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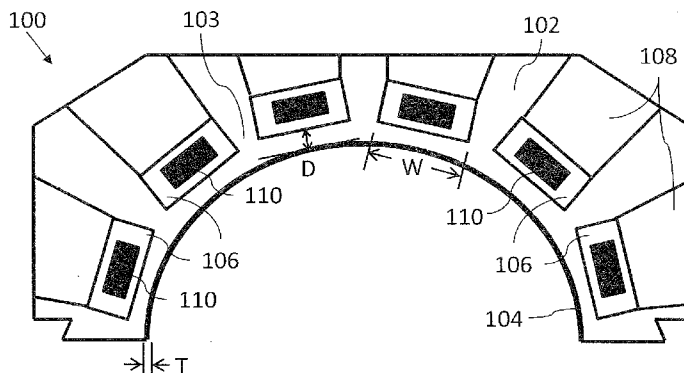
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(54) **Title:** SYSTEM AND APPARATUS FOR HEATING MOLDS



**FIG. 1A**

(57) **Abstract:** Various systems and apparatuses for heating molds, including for example tire molds, are disclosed. Heating of molds may be effected via induction heating technology. In one embodiment, a system for heating a tire mold is provided, the system comprising: a tire mold formed from a mold material having a base material relative permeability, wherein the tire mold includes a mold surface for contacting a tire, the mold surface for contacting a tire having a mold surface for contacting a tire relative permeability, wherein the tire mold includes a mold back oriented substantially opposite the mold surface for contacting a tire, and wherein the mold surface for contacting a tire relative permeability is greater than the base material relative permeability.

## SYSTEM AND APPARATUS FOR HEATING MOLDS

### BACKGROUND

[0001] Many articles are manufactured via a molding of materials into a desired shape. For example, many polymeric articles, including composites containing polymers, are formed via heated molds. One such article may include tires. Tires may be placed into contact with a mold and heated, under pressure, until the rubber within the tire is crosslinked and cured.

[0002] Many molds, including tire molds, are heated by a hot water, steam, heated gas, or other heating mediums. Molds are typically made from a metallic material. The metallic material of the mold may be heated through thermal conduction wherein heat is transferred from a heat medium, through the mold, and into the article to be molded. As a result, each portion of the mold typically obtains the same or similar temperature upon heating of the mold to the desired curing temperature. Also, portions of the mold, molding press, peripheral components, and other elements may be unnecessarily heated as these elements do not contribute to heating the article to be molded.

[0003] Heating of molds via hot water, steam, heated gas, or other heating mediums typically requires extended periods of down time during which an entire mold is heated to a curing temperature before molding, and cooled to a safe temperature following molding to permit manipulation of the mold to remove a molded article, the totality of which, including cure time, is commonly referred to as "cycle time." Additionally, heating of molds in such a manner may lead to inefficiency due to loss of heat from the mold to the surrounding environment via thermal convection and thermal conduction. Heat transferred to the surrounding environment may need to be removed via cooling such that workers in the surrounding environment are comfortable and to prevent damage to other equipment.

[0004] What is needed is a system and apparatus for heating a mold that minimizes heating and cooling times, allows for application of different mold temperatures at different portions of the mold, and maximizes energy efficiency.

### SUMMARY

[0005] In one embodiment, a system for heating a tire mold is provided, the system comprising: a tire mold formed from a mold material having a base material relative permeability, wherein the tire mold includes a mold surface for contacting a tire, the mold surface for contacting a tire having a mold surface for contacting a tire relative permeability, wherein the tire mold includes a mold back oriented substantially opposite the mold surface for contacting a tire, and wherein the mold surface for contacting a tire relative permeability is greater than the base material relative permeability.

[0006] In another embodiment, a system for heating a tire mold is provided, the system comprising: a tire sideplate mold, wherein the tire sideplate mold includes a mold surface for contacting a tire, wherein the tire sideplate mold includes a mold back oriented substantially opposite the mold surface for contacting a tire, wherein the tire sideplate mold includes at least one pocket; and at least one induction heating element contained within the at least one pocket.

[0007] In another embodiment, a system for heating a tire mold is provided, the system comprising: a tire bead ring mold, wherein the tire bead ring mold includes a mold surface for contacting a tire, wherein the tire bead ring mold includes a mold back oriented substantially opposite the mold surface for contacting a tire, wherein the tire bead ring mold includes at least one pocket; and at least one induction heating element contained within the at least one pocket.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The accompanying figures, which are incorporated in and constitute a part of the specification, illustrate various example systems and apparatuses, and are used merely to illustrate various example embodiments. In the figures, like elements bear like reference numerals.

[0009] **FIG. 1A** illustrates a sectional view of an example arrangement of an apparatus **100** for heating molds.

[0010] **FIG. 1B** illustrates a plan view of an example arrangement of apparatus **100** for heating molds.

[0011] **FIG. 2A** illustrates a sectional view of an example arrangement of an apparatus **200** for heating molds.

[0012] **FIG. 2B** illustrates a plan view of an example arrangement of apparatus **200** for heating molds.

[0013] **FIG. 3A** illustrates an elevation view of an example arrangement of an apparatus **300** for heating molds.

[0014] **FIG. 3B** illustrates a sectional view of apparatus **300** taken on line 3-3 in **FIG. 3A**.

[0015] **FIG. 4A** illustrates an elevation view of an example arrangement of an apparatus **400** for heating molds.

[0016] **FIG. 4B** illustrates a sectional view of apparatus **400** taken on line 4-4 in **FIG. 4A**.

#### DETAILED DESCRIPTION

[0017] A mold for molding and/or curing an article may be heated by induction heating. Induction heating may involve heating an electrically conducting object by electromagnetic induction, where eddy currents are generated within the electrically conducting object and resistance leads to Joule heating of the object. An induction heater may include an electromagnet, through which a high-frequency AC is passed. In one embodiment, induction heating generates heat by magnetic hysteresis losses in materials that have significant relative permeability.

[0018] An alternating current (“AC”) having any of a variety of frequencies may be used in inductive heating. The frequency of the AC may depend upon the size of the object to be heated, the material type to be heated, the coupling/distance (between the coil and the object to be heated), the penetration depth, and the like.

[0019] The AC may be applied at a low voltage. The AC may be applied at a high current. The AC may be applied at a high frequency.

[0020] Any of various frequencies of AC may be used in induction heating. For example, frequencies between about 5 kHz and about 30 kHz may be used with thicker workpiece materials, frequencies between about 100 kHz and about 400 kHz may be used with smaller and/or thinner workpiece materials or workpiece materials in which shallower penetration is

desired, and frequencies near about 480 kHz may be used with microscopic or otherwise extremely small workpieces.

[0021] Induction heating may be particularly efficient for molding articles due to the ability to focus energy to heat a mold in a specific surface, including for example a mold surface. Heat from the mold surface can be imparted into the article to be cured via conduction heating. In one embodiment, induction heating may result in about 85% of heat generated in a material, such as a mold, being focused near its surface.

[0022] FIG. 1A illustrates a sectional view of an example arrangement of an apparatus **100** for heating molds. Apparatus **100** may include a mold **102**. Mold **102** may include a mold for molding any of a variety of polymeric materials, including for example rubber. Mold **102** may include a mold for a tire, including for example a pneumatic tire or a non-pneumatic tire. Mold **102** may include a base material **103**. Mold **102** may include a mold surface contacting a tire (“MSCT”) **104**. MSCT **104** may be that portion of mold **102** configured to engage with any article to be molded within mold **102**.

[0023] MSCT **104** may be a separate portion of mold **102** that is configured to engage with base material **103**, and to engage with any article to be molded within mold **102**. MSCT **104** and base material **103** may be configured to operatively connect to one another to form at least a portion of mold **102**. MSCT **104** may be an integral portion of at least one of mold **102** and base material **103**, inasmuch as MSCT **104** may be permanently attached to at least one of mold **102** and base material **103**.

[0024] Mold **102** may include any of a variety of mold types. Mold **102** may include any of a variety of portions of a tire mold. Mold **102** may include any of a variety of portions of a tire mold, including for example a mold segment, a sidewall, a sideplate, a bead ring, a tread ring (non-segmented mold), a mold back (non-segmented mold), peripheral equipment, and the like. Mold **102** may be a segmented mold, wherein a plurality of separate segments are configured to be assembled for molding a tire, including a tire tread. Mold **102** may be a non-segmented mold including a tread ring and mold backs. Mold **102** may be a non-segmented mold, which incorporates tread geometry directly engraved into the mold backs.

[0025] Mold **102** may include at least one pocket **106** oriented within the body of mold **102**. At least one pocket **106** may be machined into mold **102**. At least one pocket **106** may be cast into mold **102**. At least one pocket **106** may be formed into mold **102** through any of a variety of methods.

[0026] At least one pocket **106** may be oriented near MSCT **104**. At least one pocket **106** may be oriented adjacent MSCT **104**. At least one pocket **106** may be oriented in base material **103**. At least one pocket may be oriented between base material **103** and MSCT **104**.

[0027] MSCT **104** may have a thickness **T**. Thickness **T** may be about 3.2 mm. Thickness **T** may be between about 1.6 mm and about 4.8 mm. Thickness **T** may be between about 2.4 mm and about 5.6 mm. Thickness **T** may be between about 1.6 mm and about 6.4 mm. Thickness **T** may be less than about 1.6 mm. Thickness **T** may be greater than about 6.4 mm. Thickness **T** may have any value within the recited ranges. Thickness **T** may be in a range between any recited lower bound and any recited upper bound herein.

[0028] MSCT **104** may have a thickness limited by the material of MSCT **104**. That is, thickness **T** may need to be greater, or lesser, due to material constraints. Thickness **T** may be limited to a minimum value that is thick enough to encapsulate the depths of various features of mold **102** that are contained within MSCT **104**, for example, logos, lettering, information, and the like. Thickness **T** may be limited to a minimum value that is thick enough to avoid distortion, warping, or the like, of MSCT **104** during exposure to heat of curing. MSCT **104** may be prepared via machining, so as to create a negative of the surface of the article to be molded in mold **102**. Thickness **T** may be limited to a minimum value that is thick enough to withstand machining without being distorted, deformed, damaged, destroyed, or the like. MSCT **104** may be applied to base material **103** to create mold **102**, and any article molded therein may be exposed to heat and pressure. Accordingly, thickness **T** may be limited to a minimum value that is thick enough to withstand the heat and/or pressure of molding and/or curing an article within mold **102**.

[0029] MSCT **104** may have a substantially uniform thickness **T**, such that each part of MSCT **104** is the same thickness **T**. Alternatively, MSCT **104** may have varying thicknesses, such that part of MSCT **104** has a thickness **T**, while another part has a thickness less than and/or greater than thickness **T**.

[0030] In one embodiment, MSCT **104** may be created by spraying, laminating, or the like, a material, such as a molten metal, a ceramic, or the like, onto a forming apparatus. MSCT **104** may be formed by a layer of spray. The layer may have a thickness **T** as disclosed above.

[0031] MSCT **104** may be made out of any of a variety of materials. For example, MSCT **104** may be a metal, such as an iron or a steel. MSCT **104** may be an alloy. MSCT **104** may be a composite. MSCT **104** may be made out of a material that responds to induction heating, which materials may include an iron or an iron alloy. MSCT **104** may be made out of a material that responds to induction heating, which material may include a ferromagnetic material. MSCT **104** may be made out of a material that responds to induction heating and/or in which magnetic hysteresis may occur, which material may include a magnetic material.

[0032] MSCT **104** may be a material plated or coated with another material, for example, a nickel coating. MSCT **104** may have a uniform thickness or gauge, such that it is always the same thickness regardless of features machined into MSCT **104** to be imparted on an article to be molded. MSCT **104** may be plated or coated with another material, wherein the other material is applied in a uniform thickness.

[0033] MSCT **104** may comprise a material having magnetic properties. That is, MSCT **104** may comprise a material, such as steel, that has magnetic properties. MSCT **104** may comprise a material having a relative permeability in a range between about 100 and about 600. MSCT **104** may comprise a material having a relative permeability in a range between about 100 and about 500.

[0034] Relative permeability may be defined as the ratio of permeability of a medium to the permeability of free space.

[0035] Permeability, or magnetic permeability, may be defined as the degree to which the magnetic lines of force can penetrate or permeate a material. Permeability, or magnetic permeability, may be defined as the ability of a material to permit passage of magnetic lines of force through it. Permeability may be equal to, or proportionate to, the magnetic flux density established within a material by a magnetizing field, divided by the magnetic field strength of the magnetizing field.

[0036] At least one induction heating element (“IHE”) **110** may interact with MSCT **104** via inductive heating to cause MSCT **104** to heat. Materials with higher relative permeability may heat more quickly when exposed to IHE **110** than materials with a lower relative permeability. In one embodiment, base material **103** may be a material having less relative permeability than MSCT **104**. As a result, at least one IHE **110** may cause MSCT **104** to heat via inductive heating more than base material **103**. That is, more heat may be generated by IHE **110** in MSCT **104** than in base material **103**. MSCT **104** may have a higher relative permeability than the remainder of mold **102**. MSCT **104** may heat more quickly than at least one of the remainder of mold **102** and base material **103**.

[0037] At least one pocket **106** may be in communication with an outside of mold **102** via at least one channel **108**. At least one channel **108** may be machined into base material **103**. At least one channel **108** may be cast into base material **103**. At least one channel **108** may be formed in base material **103** via any of a variety of methods. At least one channel **108** may communicate with an outside surface of mold **102** substantially opposite MSCT **104**. At least one channel **108** may communicate with a surface of base material **103** adjacent MSCT **104**. At least one channel **108** may be in communication with an outside surface of base material **103** other than that surface contacting MSCT **104**. Mold **102** may include a mold back, which may be an outside surface of mold **102** substantially opposite MSCT **104**. Each of at least one pocket **106** may include a corresponding channel **108**. A series of pockets **106** may include a channel **108**.

[0038] Apparatus **100** may include at least one IHE **110**. IHE **110** may be operatively connected to mold **102**. Each of at least one pocket **106** may include at least one IHE **110**. At least one IHE **110** may be located in any of a variety of portions of mold **102**, including for example in a mold segment, in a sidewall, in a sideplate, in a bead ring, in a tread ring, in a mold back, in peripheral equipment, and the like. At least one IHE **110** may be used for inductive heating of at least a portion of mold **102**.

[0039] At least one IHE **110** may be configured to heat the portion of mold **102** adjacent to its respective pocket **106**. At least one IHE **110** may be configured to heat a portion of MSCT **104** oriented near IHE **110**.

[0040] A portion of base material **103** having a depth **D** may be oriented between at least one IHE **110** and MSCT **104**. Depth **D** may be selected to achieve desired heating of the specific portion of MSCT **104** oriented near a specific IHE **110**. Depth **D** may be the same for any number of IHEs **110**. Depth **D** may vary for any number of IHEs **110**. Depth **D** may be increased at a specific point where the desired temperature of MSCT **104** at that specific point is lower than other portions of MSCT **104**. Depth **D** may be decreased at a specific point where the desired temperature of MSCT **104** at that specific point is higher than other portions of MSCT **104**. It may be desirable to apply more heat to thicker portions of an article to be molded. It may be desirable to apply less heat to thinner portions of an article to be molded. It should be understood that depth **D** may vary from any of at least one pocket **106** to another pocket **106**. Additionally, it should be understood that the frequency and/or amperage of electrical input to IHE **110** may be varied, or constant, between pockets **106** so as to affect the heat produced in MSCT **104** near a particular IHE **110**.

[0041] At least one pocket **106** may have a width **W**. Width **W** may be measured substantially laterally. Where mold **102** is a tire mold, width **W** may be measured substantially laterally, substantially radially, or a combination of laterally and radially as pockets **106** are oriented around the periphery of the molded tire. Width **W** may be selected to permit installation of at least one IHE **110** into at least one pocket **106**. Width **W** may be selected to provide apparatus **100** with an adequate density of IHEs **110** to heat mold **102** and/or MSCT **104** as desired or necessary for curing a molded article. It should be understood that width **W** may vary from any of at least one pocket **106** to another pocket **106**.

[0042] IHE **110** may have any of a variety of sizes depending upon any of a variety of factors. For example, size of at least one IHE **110** may depend upon the portion of mold **102** in which that specific IHE **110** is to be oriented, heat needed from that specific IHE **110**, depth **D** of base material **103** adjacent to that specific IHE **110**, size of pocket **106** into which IHE **110** is to be placed, and the like. IHE **110** may be any of a variety of IHE systems. IHE **110** may be a coiled copper element. IHE **110** may be a coil of electrically conductive material through which a current is directed. In one embodiment, IHE **110** may be operatively connected with a cooling device to prevent IHE **110** from overheating, which may lead to destruction of, or damage to, IHE **110** or mold **102**. The cooling device may be local to IHE **110** and oriented in or near

pocket **106**. The cooling device may be oriented in base material **103** near IHE **110**. The cooling device may be oriented on a surface of mold **102** adjacent IHE **110**.

[0043] IHE **110** may have any of a variety of shapes depending upon any of a variety of factors. For example, shape of IHE **110** may depend upon the portion of mold **102** in which that specific IHE **110** is to be oriented, size of pocket **106** into which IHE **110** is to be placed, and the like. That is, where an IHE **110** is configured to be located near and heat a curved portion of MSCT **104**, that IHE **110** may be curved in a manner similar to that portion of MSCT **104**. Where an IHE **110** is configured to be located near a substantially planar portion of MSCT **104**, that IHE **110** may be substantially planar.

[0044] Alternatively, each IHE **110** may be sized and/or shaped the same so as to simplify assembly and/or manufacture of apparatus **100**.

[0045] The number of IHEs **110** contained within a specific portion of mold **102** may depend upon the size, shape, and desired temperature of the mold portion being heated. The density and/or spacing of IHEs **110** in a specific portion of mold **102** may depend upon the size, shape, and desired temperature of the mold portion being heated.

[0046] At least one IHE **110** may be operatively connected to a controller (not shown). At least one IHE **110** may be connected via at least one wire to a controller (not shown). At least one IHE **110** may act in concert with one or more other IHE **110** to selectively heat at least a portion of mold **102** and MSCT **104**. At least one IHE **110** may act in concert with one or more other IHE **110** to selectively heat a first portion of mold **102** and MSCT **104** to a first temperature and selectively heat a second portion of mold **102** and MSCT **104** to a second temperature. At least one IHE **110** may act in concert with any number of other IHEs **110** to selectively control the temperature of various portions of mold **102** and MSCT **104**.

[0047] IHE **110** may be operatively connected to an AC source. IHE **110** may be electrically connected to an AC source. IHE **110** may be wired to an AC source. In use, current from an AC source may flow through IHE **110**. Electromagnetic current may create a change in magnetic field near IHE **110**, including within MSCT **104**. The flow of current, also known as an eddy current, may be induced in MSCT **104** to generate heat. As a result, IHE **110** may create a localized heating of MSCT **104**. The heat generated by IHE **110** may be proportional to the

electric current squared, multiplied by the resistance of the material of mold **102**. The heat generated by IHE **110** may be proportional to the electric current squared, multiplied by the resistance of the material of base material **103**. The heat generated by IHE **110** may be proportional to the electric current squared, multiplied by the resistance of the material of MSCT **104**.

[0048] At least one IHE **110** may include a plurality IHEs **110**. Current applied to IHE **110** may be directly related to the heat generated by IHE **110**. Different amperages may be applied to different IHEs **110** such that different IHEs **110** generate different heats. One may select different heats based upon the portion of mold **102** and/or MSCT **104** to which heat is being applied. For example, where the molded article is a tire, one may apply greater amounts of heat to portions of the tire having higher gauge and lesser amounts of heat to portions of the tire having lesser gauge. In this manner, a controller (not shown) may control localized heat applied to any of various portions of mold **102** and/or MSCT **104** depending upon heat needed to cure any of corresponding portions of the molded article.

[0049] IHE **110** may include an amperage and frequency. Amperage and frequency may be selected based upon a number of factors, including for example: material of MSCT **104**, thickness of MSCT **104**, material of mold **102**, overall thickness of mold **102**, depth **D**, and the like. Regarding material of mold **102**, more resistive materials, such as steel, may heat faster while less resistive materials, such as aluminum or copper, may heat slower. The rate at which IHE **110** heats MSCT **104** may be a function of at least one of: depth **D**, which may represent the distance between IHE **110** and MSCT **104**; the material of MSCT **104**; the material of base material **103**; the frequency of current supplied to IHE **110**; and the amplitude of current supplied to IHE **110**.

[0050] A plurality of IHEs **110** may be oriented in any of a variety of patterns. For example, a plurality of IHEs **110** may be oriented using a concentric pattern, a radial pattern, a combination of a concentric pattern and a radial pattern, or any other pattern or combination.

[0051] MSCT **104** may include a metallic surface coating that is a material that is different from other portions of mold **102**. Base material **103** may be made from any of a variety of materials, including for example a steel, an aluminum, a non-metallic material, and the like. MSCT **104** may include a metallic surface coating that is applied to base material **103** and which

is more resistive compared to base material **103**. MSCT **104** may include a metallic surface coating having a high relative permeability. Base material **103** may have a relative permeability and MSCT **104** may include a MSCT material having a relative permeability, wherein the relative permeability of the MSCT material is greater than the relative permeability of base material **103**.

[0052] Materials having high resistance may heat faster. Materials having high relative permeability may heat faster. Materials having high resistance may heat faster when heating with IHEs **110**. MSCT **104** may include a coating having a higher resistance or relative permeability than other portions of mold **102** such that MSCT **104** heats faster than other portions of mold **102** (e.g., base material **103**). Application of a higher resistance coating to MSCT **104** may permit a higher rate of heat transfer from IHE **110** to MSCT **104**.

[0053] Mold **102** may be a mold for curing a tire bead, which may be a bead ring. MSCT **104** may be configured to contact at least a portion of a tire bead area. At least one pocket **106** for at least one IHE **110** may be oriented below (e.g., radially inward of) the bead ring mold **102** bead contour. At least one pocket **106** can be machined from the back of mold **102** via a channel **108**. IHEs **110** may be oriented in a concentric pattern about at least a portion of the circumference of bead ring mold **102**. IHEs **110** may be oriented in a radial pattern about at least a portion of the circumference of bead ring mold **102**. IHEs **110** may be oriented in any of a variety of patterns about at least a portion of the circumference of bead ring mold **102**, including a combination of patterns.

[0054] In one embodiment, apparatus **100** may operate in conjunction with a curing bladder (not shown). The curing bladder may be oriented within the article to be cured, including for example a tire. The curing bladder may apply heat and pressure to the interior of the article to be cured, thereby forcing the article to be cured into mold **102**. The curing bladder may be heated via any of a variety of traditional means, including for example hot water within the bladder, hot gas (such as nitrogen) within the bladder, steam within the bladder, and the like. Alternatively, or additionally, the curing bladder may include an integrated thin metallic mesh, such as a steel mesh. IHEs located within the curing bladder (not shown) may react with the metallic mesh thus causing heat within the curing bladder. Heat may transfer from the curing bladder to the article

to be molded and cured. The metallic mesh may be oriented either within the thickness of the curing bladder, or on a surface of the curing bladder.

[0055] Apparatus **100** may be used to mold articles in any of a variety of ways.

[0056] For example, apparatus **100** may utilize at least one IHE **110** to provide the heat required to cure a molded article. At least one IHE **110** may exclusively provide all heat necessary for curing.

[0057] Alternatively, apparatus **100** may utilize at least one IHE **110** to provide a primary source of heat required to cure a molded article, with supplemental sources of heat utilized as needed. That is, apparatus **100** may include mold **102** utilizing both at least one IHE **110** and at least one of a traditional mold heating means, such as a hot water, steam, heated gas, or other heating mediums. The traditional mold heating means may maintain mold **102** at a first temperature or within a first temperature range, while at least one IHE **110** may be controlled, activated, or otherwise selectively operated to raise the temperature of mold **102** to a second temperature or within a second temperature range. The first temperature or first temperature range may be a temperature that allows mold **102** to be safely manipulated by personnel or equipment used during the molding process. The second temperature or second temperature range may be that temperature desired or necessary for curing the molded article. Use of at least one IHE **110** as a primary source of heat may reduce the time needed to heat mold **102** prior to curing a rubber article within mold **102**. In one embodiment, only MSCT **104** may be heated, or targeted for heating, by IHE **110**.

[0058] In one embodiment, at least one IHE **110** is used to heat at least MSCT **104**. MSCT **104** may be heated to an appropriate temperature for curing more quickly than through traditional mold heating mediums. Additionally, where MSCT **104** is specifically targeted for heating, and where MSCT **104** has less mass than the rest of mold **102**, MSCT **104** may cool more quickly than traditional molds using traditional mold heating mediums (e.g., wherein the entire mold is heated). As a result, the cycle time for a rubber article in mold **102** using MSCT **104** and at least one IHE **110** may be reduced due to faster heating, and cooling, of MSCT **104** compared to traditional molds. That is, while cure time for the rubber article may remain the same (the amount of time it takes a rubber article to cure may be a property of the specific rubber compound(s) used in the article, rather than a property of the mold), the cycle time for curing

that rubber article may be less than through traditional methods, where the cycle time accounts for heating and cooling of mold **102**.

[0059] Alternatively, apparatus **100** may utilize at least one IHE **110** to provide a supplementary source of heat required to cure a molded article, with primary sources of heat also utilized as needed. That is, apparatus **100** may include mold **102** utilizing both at least one IHE **110** and at least one of a traditional mold heating means, such as a hot water, steam, heated gas, or other heating mediums. At least one IHE **110** may be controlled, activated, or otherwise selectively operated to maintain the temperature of mold **102** to a first temperature or within a first temperature range. The traditional mold heating means may raise mold **102** to a second temperature or within a second temperature range. The first temperature or first temperature range may be a temperature that allows mold **102** to be safely manipulated by personnel or equipment used during the molding process. The second temperature or second temperature range may be that temperature desired or necessary for curing the molded article.

[0060] In one embodiment, apparatus **100** may undergo two stages of operation. One stage may be that during which mold **102** is heated to adequately cure a molded article contained within or contacted to mold **102**. Another stage may be that during which mold **102** and/or a press containing apparatus **100** and mold **102** is opened during loading or unloading of a molded article to be molded, or which has been molded, in mold **102**. The curing stage may require a second temperature or second temperature range, wherein the loading/unloading stage may require a first temperature or first temperature range.

[0061] Different curing temperatures (second temperature or second temperature range) may be maintained between various portions of the article to be molded, which may be a tire. For example, different curing temperatures may be maintained in the tread surface portion of the tire, one or more portions of the sidewall of the tire, one or more portions of a bladder utilized to cure a tire, and/or a bead portion of the tire. These different curing temperatures may be achieved through control of at least one IHE **110** as described above.

[0062] **FIG. 1B** illustrates a plan view of an example arrangement of apparatus **100** for heating molds. **FIG. 1B** illustrates a plan view of the MSCT **104** side, and in the case of a tire mold, radially inner side, of mold **102**.

[0063] At least one pocket **106** may be oriented in circumferentially-extending rows. As illustrated, rows of pockets **106** may appear to overlap adjacent rows, but this may be by virtue of the fact that mold **102** may be a tire mold and thus curve about the radially outer portion of the tire from one tire shoulder to the other.

[0064] Rows of at least one pocket **106** may have a spacing **S** between adjacent rows. Spacing **S** may be measured substantially laterally. Where mold **102** is a tire mold, spacing **S** may be measured substantially laterally, substantially radially, or a combination of laterally and radially as pockets **106** are oriented around the periphery of the molded tire. Spacing **S** may be selected to provide apparatus **100** with an adequate density of IHEs **110** to heat mold **102** and/or MSCT **104** as desired or necessary for curing a molded article. It should be understood that spacing **S** may vary either between a first set of rows and a second set of adjacent rows, or even within a single set of rows (that is, pockets **106** may be separated by more or less space as one measures along two adjacent rows).

[0065] At least one pocket **106** may include a length **L**. Length **L** may be measured substantially longitudinally. Where mold **102** is a tire mold, length **L** may be measured substantially circumferentially as pockets **106** may be oriented around the circumference of the molded tire. Length **L** may be selected to permit installation of at least one IHE **110** into at least one pocket **106**. Length **L** may be selected to provide apparatus **100** with an adequate density of IHEs **110** to heat mold **102** and/or MSCT **104** as desired or necessary for curing a molded article. It should be understood that length **L** may vary from any of at least one pocket **106** to another pocket **106**, including pockets **106** in the same row.

[0066] At least one pocket **106** may be oriented in at least one row. At least two pockets may have a pitch **P** within the row, defined as the distance from a first point on a first pocket **106** to the same point on a second adjacent pocket **106** in the same row. Pitch **P** may be measured substantially longitudinally. Where mold **102** is a tire mold, pitch **P** may be measured substantially circumferentially as pockets **106** may be oriented around the circumference of the molded tire. Pitch **P** may be selected to provide apparatus **100** with an adequate density of IHEs **110** to heat mold **102** and/or MSCT **104** as desired or necessary for curing a molded article. It should be understood that pitch **P** may vary from any set of adjacent pockets **106** to another set of adjacent pockets **106** oriented in a row.

[0067] As illustrated, at least one pocket **106** may have a substantially longitudinal and/or circumferentially-extending orientation. It should be understood that at least one pocket **106** may have any of a variety of orientations, including circumferentially, axially, radially, or some orientation between two of these directions. It should be understood that at least one pocket **106** may have any of a variety of shapes or cross-sections, including square, rectangular, oval, circular, spherical, elliptical, or any regular or irregular shape.

[0068] In one embodiment, mold **102** comprises a plurality of molds oriented adjacent one another. For example, a first mold **102** may be a tread ring mold, while a second mold **102** may be a sidewall mold. The two molds may be fitted against one another to mold a tire. The two molds may each form adjoining portions of the tire. In one embodiment, first mold **102** may comprise base material **103** including a first thermal expansion coefficient. For example, first base material **103** may include aluminum, having a relatively high thermal expansion coefficient. Second mold **102** may comprise base material **103** including a second thermal expansion. For example, second base material **103** may include steel, having a relatively low thermal expansion coefficient, and lower than that of aluminum. In such an arrangement, the two molds **102** being oriented adjacent one another may expand at different rates, thus possibly creating a gap through which rubber from the molded tire could flow, creating what is referred to as “flash.” Flash may be undesirable in the molding of many rubber articles, such as tires.

[0069] However, first mold **102** may include first MSCT **104** formed from steel, and thus matching second base material **103**. Second mold **102** may not include any MSCT **104**. In such an arrangement, first MSCT **104** and second base material **103** may have the same thermal expansion coefficient, such that when heated the two expand together and avoid gaps that may allow for the creation of flash.

[0070] FIG. 2A illustrates a sectional view of an example arrangement of an apparatus **200** for heating molds. Apparatus **200** may include a mold **202**. Mold **202** may include a mold for molding any of a variety of polymeric materials, including for example rubber. Mold **202** may include a mold for a tire, including for example a pneumatic tire or a non-pneumatic tire. Mold **202** may include a base material **203**. Mold **202** may include a mold surface contacting a tire (“MSCT”) **204**. MSCT **204** may be that portion of mold **202** configured to engage with any article to be molded within mold **202**. MSCT **204** may be an independent element selectively

attached to base material **203**. MSCT **204** may be an integral element integrally attached to base material **203**.

[0071] Mold **202** may include at least one central pocket **206** oriented at or near the center of mold **202** in base material **203**. Central pocket **206** may be in communication with a side of mold **202** via a channel **208**. Channel **208** may open to a side of mold **202** opposite MSCT **204**. Channel **208** may open to a side of mold **202** adjacent to MSCT **204**. Pocket **206** may contain at least one IHE **210**. Pocket **206** may include a width **W1** selected in the same manner as width **W** of pockets **106** described above with respect to **FIGS. 1A** and **1B**. Pocket **206** may be separated from MSCT **204** by a depth **D1** of mold **202**, selected in the same manner as depth **D** described above with respect to **FIG. 1A**.

[0072] Mold **202** may include at least one lateral pocket **212** oriented at or near the axially outer sides of mold **202**. At least one pocket **212** may contain at least one IHE **214**. At least one pocket **212** may have a width **W2** selected in the same manner as width **W** of pockets **106** described above with respect to **FIGS. 1A** and **1B**. At least one pocket **212** may have a height **H**. Height **H** may be selected to permit installation of IHE **214** of a size necessary for heating of mold **202** and/or MSCT **204**. Pocket **212** may be separated from MSCT **204** by a depth **D2** of mold **202**, selected in the same manner as depth **D** described above with respect to **FIG. 1A**.

[0073] **FIG. 2B** illustrates a plan view of an example arrangement of apparatus **200** for heating molds. **FIG. 2B** illustrates a plan view of the MSCT **204** side, and in the case of a tire mold, radially inner side, of mold **202**.

[0074] At least one pocket **206** may be oriented substantially axially, such that it includes a greater length in its axially-extending edge than its longitudinal or circumferentially-extending edge. At least one pocket **206** may be oriented in any of a variety of directions within mold **202**. At least one pocket **206** may include a plurality of similar pockets organized substantially within at least one longitudinally-extending/circumferentially-extending row.

[0075] At least one pocket **206** may include a length **L1**, selected in the same manner as length **L** described above with respect to **FIG. 1B**.

[0076] At least one pocket **206** may include a pitch **P**, selected in the same manner as pitch **P** described above with respect to **FIG. 1B**.

[0077] At least one pocket **212** may be oriented substantially longitudinally and/or circumferentially. At least one pocket **212** may include a greater length on its longitudinal or circumferentially-extending edge than its axially-extending edge. At least one pocket **212** may extend about the entire longitudinal or circumferential length of mold **202**. Where mold **202** is a segmented mold, at least one pocket **212** may be configured to align with at least one pocket (not shown) of an adjacent mold segment (not shown) such that when assembled, a continuous circumferential or longitudinal pocket exists in mold **202**. Alternatively, at least one pocket **212** may extend discontinuously about the longitudinal or circumferential length of an assembled segmented mold **202**. At least one pocket **212** may be oriented in any of a variety of directions within mold **202**. At least one pocket **212** may include a plurality of similar pockets organized substantially within at least one longitudinally-extending/circumferentially-extending row.

[0078] At least one pocket **212** may include a length **L2**, selected in the same manner as length **L** described above with respect to **FIG. 1B**. Length **L2** may be the same as or less than the length of mold **202**.

[0079] **FIG. 3A** illustrates an elevation view of an example arrangement of an apparatus **300** for heating molds. Apparatus **300** may include a mold **302**. Mold **302** may be a sideplate for a tire mold.

[0080] Mold **302** may include at least one pocket **306**. At least one pocket **306** may contain at least one IHE **310**. At least one IHE **310** may be configured to heat at least a portion of a MSCT (not shown) of mold **302**. At least one IHE **310** may be configured to heat at least a portion of mold **302**.

[0081] As illustrated, at least one pocket **306** and/or IHE **310** may extend substantially circumferentially about mold **302**. Alternatively, at least one pocket **306** and/or IHE **310** may extend in any of a variety of directions, including for example circumferentially, radially, or a combination of the circumferential and radial directions. Alternatively, at least one pocket **306** and/or IHE **310** may extend in a combination of directions.

[0082] **FIG. 3B** illustrates a sectional view of apparatus **300** taken on line 3-3 in **FIG. 3A**. Mold **302** may include a base material **303**. Mold **302** may include a MSCT **304**. At least one pocket **306** may be separated from MSCT **304** by a depth **D** of mold **302**. Depth **D** may be

selected in the same manner as depth **D** described above with respect to **FIG. 1A**. At least one pocket **306** may have a width **W**, selected in the same manner as width **W** described above with respect to **FIG. 1A**.

[0083] Mold **302** may include multiple mold portions, including for example a sidewall mold **316** and a bead ring mold **318**. In practice, sidewall mold **316** may be used to form a tire sidewall surface, whereas bead ring mold **318** may be used to form a tire bead profile surface.

[0084] Bead ring mold **318** may be a negative of a desired bead profile surface. At least one pocket **306** and IHE **310** may be oriented in bead ring mold **318**. IHE **310** may heat at least a portion of MSCT **304**. IHE **310** may heat a metallic bead bundle and/or steel cord oriented within the tire's bead portion. IHE **310** may heat both at least a portion of MSCT **304** oriented in bead ring mold **318**, and a metallic bead bundle and/or steel cord.

[0085] **FIG. 4A** illustrates an elevation view of an example arrangement of an apparatus **400** for heating molds. Apparatus **400** may include a mold **402**. Mold **402** may be a sideplate for a tire mold.

[0086] Mold **402** may include at least one pocket **406**. At least one pocket **406** may contain at least one IHE **410**. At least one IHE **410** may be configured to heat at least a portion of a MSCT (not shown) of mold **402**. At least one IHE **410** may be configured to heat at least a portion of mold **402**.

[0087] As illustrated, at least one pocket **406** and/or IHE **410** may extend substantially circumferentially about mold **402** and at least one pocket **406** and/or IHE **410** may extend substantially radially in mold **402**. Alternatively, at least one pocket **406** and/or IHE **410** may extend in any of a variety of directions, including for example circumferentially, radially, or a combination of the circumferential and radial directions. Alternatively, at least one pocket **406** and/or IHE **410** may extend in any combination of directions.

[0088] **FIG. 4B** illustrates a sectional view of apparatus **400** taken on line 4-4 in **FIG. 4A**. Mold **402** may include a base material **403**. Mold **402** may include a MSCT **404**. At least one pocket **406** may be separated from MSCT **404** by a depth **D** of mold **402**. Depth **D** may be selected in the same manner as depth **D** described above with respect to **FIG. 1A**. At least one

pocket **406** may have a width **W**, selected in the same manner as width **W** described above with respect to **FIG. 1A**.

[0089] To the extent that the term “includes” or “including” is used in the specification or the claims, it is intended to be inclusive in a manner similar to the term “comprising” as that term is interpreted when employed as a transitional word in a claim. Furthermore, to the extent that the term “or” is employed (e.g., A or B) it is intended to mean “A or B or both.” When the applicants intend to indicate “only A or B but not both” then the term “only A or B but not both” will be employed. Thus, use of the term “or” herein is the inclusive, and not the exclusive use. See Bryan A. Garner, *A Dictionary of Modern Legal Usage* 624 (2d. Ed. 1995). Also, to the extent that the terms “in” or “into” are used in the specification or the claims, it is intended to additionally mean “on” or “onto.” To the extent that the term “substantially” is used in the specification or the claims, it is intended to take into consideration the degree of precision available or prudent in manufacturing. To the extent that the term “selectively” is used in the specification or the claims, it is intended to refer to a condition of a component wherein a user of the apparatus may activate or deactivate the feature or function of the component as is necessary or desired in use of the apparatus. To the extent that the term “operatively connected” is used in the specification or the claims, it is intended to mean that the identified components are connected in a way to perform a designated function. As used in the specification and the claims, the singular forms “a,” “an,” and “the” include the plural. Finally, where the term “about” is used in conjunction with a number, it is intended to include  $\pm 10\%$  of the number. In other words, “about 10” may mean from 9 to 11.

[0090] As stated above, while the present application has been illustrated by the description of embodiments thereof, and while the embodiments have been described in considerable detail, it is not the intention of the applicants to restrict or in any way limit the scope of the appended claims to such detail. Additional advantages and modifications will readily appear to those skilled in the art, having the benefit of the present application. Therefore, the application, in its broader aspects, is not limited to the specific details, illustrative examples shown, or any apparatus referred to. Departures may be made from such details, examples, and apparatuses without departing from the spirit or scope of the general inventive concept.

## CLAIMS

1. A system for heating a tire mold, comprising:  
a tire mold formed from a mold material having a base material relative permeability,  
wherein the tire mold includes a mold surface for contacting a tire, the mold surface for contacting a tire having a mold surface for contacting a tire relative permeability,  
wherein the tire mold includes a mold back oriented substantially opposite the mold surface for contacting a tire, and  
wherein the mold surface for contacting a tire relative permeability is greater than the base material relative permeability.
2. The system of claim 1, wherein the tire mold is a segmented tread mold including individual tread mold segments.
3. The system of claim 1, wherein the tire mold at least one of a sideplate mold, a sidewall mold, a bead ring mold, and a tread ring mold.
4. The system of claim 1, further comprising at least one induction heating element operatively connected to the tire mold.
5. The system of claim 1, further comprising at least one induction heating element connected to the mold back.
6. The system of claim 1, wherein the tire mold includes at least one pocket, and wherein the at least one pocket contains at least one induction heating element.
7. The system of claim 1, wherein the tire mold includes at least one pocket, and wherein a channel extends from the at least one pocket to the mold back.
8. A system for heating a tire mold, comprising:  
a tire sideplate mold,  
wherein the tire sideplate mold includes a mold surface for contacting a tire,  
wherein the tire sideplate mold includes a mold back oriented substantially opposite the mold surface for contacting a tire,  
wherein the tire sideplate mold includes at least one pocket; and  
at least one induction heating element contained within the at least one pocket.

9. The system of claim 8, wherein a channel extends from the at least one pocket to the mold back.

10. The system of claim 8, wherein the at least one pocket is a plurality of pockets, and wherein the plurality of pockets are oriented circumferentially about the tire sideplate mold.

11. The system of claim 8, wherein the at least one pocket is a plurality of pockets, and wherein the plurality of pockets are oriented radially about the tire sideplate mold.

12. The system of claim 8, wherein the at least one pocket is a plurality of pockets, and wherein at least one of the plurality of pockets is oriented circumferentially and at least one of the plurality of pockets is oriented radially.

13. The system of claim 8, wherein at least a portion of the mold surface for contacting a tire is coated with a metallic surface coating.

14. The system of claim 8, wherein the tire sideplate mold is formed from a base material having a base material relative permeability, wherein at least a portion of the mold surface for contacting a tire has a mold surface for contacting a tire relative permeability, and wherein the mold surface for contacting a tire relative permeability is greater than the base material relative permeability.

15. A system for heating a tire mold, comprising:

a tire bead ring mold,

wherein the tire bead ring mold includes a mold surface for contacting a tire,

wherein the tire bead ring mold includes a mold back oriented substantially opposite the mold surface for contacting a tire,

wherein the tire bead ring mold includes at least one pocket; and  
at least one induction heating element contained within the at least one pocket.

16. The system of claim 15, wherein at least one channel extends from the at least one pocket to the mold back.

17. The system of claim 15, wherein the at least one pocket is a plurality of pockets, and wherein the plurality of pockets are oriented circumferentially about the tire bead ring mold.

18. The system of claim 15, wherein at least a portion of the mold surface for contacting a tire is coated with a metallic surface coating.

19. The system of claim 15, wherein the tire bead ring mold is formed from a base material having a base material relative permeability, wherein at least a portion of the mold surface for contacting a tire has a mold surface for contacting a tire relative permeability, and wherein the mold surface for contacting a tire relative permeability is greater than the base material relative permeability.

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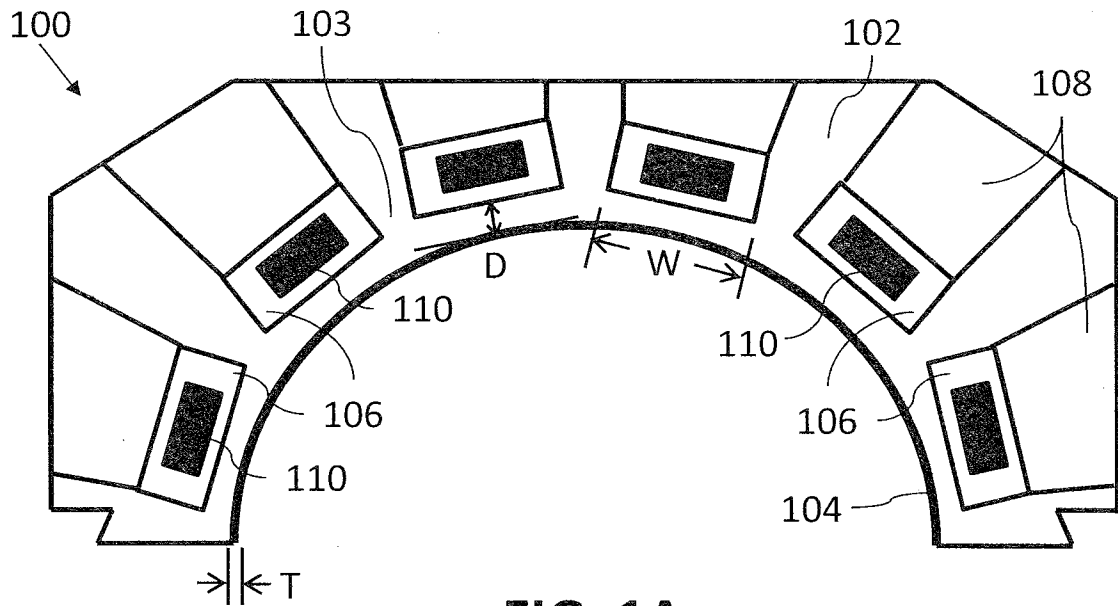


FIG. 1A

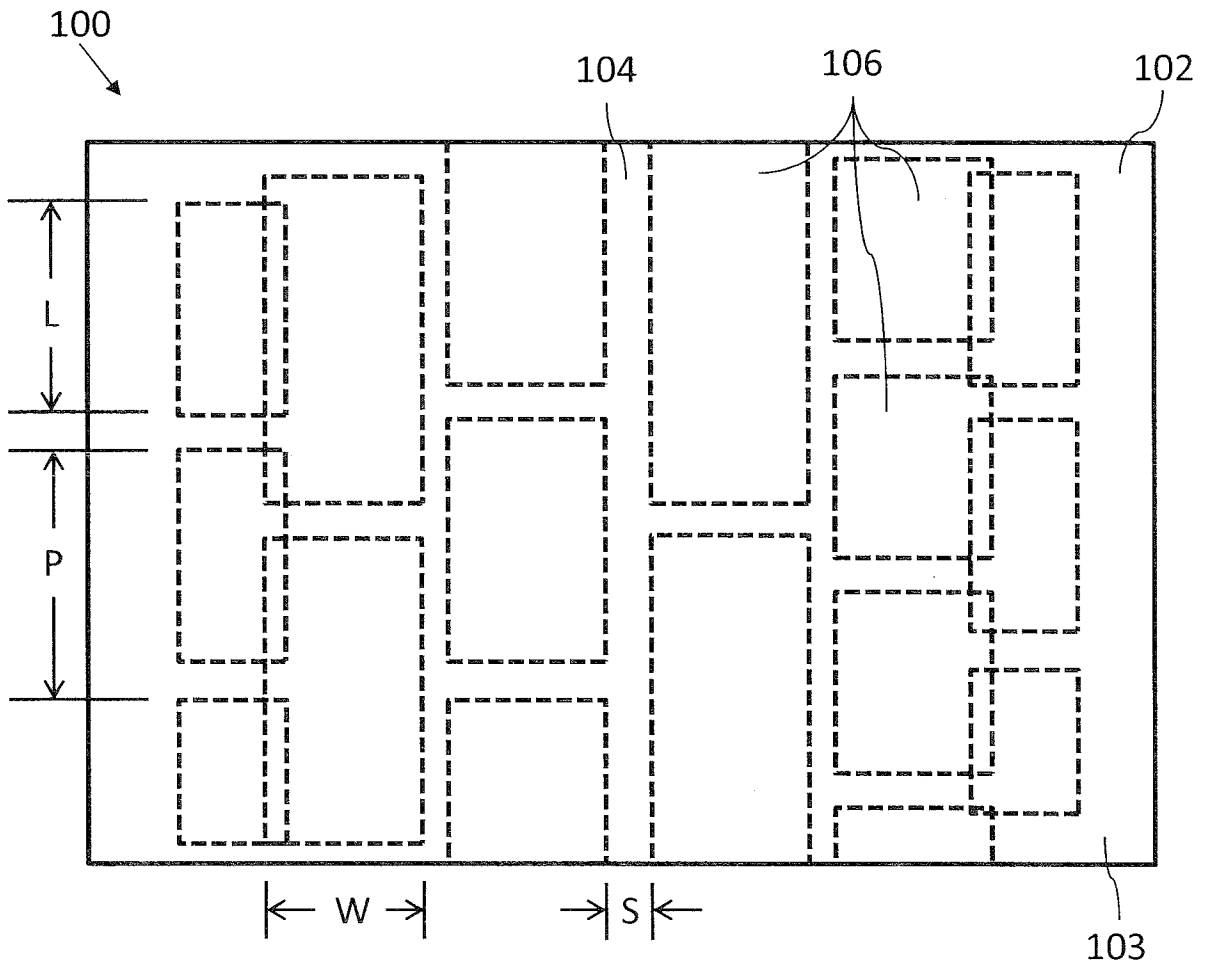


FIG. 1B

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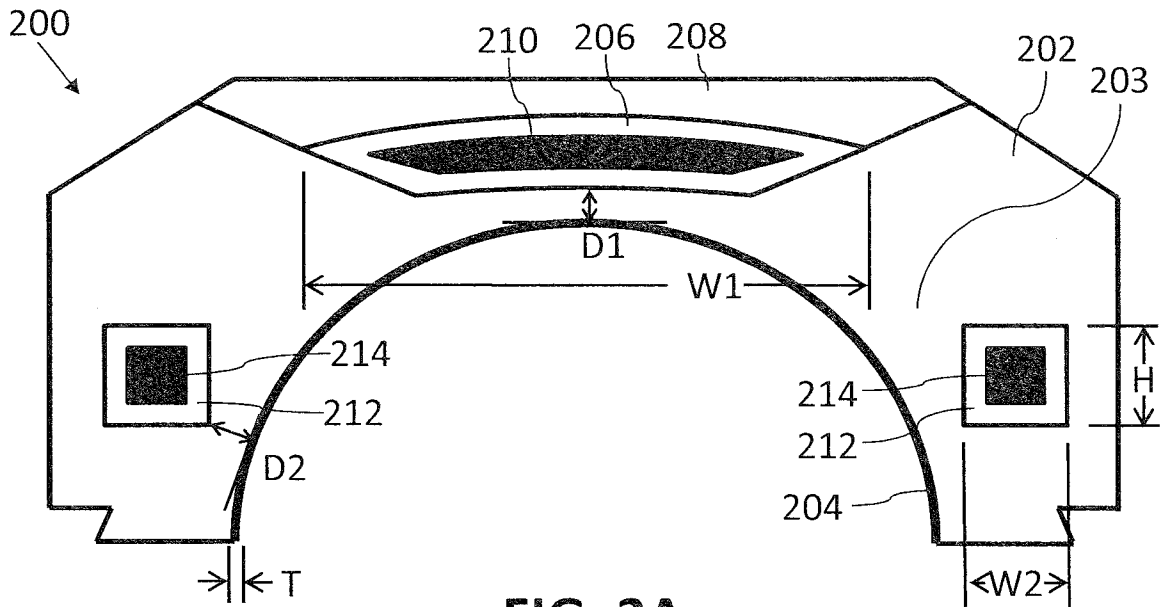


FIG. 2A

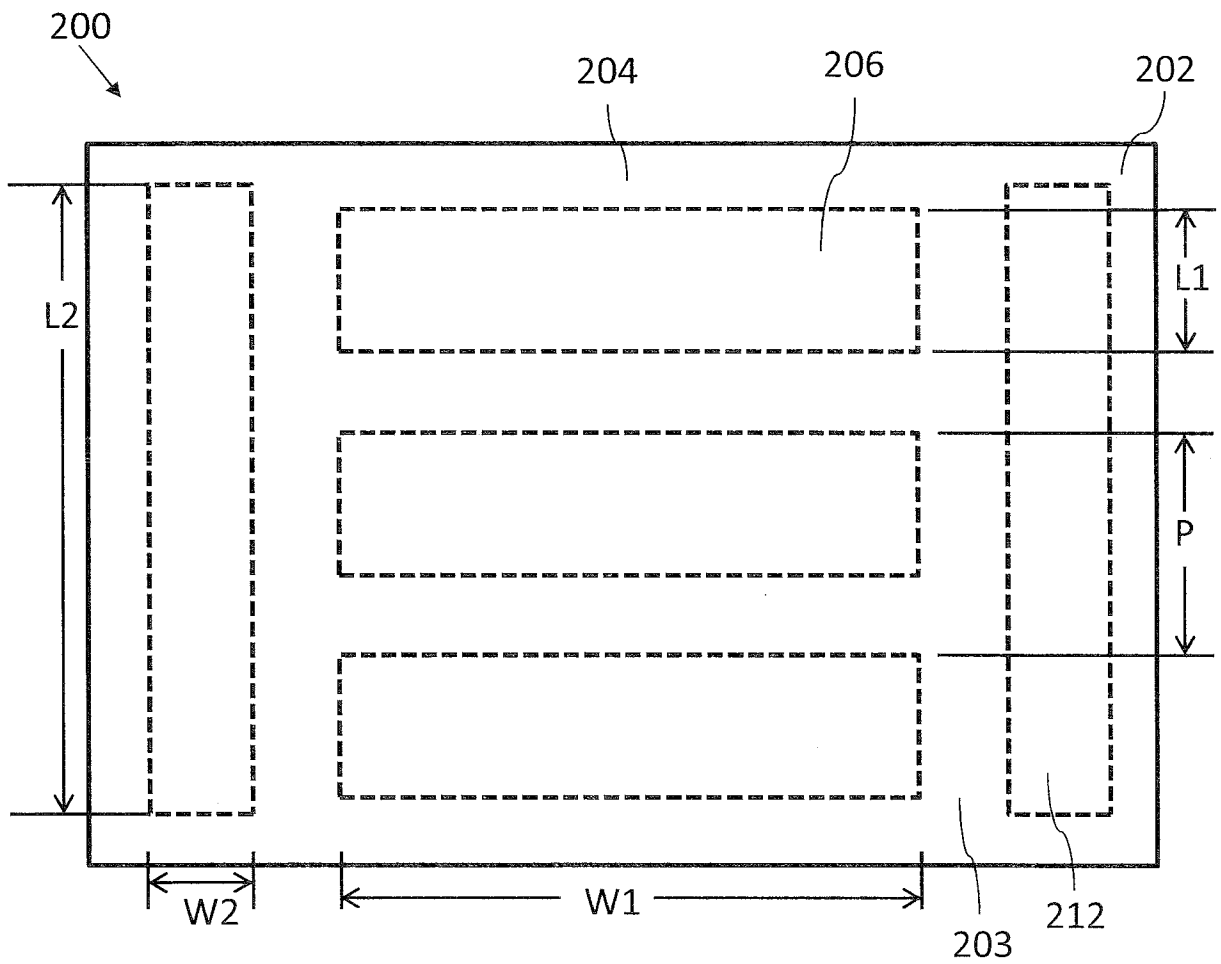


FIG. 2B

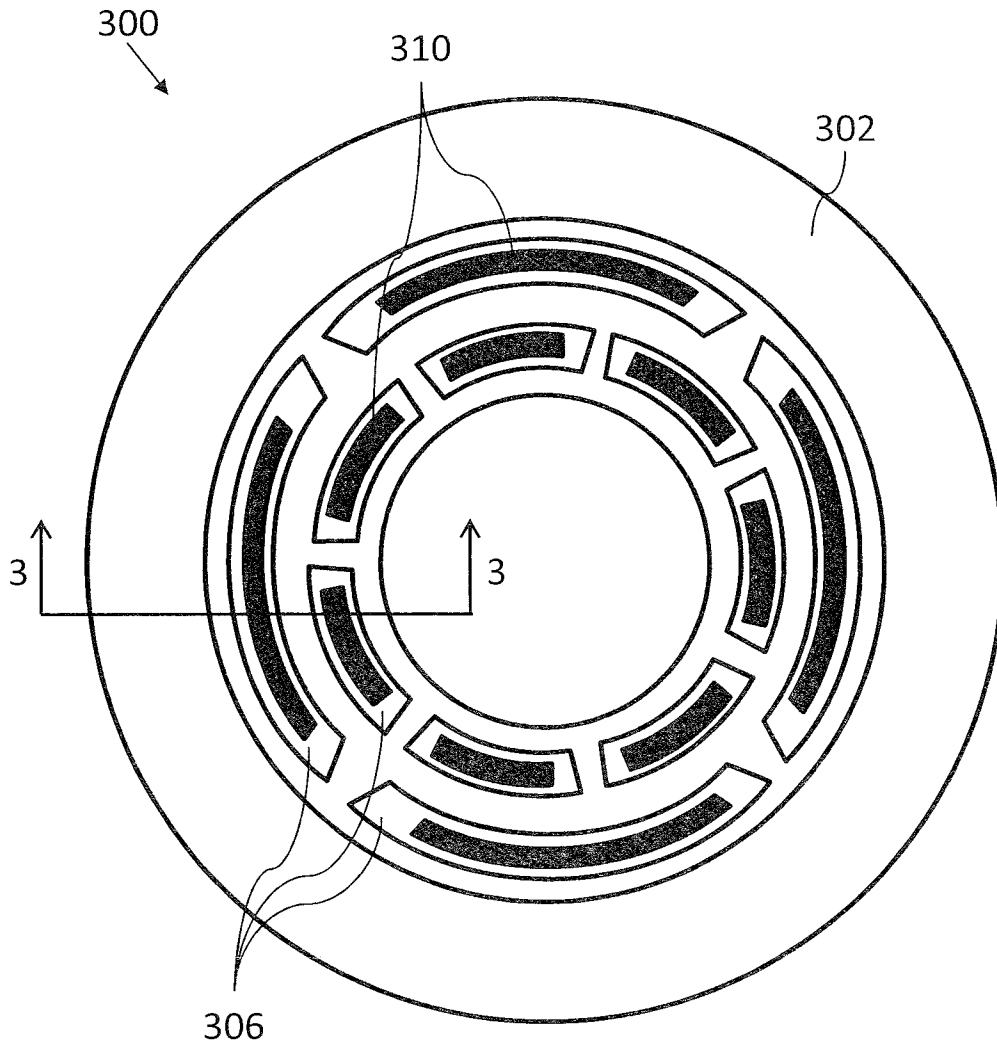


FIG. 3A

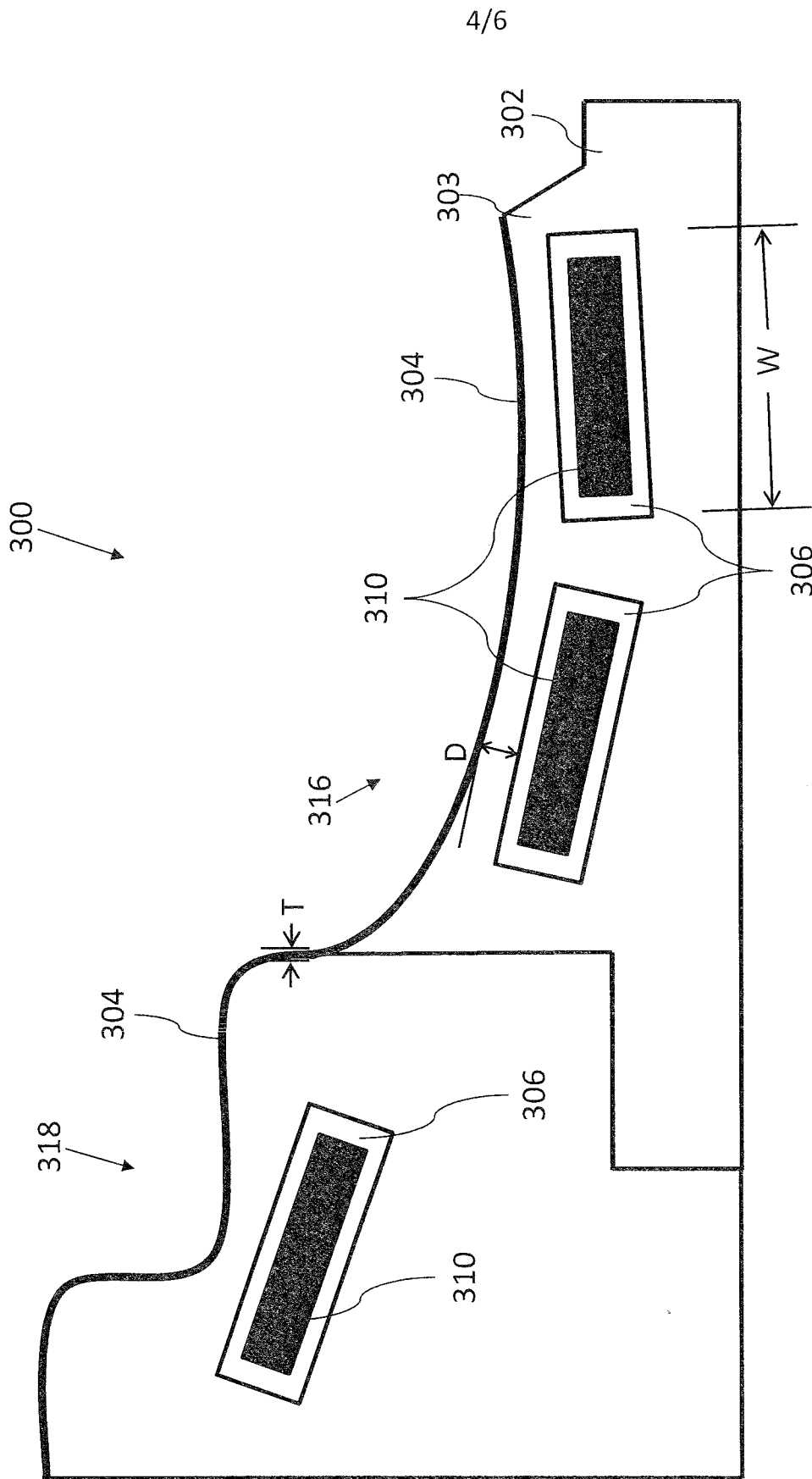


FIG. 3B

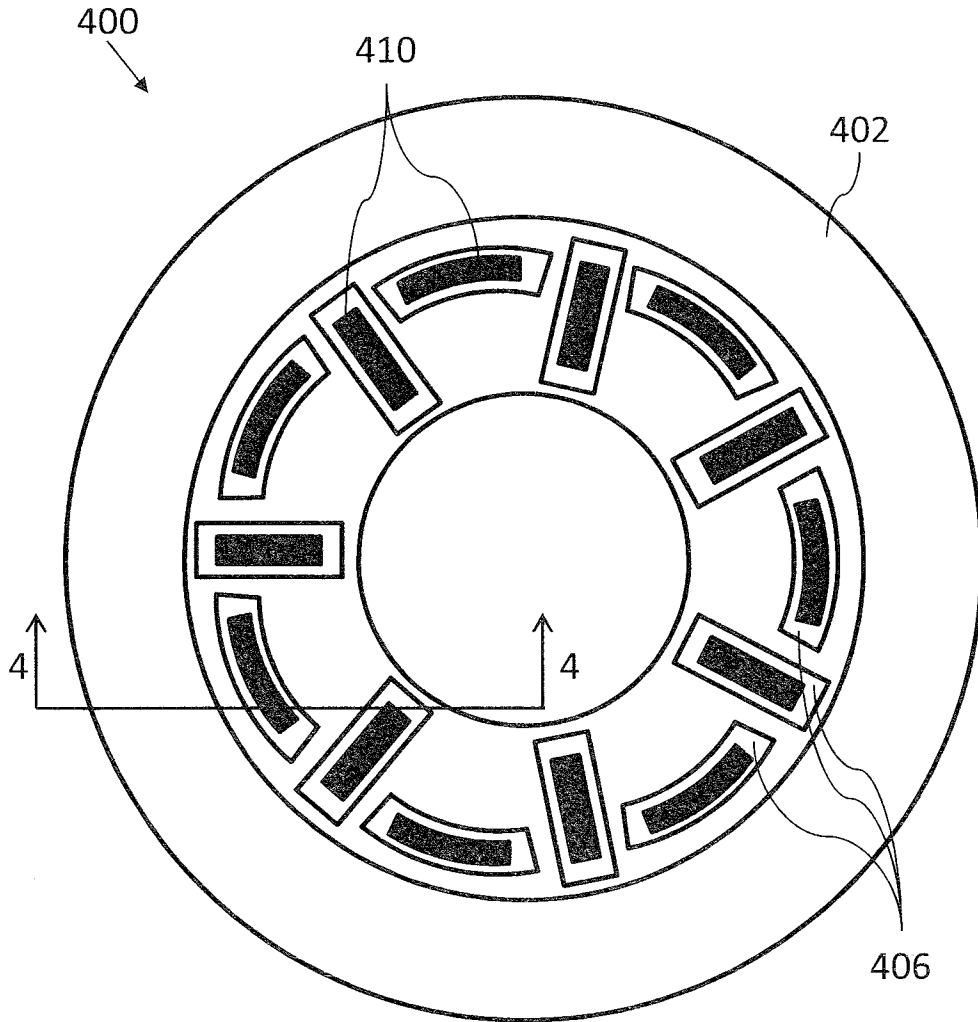


FIG. 4A

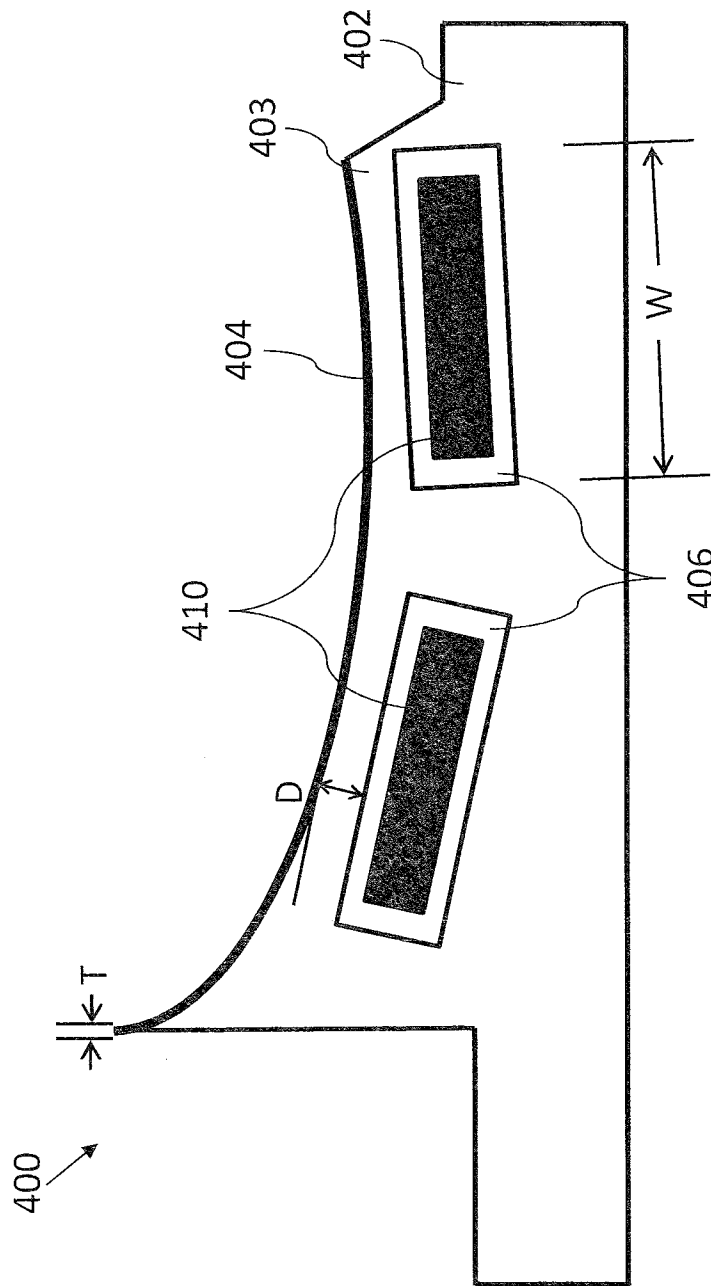


FIG. 4B

## INTERNATIONAL SEARCH REPORT

International application No.  
**PCT/US2015/055279****A. CLASSIFICATION OF SUBJECT MATTER****B29D 30/06(2006.01)i, B29C 33/04(2006.01)j**

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

B29D 30/06; B29K 21/00; B29C 35/02; H05B 6/10; H02K 21/30; B29C 33/02; B29C 35/12; B60C 23/02; B29C 33/04

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models  
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) &amp; keywords: heating, induction heating element, mold, relative permeability, surface, tread, bead, sideplate, pocket

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2012-025126 A (BRIDGESTONE CORP.) 09 February 2012 See abstract; paragraphs [0032]-[0048]; figures 1-3.	8-13, 15-18
A		1-7, 14, 19
Y	US 2009-0308861 A1 (OKADA, KAZUTO et al.) 17 December 2009 See abstract; paragraphs [0053]-[0056]; figures 1-5.	8-13, 15-18
A	JP 2002-036244 A (KOBE STEEL LTD.) 05 February 2002 See abstract; paragraphs [0007] and [0025]; figures 1-4.	1-19
A	KR 10-2003-0043245 A (HANKOOK TIRE WORLDWIDE CO., LTD.) 02 June 2003 See abstract; pages 2 and 3; figures 1-3.	1-19
A	JP 2004-023904 A (BRIDGESTONE CORP.) 22 January 2004 See abstract; paragraphs [0011]-[0015]; figures 1-5.	1-19

 Further documents are listed in the continuation of Box C. See patent family annex.

\* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&amp;" document member of the same patent family

Date of the actual completion of the international search

21 December 2015 (21.12.2015)

Date of mailing of the international search report

**22 December 2015 (22.12.2015)**

Name and mailing address of the ISA/KR

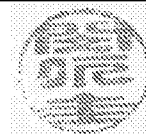
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**INTERNATIONAL SEARCH REPORT**

Information on patent family members

International application No.

**PCT/US2015/055279**

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