, 200, respectively.

[0022] As noted above, the guide and actuation rods 106 are coupled to one or more of the horizontal and/or vertical beams 108, 110 of the housing 104 to vertically position the upper and/or lower shroud assemblies 150, 200 within the housing 104 such that a selected one or both can be selectively positioned about the part to be treated as may be desired for different applications, e.g., the upper shroud assembly can be raised or lowered as desired. In some embodiments, a selected one of the upper shroud assembly 150 or the lower shroud assembly 200 is fixedly coupled to the housing 104 and is not configured to move vertically.

[0023] As shown more clearly in FIG. 3, the upper shroud assembly 150 includes three manifold sub-assemblies 153, 154 and 156, which are generally stackedly arranged. Manifold sub-assembly 153 is positioned uppermost within the shroud assembly 150; manifold sub-assembly 154 is positioned intermediate, and manifold assembly 146 is lowermost-positioned in the stacked arrangement. The manifold sub-assemblies 153, 154 and 156 collectively define an annular dome shape for cooling the upper portion of the part to be treated. With respect to manifold sub-assemblies 154 and 156, the assemblies have diameters effective to accommodate the diameter of a part to be cooled. In contrast, the uppermost manifold sub-assembly 153 is configured to cool the interior regions of part to be treated as will be discussed in greater detail below. Each of the different manifold sub-assemblies 153, 154 and 156 in the upper shroud assembly 150 is coupled to a plate 170, which can be rotatably coupled to or integral to stage 151.

[0024] For ease in understanding as it relates to construction of the upper shroud assembly 150, specific reference will now be made in FIGS. 4-6 to the manifold sub-assembly 154. The manifold sub-assemblies 153 and 156 will generally be constructed in a similar manner based on the description of the upper annular manifold assembly 154 albeit configured to cool different surfaces of the complex geometric part to be treated. It should be apparent based on the disclosure that more or less manifold sub-assemblies could be included to define the lower shroud assembly depending on the shape, size and complexity of the part to be cooled. Each of the sub-assemblies 150, 200, and 230 includes a plurality of atomization nozzles 212, 222, and 232 configured to be concentrically disposed about selected portions of a part to be cooled, wherein each atomization nozzle includes outlets oriented towards the part to be fluidly cooled. The atomization nozzles 162, 172, and 182 for each sub-assembly may be the same or different, and each can be configured to provide a particular spray pattern, e.g., flat, fan, round, or the like, depending on the particular atomization nozzle employed.

[0027] Referring back to FIG. 3, the lower shroud assembly 200 is generally configured to discharge atomized fluid upwards relative to ground along the y and z-axes. The illustrated lower shroud assembly 200 includes three annular sub-assemblies 210, 220, and 230, wherein the three annular sub-assemblies may be coupled together. Again, it should be apparent based on the disclosure that more or less manifold sub-assemblies could be included to define the lower shroud assembly depending on the shape, size and complexity of the part to be cooled. Each of the sub-assemblies 210, 220, and 230 includes a plurality of atomization nozzles 212, 222, and 232 configured to be concentrically disposed about selected portions of a part to be cooled, wherein each atomization nozzle includes outlets oriented towards the part to be fluidly cooled. The atomization nozzles 162, 172, and 182 for each sub-assembly may be the same or different, and each can be configured to provide a particular spray pattern, e.g., flat, fan, round, or the like, depending on the particular atomization nozzle employed. The different manifold sub-assemblies 210, 220, 230 of the lower shroud assembly 200 are each coupled to a plate 270, which can be rotatably coupled to or integral to stage 201. Each manifold lower manifold sub-assembly includes at least two annular fluid channels, similar to that of upper sub-assembly 154 described above.

[0028] The various atomization nozzles in the upper and lower shroud assemblies 150, 200 are configured to atomize and project a fine spray of droplets onto the heat-treated part to be cooled in a pattern that provides uniform cooling of the heat treated part regardless of thickness variation. The droplet spray pattern can be configured to be substantially repeatable. The number and spacing between adjacent nozzles is not intended to be limited and may be optimized for the intended application. For example, the atomization nozzles may be axisymmetrically disposed radially about the annular array at equal distances or in some embodiments, the spacing between adjacent atomization nozzles may or may not be equal.

[0029] In the depicted embodiments, the atomization nozzles disposed in the upper and lower shroud assemblies 150, 200 are generally configured to be spaced apart from the surfaces defining the complex geometric part to be cooled at a distance from about 1 to about 24 inches, which may be oriented to spray an atomized fluid onto the heat treated part at an angle that is not normal to the surface. In
other embodiments, some or all of the atomization nozzles may spray at an angle that is normal to the surface of the heat-treated part to be cooled. Each array of atomization nozzles within the upper and lower shroud assembly 150 or 200 can be in a circular pattern that can be axisymmetric around the heat-treated part and oriented to spray inwardly towards the heat-treated part to be cooled. The atomization nozzles are in fluid communication with one or more fluid sources (not shown), which are not intended to be limited. Generally, the fluid sources include at least one gas and at least one liquid. A regulator (not shown) can be employed to control fluid flow for each array. Using air and water as exemplary fluid sources, a system using the atomization nozzles can be configured to selectively spray a fine mist of water in the form of fine droplets upon the surfaces of the part to be treated, wherein the water is gravity fed, lifted via a Venturi effect as is generally well known in the art, or fed via pressurized accumulators or a similar system to achieve required pressures. Air pressures are controlled from greater than 0 to 300 pounds per square inch (psi) and water pressure is controlled from greater than 0 to 300 psi. The fluid can be externally mixed as a mixture or within conduits (i.e., upstream of the nozzle) or internally mixed within the atomization nozzle. In this manner, each part surface that requires a different cooling rate can be sprayed with a set of atomization nozzles whose fluid pressures, e.g., water and air pressure, are tailored to achieve that surface’s cooling rate such that the cooling rates are substantially uniform for the different thicknesses. The fluid pressures may be adjusted via the regulator during cooling to adjust a surface’s cooling rate as may be desired to provide the intended metallurgical properties. The fluid sources may be contained within vessels (not shown) fluidly connected to the fluid inlets, e.g., 166,168 using a conduit (not shown) or via a manifold (not shown).

[0030] Using fluid sources that include at least one gas and at least one liquid is beneficial relative to gas-only or liquid-only cooling. Gas only provides convective cooling that limits the minimal spacing between nozzles to permit egress of the gas after contact with the part surface. With regard to liquid-only quenching systems, liquids are non-compressible and thus functions hydraulically, which limits it practicality. By use of gas-liquid atomization, more effective cooling has been realized in terms of uniformity and efficiency. In one embodiment, an air and water mixture is atomized within the atomization nozzles and sprayed onto the part to be cooled. In one embodiment, the water (or liquid) is fed to the atomization nozzles via a pump, compressed gas, or the like. To minimize pulsing flow such as may occur with the use of pumps that hydraulically deliver the liquid to the atomization nozzles, the liquid can be pressurized using a gas, i.e., gas over liquid delivery, to provide a more constant fluid flow to the atomization nozzles.

[0031] A part holder (not shown) such as a cantilevered beam, support surface, or the like can be employed in the housing 104 to support the part during cooling. The cantilevered beam or like support can be fixedly attached to the housing or may be separate therefrom. The part holder is generally configured to permit maximum impact of an atomized air-water mixture onto the heat-treated part to be cooled, the mechanics of which be discussed in greater detail below.

[0032] Optionally, a selected one or both of the plates 170, 270 (see FIG. 3), upon which the upper and lower shroud assemblies 150, 200, respectively, are coupled thereto, are rotatably seated in the stage 151, 201, respectively. In this manner, the one or more shroud assemblies 150 and 200 including the arrays of atomization nozzles in each respective subassembly can be configured to oscillate or rotate in a horizontal plane while the heat-treated part is stationary such as by an actuator, e.g., a hydraulic linear actuator, motorized crank or the like to further increase cooling uniformity. That is, during cooling the array of atomization nozzles horizontally rotates about the axis of a stationary heat-treated part to be cooled. The actuator is not intended to be limited and may be mechanical, hydraulic, pneumatic, piezoelectric, electromechanical or any other actuation system intended to oscillate and/or rotate the shroud assemblies relative to the stationary part. It is advantageous to maintain the heat-treated part in a stationary position as to make it less likely for the part to fall and become damaged. Moreover, increased cooling uniformity is provided especially in the situation where one or more nozzles may have failed. The shrouds can independently be configured to rotate or oscillate about its axis during the cooling process. Again, it should be apparent that the rate of oscillation may be unique for each forging.

[0033] Optionally, the atomization nozzles can be configured to vertically oscillate during the cooling process. In this optional embodiment, the plurality of atomization nozzles can be selected to vertically oscillate or alternatively, the shrouds 150 or 200 upon which the atomization nozzles are disposed, can configured to move in a horizontal direction during the cooling process. Thus, oscillation relative to a stationary heat treated part to be cooled can be effected in the horizontal direction, the vertical direction, or both the horizontal and vertical directions as may be desired for some applications.

[0034] In operation of the exemplary cooling system 100, a heated-treated part 10 at an elevated temperature is removed from a furnace and inserted into the cooling system. One or both shroud assemblies 150, 200 are first vertically positioned to accommodate insertion of the heat-treated part and repositioned such that the upper and lower shroud assemblies 150 and 200 and arrays of atomization nozzles thereon are concentrically disposed about the heat-treated part. The heated part may be seated on a cantilevered beam (not shown) or the like. A fluid mixture of gas and liquid, e.g., air and water, is then fed to the atomization nozzles, wherein the pressures of the air and water are effective to atomize the water so as to provide fine droplets to about the surface of the heat-treated part, thereby, in the case of an air/water mixture, generating mist. The liquid component of the atomization fluid can be the primary coolant for the cooling system. The spray is continued until a desired temperature is reached, e.g., ambient temperature. In some embodiments, the temperatures of the air and/or water can vary prior to discharge from the atomization nozzles.

[0035] The period of time required to cool the forging (i.e., heat-treated part) will generally depend upon the cross-sectional area of the forging. The cooling rate may be constant throughout the cooling process or ramped by adjusting the fluid pressures to the nozzles and/or by selection of the atomization nozzles.
The terms “first,” “second,” and the like, herein do not denote any order, quantity, or importance, but rather are used to distinguish one element from another. The terms “a” and “an” herein do not denote a limitation of quantity, but rather denote the presence of at least one of the referenced item.

While the invention has been described with reference to various exemplary embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

What is claimed is:

1. A system for cooling a heat-treated metallic part, comprising:
   a housing configured to hold the heat-treated metallic part;
   an upper shroud assembly comprising at least one subassembly coupled to the housing comprising an annular-shaped body, at least two annular channels disposed within the annular shaped body, a cover attached to the annular shaped body including at least two fluid inlets for receiving a fluid source, and a plurality of atomization nozzles annularly arranged on an outer surface of the annular shaped body comprising outlets oriented to discharge atomized fluid at the metallic part, wherein the at least two fluid inlets are in fluid communication with the atomization nozzles via the at least two annular channels; and
   a lower shroud assembly comprising at least one subassembly coupled to the housing comprising an annular-shaped body, at least two annular channels disposed within the annular shaped body, a cover attached to the annular shaped body including at least two fluid inlets, and a plurality of atomization nozzles annularly arranged on an outer surface of the annular shaped body comprising outlets oriented to cool the metallic part, wherein the at least two fluid inlets are in fluid communication with the atomization nozzles via the at least two annular channels;
   wherein the at least two inlets in the upper and lower shroud assemblies are in fluid communication with at least one liquid source and at least one gas source such that each one of the plurality of atomization nozzles are in fluid communication with the at least one liquid source and the at least one gas source produce an atomized fluid discharge when in use.

2. The system of claim 1, wherein the heat-treated metallic part is substantially circular in shape with radial cross-sections having complex geometries and varying thickness across a diameter of the part.

3. The system of claim 1, wherein the at least one subassembly of the upper shroud comprises a first subassembly, wherein the outlets of the plurality of atomization nozzles are oriented to discharge the discharge atomized fluid along a y-axis; and a second subassembly, wherein the outlets of the plurality of atomization nozzles are oriented to discharge the discharge atomized fluid along an a-axis, wherein the y-, z-, and x-axes are relative to ground, and wherein the annular shaped body of the first subassembly has a smaller diameter than a diameter of the annular shaped body of the second subassembly, and the second subassembly diameter is smaller than a diameter of the annular shaped body of the third subassembly; and
   wherein the at least one subassembly of the lower shroud comprises a first subassembly, wherein the outlets of the plurality of atomization nozzles are oriented to discharge the discharge atomized fluid along a y-axis; and at least one second subassembly, wherein the outlets of the plurality of atomization nozzles are oriented to discharge the discharge atomized fluid along a z-axis, wherein the y- and z-axes are relative to ground, and wherein the annular shaped body of the first subassembly has a smaller diameter than a diameter of the annular shaped body of the second subassembly, and the second subassembly diameter is smaller than a diameter of the annular shaped body of the third subassembly.

4. The system of claim 1, wherein the at least one subassembly of the upper shroud comprises a first subassembly, wherein the outlets of the plurality of atomization nozzles are oriented to discharge the discharge atomized fluid along a y-axis; a second subassembly, wherein the outlets of the plurality of atomization nozzles are oriented to discharge the discharge atomized fluid along a x-axis, and a third subassembly, wherein the outlets of the plurality of atomization nozzles are oriented to discharge the discharge atomized fluid along an x-axis, wherein the y-, z-, and x-axes are relative to ground, and wherein the annular shaped body of the first subassembly has a smaller diameter than a diameter of the annular shaped body of the second subassembly, and the second subassembly diameter is smaller than a diameter of the annular shaped body of the third subassembly.

5. The system of claim 1, wherein the at least one subassembly of the lower shroud comprises a first subassembly, wherein the outlets of the plurality of atomization nozzles are oriented to discharge the discharge atomized fluid along a y-axis; and at least one second subassembly, wherein the outlets of the plurality of atomization nozzles are oriented to discharge the discharge atomized fluid along a z-axis, wherein the y- and z-axes are relative to ground, and wherein the annular shaped body of the first subassembly has a smaller diameter than a diameter of the annular shaped body of the second subassembly, and the second subassembly diameter is smaller than a diameter of the annular shaped body of the third subassembly.

6. The system of claim 1, wherein the heat-treated metallic part is axisymmetric.

7. The system of claim 1, wherein the at least one gas source is air and the at least one liquid source is water.

8. The system of claim 7, wherein the plurality of atomization nozzles are configured to provide atomization external to the nozzle.

9. The system of claim 7, wherein the plurality of atomization nozzles are configured to provide atomization within the nozzle.

10. The system of claim 7, wherein the plurality of atomization nozzles are configured to provide atomization upstream of the atomization nozzle.

11. The system of claim 7, wherein the air is at a pressure of greater than 0 to 300 pounds per square inch (psi) and the water is at a pressure of greater than 0 to 300 psi.
12. The system of claim 7, wherein the water is pressurized in a vessel by a gas and is in fluid communication with the atomization nozzles.

13. The system of claim 1, wherein a selected one or both of the upper and lower shroud assemblies are independently coupled to a plate rotatable in a horizontal direction relative to ground during operation, wherein the heat-treated part is stationary.

14. The system of claim 1, wherein the plurality of atomization nozzles are configured to vertically oscillate relative to ground during operation.

15. The system of claim 12, wherein the plurality of atomization nozzles are further configured to vertically oscillate in the vertical direction relative to ground.

16. The system of claim 1, wherein the at least one shroud assembly is configured to be vertically adjustable relative to ground.

17. The system of claim 1, wherein the plurality of atomization nozzles are radially disposed about the heat treated part at equal distances.

18. The system of claim 1, wherein the plurality of atomization nozzles are at a distance of about 1 to about 24 inches from the heated-treated part during operation.

19. The system of claim 1, wherein the plurality of atomization nozzles are configured to rapidly cool a thicker section of the heat-treated part relative to a thinner section.

20. The system of claim 1, wherein the upper shroud assembly and/or the lower shroud assembly are movably coupled to the housing.

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