Self-heated tools for the production of composite parts are described. The tools include a tool body which, at least in part, includes carbon foam materials that are electrically conductive or permeable to the passage of fluids. These materials can be both electrically conductive and permeable to the passage of fluids. The electrically conductive or fluid permeable carbon foam materials are an intrinsic part of the construction of these tool bodies and are not add-on devices. Electricity may be used to heat the electrically conductive carbon foam material and transfer heat to the tool face. In other embodiments, heated fluid may be passed through and used to heat the fluid permeable carbon foam material and transfer heat to tool body. The electrically conductive or permeable carbon foam materials may define the tool face of the tool body. The tool bodies may comprise carbon foam, which is both electrically conductive and permeable. The electrically conductive carbon foam material and the fluid permeable carbon foam material may be constructed and/or configured to apply relatively uniform heating across the surface of the tool face or in certain circumstances non-uniform heating across the surface of the tool face.
TOOL BODIES HAVING HEATED TOOL FACES

CROSS-REFERENCE TO RELATED APPLICATIONS


FIELD OF INVENTION

[0002] This invention relates to composite tooling and methods for using the same, more specifically to a reusable tool body that can be heated to effect a curing of the composite forming materials shaped by the tool.

SUMMARY OF THE INVENTION

[0003] The invention may include a tool comprising a tool body defining a tool face and comprising an electrically conductive carbon foam material. Electrical connections may be connected to one portion of the electrically conductive carbon foam material and a second portion of the electrically conductive carbon foam material. A power source may be connected to the electrically conductive carbon foam material through the electrical connections to produce a current flow resulting in the heating of the electrically conductive carbon foam material. In some embodiments, the tool body may be entirely or partially made from the electrically conductive carbon foam material. In some embodiments, the electrically conductive carbon foam material may provide substantially even heating of the surface of the tool face. In certain embodiments, the tool face may include a tool face material. In other embodiments, a thermostat may be placed in communication with the tool face and the power source, where the thermostat monitors the temperature of the tool face and adjusts the power of the power source.

[0004] In yet another embodiment, the invention may include a tool comprising a tool body defining a tool face and comprising a fluid permeable carbon foam material. A fluid inlet port may be connected to one portion of the fluid permeable carbon foam material. Heated fluid is passed through the fluid permeable carbon foam material to result in heating of the fluid permeable carbon foam material. In some embodiments, the fluid permeable carbon foam material may provide substantially even heating of the surface of the tool face when heated fluid is passed through the fluid permeable carbon foam. Further, a surface of the fluid permeable carbon foam material may optionally define the tool face. In certain embodiments, the tool face may comprise a tool face material. In yet further embodiments the tool may also include a fluid exhaust port connected to the second portion of the permeable material. Further, the invention may include a pump adapted to be in fluid communication with the fluid inlet port. Still further, the invention may include a pump adapted to be in fluid communication with a fluid inlet port and a heated fluid supply in fluid communication with the pump, where the pump moves fluid from the heated fluid supply to the fluid inlet port. The fluid supply may be a reservoir and the fluid exhaust port may be connected to the reservoir to return the fluid from the fluid permeable carbon foam material. Still further, the tool may include a thermostat in communication with the tool face and the heated fluid supply, where the thermostat monitors the temperature of the tool face and adjusts the temperature of the heated fluid supply.

[0005] In yet another embodiment, the invention may include a tool comprising a tool body defining a tool face, where the tool face is substantially uniformly heated by the tool body. The tool body may comprise an electrically conductive carbon foam material. The electrically conductive carbon foam material may provide substantially uniform heating across the tool face when current is applied to the electrically conductive carbon foam material. Further, tool body may comprise a fluid permeable carbon foam material. The fluid permeable carbon foam material may provide a substantially uniform heating of the tool face when a heated fluid is passed through the fluid permeable carbon foam material.

BRIEF DESCRIPTION OF THE FIGURES

[0006] FIG. 1 is an illustration of a self-heated tool in accordance with an embodiment of the invention.

[0007] FIG. 2 is an illustration of a self-heated tool in accordance with another embodiment of the invention.

DESCRIPTION OF THE INVENTION

[0008] Generally, composite materials are prepared by imbedding a reinforcing material within a matrix material. Composite materials having high degrees of utility typically exhibit mechanical, or other, properties superior to those of the individual materials from which the composite was formed. A common example of a composite material is fiberglass. fiberglass is produced by infusing glass fibers, which are the reinforcing material, with a resin, which constitutes the matrix material. Reinforcing materials known in the art have included, but are not limited to, for example, fiberglass, carbon fibers, quartz fibers, ceramic fibers, Kevlar® fibers, Aramid® fibers, and particulates of glass, ceramic, carbides, carbon, and the like. Matrix materials known in the art have also included, but are not limited to, thermoset and thermosetsetting resins, including phenolics and epoxies, and the like. Such matrix materials will be collectively referred to as resins.

[0009] Composite materials have been found to have a high degree of utility when used as parts of structures, components, sub-assemblies, and the like, herein after collectively referred to as parts, or assemblages such as, for example, aircraft, missiles, vehicles, medical equipment, and sporting goods. The utility of such composites is typically related to their high strength-to-weight ratio and their fatigue and corrosion resistance. In many instances, these beneficial properties exceed those of the metals or other materials supplanted by the use of the composites.

[0010] Composites materials are typically formed to required dimensions by the use of mold-like devices commonly referred to as tools. These tools encompass one or more surfaces, referred to as tool-faces, upon which the composite is formed, shaped, molded, or otherwise produced into parts of predetermined sizes and shapes. Such parts can include structures, sub-assemblies, and the like. The tool face is a surface, typically formed such that the shape of its surface produces the predetermined size and shape of the desired composite part.

[0011] In addition to the tool face, a tool is also includes a tool body and may include a support structure. The tool body defines, includes, or otherwise comprises, the tool face.
That is, the tool face, upon which the composite is formed, may be a surface of the tool body. The support structure is connected to the tool body and may serve a number of purposes, including but not limited to, such purposes as support, orientation, and transportation of the tool body and tool face along with protection of the tool body and face from damage.

In forming the composite part, mixed matrix material and reinforcing material are placed upon the tool face by any of a number of procedures known to those skilled in the art, and brought into essentially intimate contact with the tool face. The dimensions of the tool face are such that this contact effectively molds a surface of the resin and reinforcing material mixture into the desired shape and dimensions. The reinforcing material containing matrix material, for example carbon fibers in a resin, is subsequently cured, typically by the application of heat, to yield a solid composite part having the shape and dimensions imparted by the tool face.

The application of heat is typically required to cure the composite forming materials to result in a composite part and is a result of the chemical nature of many matrix materials. For example, many resins, such as thermosetting resins, require the application of heat to effect the chemical reactions that convert the fluid or semi-fluid resin to a solid polymeric material. Other matrix materials, such as epoxies, may convert from a fluid or semi-fluid material to a solid polymeric material over an extended period of time without the application of heat. However, such materials will generally solidify in a much shorter time period, and may have higher glass transition temperatures, if heated. Greater rates of matrix material solidification can result in more rapid and increased part production. This benefit may then result in greater tool utilization with corresponding reductions in part production costs. Greater tool utilization can also be achieved by partially curing the composite forming materials in the tool, followed by complete curing of the resulting partially cured composite outside of the tool.

Heating of the composite forming materials has previously been accomplished by placing the tool with an autoclave, oven, or similar heating device. Such oven-like devices can be very large, and correspondingly expensive, as some tools may be of considerable size. Also, large oven-like heating devices may be required as multiple tools, all requiring the use of an oven-like heating device, may be in use simultaneously. It may also be possible that simultaneous use of multiple tools may require that the composite formed on each tool be heated at a different temperature. Such a situation would then require the use of multiple ovens. Therefore, due to the scale involved, oven-like heating devices can be expensive and thus contribute to increased composite part cost. Additionally, the use of such oven-like heating devices typically requires the transport of the tool with the composite forming materials in place. Such transport may not be desirable as it may possibly have a detrimental effect on the quality of the resultant composite part.

Other tools have been previously designed that can heat cure tool-formed composite forming materials without the use of oven-like devices. These tools have been designed where heating devices, such as heating tapes, steam tracing, heating elements, and the like, have been incorporated into or on the tool body to result in a heating of the tool. In operation, the heating devices would be activated once the composite forming material had been adequately positioned and shaped on the tool face. The activation of the heating devices would then heat the tool body, tool face, and the shaped composite forming materials on the tool face. Such heating would then cure, or accelerate the curing of, the composite forming materials without the use of an autoclave, oven, or similar heating device. The incorporation of such heating devices into the tools can add complexity to the tool body and increase tool cost. Additionally, the heat applied by these methods is typically localized to the general area of the heating devices. Therefore it can be difficult to uniformly heat a tool face by use of these methods. Therefore, as a result of the previously described limitations, improved methods for the heating of composite forming materials on a tool face are desired.

The tools of the present invention have a tool face that can be heated by the application of an electrical current or heating fluid to the tool body. These self-heating tools differ from previous tools as the heating of the tool faces of the tools of the present invention do not require the addition of specific heating devices, such an oven, heating tape, resistance heaters, steam tracing, and the like. The capability of the self-heating tools of the present invention to be heated is derived from the materials of construction of the tools rather than from the addition of some additional heating device. In particular, the present invention uses electrically conductive or fluid permeable carbon foam material in the construction of the tool. The heating of the tools of the present invention can result in the partial or total curing of a composite part formed thereon.

The tools of the present invention may be comprised, at least in part, from carbon foam materials that are electrically conductive or permeable to the passage of fluids. These carbon foam materials can be both electrically conductive and permeable to the passage of fluids. The carbon foam materials are an intrinsic part of the construction of these tool bodies and are not add-on devices. By intrinsic part it is meant that the body of a tool of the present invention would not be substantive without the inclusion of such electrically conductive or permeable carbon foam materials.

Carbon foam is typically a strong, electrically conductive, open-cell, durable, stable, easily machined, resin-bondable, and relatively unreactive lightweight material. Carbon foams can also exhibit very low coefficients of thermal expansion (CTE) which can be essentially equivalent to that of carbon fiber composites. Such CTE equivalency makes the carbon foam especially useful for incorporation into tool bodies for the production of carbon fiber composites. The CTE of carbon foam can be modified by control of the maximum temperature to which the carbon foam is exposed during preparation. Likewise, the electrical conductivity of carbon foam can be modified by control of the maximum temperature to which the carbon foam is exposed during preparation. Also, it is believed that the electrical conductivity of carbon foam can be modified by adding various materials, such as non-electrically conductive particulates, such as glass or sand, to the carbon foam forming materials prior to foam formation to reduce the electrical conductivity of the resultant foam. Alternatively, the electrical conductivity of carbon foam may be modified
by adding various materials, such as electrically conductive particulates, such as metal particles, to the carbon foam forming materials prior to foam formation to increase the electrical conductivity of the resultant foam.

[0019] Carbon foams are materials of very high carbon content that have appreciable void volume. In appearance, excepting color, carbon foams can resemble readily available commercial plastic foams. As with plastic foams, the void volume of carbon foams is located within numerous empty cells. The boundaries of these cells are defined by the carbon structure. These cells typically approximate spheres or ovoids of regular, but not necessarily uniform, size, shape, distribution, and orientation. The void volumes in these cells typically connect directly to neighboring void volumes. Such an arrangement is referred to as an open-cell foam. The carbon in these foams forms a structure that is continuous in three dimensions across the material. Typically, the cells in carbon foams are of a size that is readily visible to the unaided human eye. Also, the void volume of carbon foams is such that it typically occupies much greater than one-half of the carbon foam volume. The regular size, shape, distribution, and orientation of the cells within carbon foam readily distinguishes this material from other materials such as metallurgical coke. Carbon foams have been prepared from a variety of feedstocks using a variety of processes. For example, feedstocks for carbon foam production have included, but are not limited to, pitches, coals, and coal derivatives. Likewise, processes for the production of carbon foams from each of these feedstocks have been identified. Most of these processes include exposure of the carbon foam to an elevated temperature, sometimes a great as about 3000°C., after preparation of the foam.

[0020] Carbon foam can be incorporated in the tools of the present invention such that a surface of the carbon defines a tool face. The carbon foam defining the tool face can be filled with a cell-filling material such as a resin or pitch to result in a sealed or otherwise impermeable surface. Other outer surfaces of the carbon foam can also be sealed in a similar manner. The other outer surfaces of the carbon foam can also be sealed by lamination so that the material remains integral to the carbon surface. Alternatively, a surface of the carbon foam can support another material, a tool-face material, which then defines the tool face.

[0021] With reference now to FIG. 1, there is shown a self-heating tool in accordance with an embodiment of the invention and designated generally by the reference numeral 10. The self-heating tool 10 includes a tool body 12 having a tool face 14. The tool body 12 comprises an electrically conductive carbon foam material 16. Preferably, the electrically resistive of the electrically conductive carbon foam material 16 is such that excessive electrical power is not required for heating. The self-heating tool 10 is constructed such that passage of an electrical current through the electrically conductive carbon foam material 16 heats the tool face 14 of the tool body 12. An electrical power source 18 is connected to the electrically conductive carbon foam material 16 through electrical connections 18a and 18b. Multiple electrical connections may be used. These connections can include any connector that provides for the transfer of electrical current from the power source to the electrically conductive carbon foam material. Such connectors may include, but are not limited to, wires, cables, combinations of wire and cables, commonly known terminal connectors, bus bars, and other similar connectors. Such connections may be located advantageously to produce the desired electrical current flow through the electrically conductive carbon foam material. As electrical current passes through the electrically conductive carbon foam material 16, heat is generated and transferred to the tool face 14. The heating of the tool face 14 then results in a heat transfer to, and a heating of, the composite forming materials on the tool face.

[0022] Preferably, the electrically conductive carbon foam material is distributed in the tool body such that it uniformly heats the entire tool face 12. In certain embodiments the electrically conductive carbon foam material should be distributed and arranged such that heat being transferred to the tool face results in substantially even curing or heating of the composite forming materials on the tool face. The configuration of the electrically conductive carbon foam material can vary widely depending upon such factors as the size, shape, and thickness of the resulting composite part. Thicker areas of the composite part may require the application of greater heat in that area of the tool face as compared to other areas of the tool face in order for all areas of the part to effectively cure at the same temperature and rate. In some embodiments, the wattage density across the tool face is relatively equal. Further, in some instances a relatively uniform wattage density may be obtained by providing a relatively uniform current density across the tool face. Additionally, a relatively uniform wattage density across the tool face may be obtained by applying electrical currents of differing magnitudes to volumes of carbon foam having differing resistances.

[0023] One or more thermostats 20 may be used to monitor and control the temperature of the tool face 12 by monitoring the temperature of the tool face 12 and adjusting the electrical power applied to the electrically conductive carbon foam material 16. The electrically conductive carbon foam material 16 may define the tool face 14. That is, a surface of the electrically conductive carbon foam material 16 of the tool body 12 may comprise the tool face 14. Alternatively, the electrically conductive carbon foam material 16 may support another material which defines the tool face 14.

[0024] The tool body 12 may be composed of an electrically conductive carbon foam material 16 in the form of a sheet, plate, block, or layer deposited on a support material 17. The carbon foam may consist of a piece of carbon foam that are bonded together with conductive or nonconductive resins or high temperature adhesives such that the desired electrically conductive pathways are present. Preferably, the electrical resistance of the material is such that excessive electrical power is not required for heating. This conductive material may be shaped or formed to define a tool face 14. Alternatively, this material may support a relatively thin layer of another material, a tool face material, which defines the tool face 14. In either configuration, the electrically conductive carbon foam material 16 comprises or underlies the entire tool face. Preferably, this electrically conductive carbon foam material 16 will produce uniform heating of the entire tool face 14.

[0025] For non-planer tool faces, such uniform heating may be provided by varying the conductive material thickness across the tool face such that the electrical current density is uniform across the tool face. Thermostats 20 may
be used to monitor and control the heating of the electrically conductive carbon foam material 16.

[0026] In use, a mixture of composite forming materials is positioned, as desired, on the tool face 14. Electrical connections 18a and 18b are made to the electrically conductive carbon foam material 16, from an electrical power source 18, such that an electrical current flows through the electrically conductive carbon foam material and across the tool face. Heat generated in this electrically conductive carbon foam material 16 transfers across any tool face material and to the composite forming materials. This transferred heat increases the temperature of the composite forming materials such that a cured composite is formed. During this process, temperature may be monitored and controlled by the thermostat 20 such that over-heating of the composite and/or composite forming materials does not occur.

[0027] Turning now to FIG. 2, there is shown another embodiment of a self-heating tool and designated generally by the reference numeral 100. The self-heating tool 100 includes a tool body 120 having a tool face 140. The tool body 120 comprises a fluid permeable carbon foam material 160. Preferably, the fluid permeable carbon foam material 160 is positioned in the tool body 120 such that the entire tool face 140 is uniformly heated. The fluid permeable carbon foam material 160 of the present invention may define the tool face 140. That is, a surface of the fluid permeable carbon foam material 160 of the tool body 120 may comprise the tool face 140. Alternatively, the fluid permeable carbon foam material 160 may support another material which defines the tool face 140.

[0028] The self-heating tool 100 is constructed such that passage of a heated fluid or gas through the fluid permeable carbon foam material 160 heats the tool face 140 of the tool body 120. A pump 180 may supply hot or heated fluid or gases from a heated fluid supply 200 to the tool body 120 through a fluid inlet port 220 connected to one portion of the fluid permeable carbon foam material 160. The heated fluid supply 200 may include heaters 210 for heating the fluid. A fluid exhaust port 240 is connected to a second portion of the fluid permeable carbon foam material 160 and allows for the fluid or gas to exit the permeable material 160. In certain embodiments, the fluid inlet port 220 and fluid exhaust port 240 are connected to the fluid permeable carbon foam material 160 such that the hot or heated fluid or gases pass through the fluid permeable carbon foam material 160 of the tool body 120 to result in heating of the tool face 140. Multiple fluid inlet ports and outlet ports may be used. In some embodiments the fluid exhaust port 240 returns the fluid to the heated fluid supply 200 for reheating. Edges and surfaces of the fluid permeable carbon foam material 160 are preferably sealed such that the fluid is not admitted or discharged except through the ports 220 and 240. Such sealing may be accomplished by coating the surfaces with materials that eliminate the surface porosity of the fluid permeable carbon foam material. Such materials can include, but are not limited to, cured resins and the like. One or more thermostats 260 may be used to monitor and control the temperature of the tool face 140 by communicating with heaters 210 to adjust the temperature of the fluid. Heated fluids may include, but are not limited to, gases and/or liquids such as steam and heated gases, including air and/or process exhausts, and liquids, including water and/or oil.

[0029] The tool body 120 may be composed of a fluid permeable carbon foam material 160 in the form of a plate or block. The carbon foam may consist of pieces of carbon foam that are bonded together with resins or high temperature adhesives such that the desired fluid transport pathways are present. A surface of the fluid permeable carbon foam material 160 may be shaped or formed to define a tool face 140. Alternatively, this material may support a relatively thin layer of another material, a tool face material, which defines the tool face. In either configuration, the permeable material 160 comprises or underlies the entire tool face 140. Opposite sides or edges of the fluid permeable carbon foam material may be equipped with fluid inlet and exhaust ports.

[0030] Preferably, the flow of heated fluid through the fluid permeable carbon foam material will produce uniform heating of the entire tool face. For non-planer tool faces, such uniform heating may be provided by varying the flow pressure drop in the permeable material across specific areas of the tool face such that heated fluid flow is uniform across the tool face. The fluid flow pressure drop in the permeable material will vary with the permeable material thickness. Thermostats may be used to monitor and control the heating/temperature of the tool face and/or fluid.

[0031] In use, a mixture of composite forming materials is positioned, as desired, on the tool face 140. The tool face 140 may include a surface of a relatively thin carbon fiber composite, in this example a tool face material, supported by a permeable material 160 made from a carbon foam block. Connections are made to the fluid inlet 220 and exhaust ports 240 positioned on the carbon foam block such that a heated fluid flows through the carbon foam block and thus across the carbon foam block volume underlying the tool face. The heated fluid is supplied from a source of heated fluid such as, but not limited to, a reservoir, process stream, or the like. The heated fluid may be forced through the carbon foam block by use of a pump, gravity, or the like. Holes may have been previously formed in the carbon foam block to lower the fluid flow pressure drop. The heat contained in the heated fluid transfers across the tool face material and to the composite forming materials. This transferred heat increases the temperature of the composite forming materials such that a cured composite is formed. During this process, the temperature of the heated fluid is monitored and controlled such that over-heating of the composite and/or composite forming materials does not occur.

[0032] Tooling may be used to fabricate composite parts of various types, shapes, sizes and materials with a high dimensional accuracy. The design of the tooling typically is dependant on the desired shape of the composite part to be formed, the materials used to form the composite part, the amount of strength and rigidity which the tooling must have.
to support the materials necessary for forming the composite part, and/or the method used to provide the materials for forming the composite part.

[0033] In practice, materials comprising the composite are placed upon the tool face by any of a number of procedures known to those skilled in the art. Typically the composites utilize a resin(s) as the matrix material and fiber as the reinforcing material. But, a resin(s) and a particulate(s) can also be used, respectively, as the matrix and reinforcing material. Sometimes fiber placement is closely controlled such that the resulting composite part exhibits a preferred fiber spacing and/or orientation. The fiber and resin may be mixed or otherwise combined prior to placement on the tool face. Alternatively, the fiber may be placed on the tool face and the resin subsequently infused into the fiber by any of a number of procedures. In some instances, prior to the placement of materials which comprise the composite, the tool face may be covered with a thin sheet of material, sometimes referred to as a parting sheet or release film, which forms closely to the tool face. Such sheets can be considered to be a temporary coating on the tool face. The surface of this sheet that is not in contact with the tool face, that is, the outside surface of the sheet, then effectively becomes the tool face. Such sheets may be used to protect the tool face and/or to provide for easier removal, or release, of the formed composite part. Alternatively, the materials comprising the composite may be prevented from bonding to the tool face by coating the tool face with a release agent. Release agents can include various polymers, including PVA, and waxes, among other materials. Release films are composed of any of a number of polymeric materials that do not bond with any of the materials comprising the composite. Many types of release materials, compounds, and agents are known in the associated arts and may be used with the present invention.

[0034] The dimensions of the tool face are such that a surface of the materials comprising the composite, typically a fiber containing resin, is effectively molded into the desired shape and dimensions. The resin(s) included in the materials comprising the composite is subsequently cured, typically by the application of heat, to yield a solid composite part having a surface of the shape and dimensions imparted by the tool face.

[0035] The above description is not to be considered limiting in any way and is only illustrative of certain embodiments of the invention. The present invention may be varied in many ways without departing from the scope of the invention and is only limited by the following claims.

What is claimed is:

1. A tool comprising:
a tool body defining a tool face and comprising an electrically conductive carbon foam material; and

electrical connections connected to one portion of the electrically conductive carbon foam material and a second portion of the electrically conductive carbon foam material.

2. The tool of claim 1, further comprising a power source adapted to be connected to the electrical connections.

3. The tool of claim 1, wherein the electrically conductive carbon foam material provides substantially even heating of the tool face when current flow through the carbon foam is produced by the power source.

4. The tool of claim 1, wherein a surface of the electrically conductive carbon foam material defines the tool face.

5. The tool of claim 1, wherein the tool body consists essentially of carbon foam.

6. The tool of claim 1, wherein the tool face comprises a tool face material.

7. The tool of claim 1, further comprising a thermostat in communication with the tool face and the power source, wherein the thermostat monitors the temperature of the tool face and adjusts the power of the power source.

8. A tool comprising:
a tool body defining a tool face and comprising a fluid permeable carbon foam material; and

a fluid inlet port connected to one portion of the fluid permeable carbon foam material.

9. The tool of claim 8, wherein the fluid permeable carbon foam material provides substantially even heating of the surface of the tool face when heated fluid is passed through the fluid permeable carbon foam.

10. The tool of claim 8, wherein a surface of the fluid permeable carbon foam material defines the tool face.

11. The tool of claim 8, wherein the tool body consists essentially of carbon foam.

12. The tool of claim 8, wherein the tool face comprises a tool face material.

13. The tool of claim 8, further comprising a fluid exhaust port connected to a second portion of the fluid permeable carbon foam material.

14. The tool of claim 8, further comprising a pump adapted to be in fluid communication with the fluid inlet port.

15. The tool of claim 8, further comprising:
a pump adapted to be in fluid communication with fluid inlet port; and

a heated fluid supply in fluid communication with the pump.

16. The tool of claim 15, further comprising a thermostat in communication with the tool face and the heated fluid supply, wherein the thermostat monitors the temperature of the tool face and adjusts the temperature of the heated fluid supply.

17. A tool comprising:
a tool body defining a tool face, wherein the tool face is substantially uniformly heated by the tool body.

18. The tool of claim 17, wherein the tool body comprises electrically conductive carbon foam material.

19. The tool of claim 18, wherein the electrically conductive carbon foam material provides substantially uniform heating across the tool face when current is applied to the electrically conductive carbon foam material.

20. The tool of claim 17, wherein the tool body comprises fluid permeable carbon foam material.

21. The tool of claim 20, wherein the fluid permeable carbon foam material provides a substantially uniform heating of the tool face when a heated fluid is passed through the fluid permeable carbon foam material.

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