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COMPOSITE WHEEL WITH FIBER-REINFORCED MOLDING COMPOUND HAVING MULTIPLE RESIN CHEMISTRIES, AND METHOD

Abstract

A composite wheel structure is made from a fiber-reinforced molding compound (FRMC) material having different resins at different axial sections of the wheel. The FRMC material can be provided as a roll of material, with different resin chemistries at different lateral sections, and applied to a wheel mold such that the different resin chemistries are provided at different axial sections. A single carrier film may have different resin chemistries at different sections, and chopped reinforcement fibers can be deposited across the width of the film. Multiple separate carrier films with different resin chemistries can be arranged side by side, and the chopped fibers added to the combined width. Reinforcing material can be provided in a prepreg and chopped and added to single carrier film at different width sections. The chopped fibers and different resins can be impregnated together to define the multi-resin FRMC material for use in the wheel layup.

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Background/Summary

FIELD

[0001] The present disclosure relates to a vehicle wheel construction. More particularly, the present disclosure relates to a composite vehicle wheel construction including fiber-reinforced molding compound and different properties across the axial direction of the wheel.

BACKGROUND OF THE DISCLOSURE

[0002] Passenger vehicle wheels are known in the art, and are typically formed of one or more materials to define the shape of the wheel. The wheel may be sized and shaped such that it is configured to support a tire mounted thereon, and such that the wheel may be mounted to a rotatable axle so the wheel can be driven by a vehicle transmission and rotated in response to the vehicle being driven.

[0003] Different portions of the wheel have different strength or temperature requirements based on the different functions performed by the different portions. Accordingly, the wheel may have various thicknesses, fiber angles, and/or reinforcement materials that are used throughout the different wheel portions or areas.

[0004] For example, a typical wheel may include a pair of tire bead flanges, such as an inner bead flange and an outer bead flange. The bead flanges typically must have very high impact performance and toughness to perform well when subjected to a pothole impact. Thus, increasing the toughness at this area is advantageous.

[0005] It is also known that in the area of the wheel that interfaces with the vehicle brake calipers, it is desirable to have an elevated temperature performance, such that the wheel material can sufficiently withstand the increased temperatures that result from the friction generated during a braking operation.

[0006] Typical composite wheel manufacturing processes utilize the same resin or material matrix for the entire wheel construction. This process therefore results in a single material being used for each of the areas of the wheel. Wheels may be manufactured using the same resin and varying the radial thickness of the wheel to provide different strengths at different portions of the wheel. Nevertheless, the use of the same matrix material will result in a compromise between strength, temperature performance, and cost.

[0007] One solution for the different requirements of the wheel is the use of different resins for different portions of the wheel. In some approaches, different resins can be “co-cured” to produce a wheel with different strength and temperature performance at different locations.

[0008] Various approaches may be used to construct a wheel with different resins. In one approach, a first preform is constructed which includes one matrix system, which may be uncured or already cured. A second preform may be constructed using a different matrix system, which may be cured or uncured. The preforms may then be placed in a mold together and then cured together.

[0009] In another approach, a preform, such as a fiber preform, may be placed in a Resin Transfer Mold (RTM), where a liquid thermoset resin is used to saturate the fiber preform in a closed mold.

The result is that the preform becomes embedded in the thermoset resin. In this approach, a first matrix system may be infused into one region of the preform, and a second matrix system is infused into another region of the preform. The two matrix systems may then be cured together to define an overall composite with the embedded preform.

[0010] The above-described methods are typically used for simplifying the bonding of multiple composite parts. The result is typically a difference in thickness along the axial width of the wheel. Put another way, there can be multiple layers of material. In this approach, each layer uses the same matrix, but some of the layers along the thickness of the wheel have different properties.

[0011] In the above-described approach, the reinforcement materials are not continuous across the multiple resin regions. Put another way, one reinforcement area with a first resin material will overlap another portion with a reinforcement area with a second resin, such that the first resin overlaps the second resin at an increased thickness area. This method is known as an overlap method, and is illustrated in FIG. **1**.

[0012] In another approach, known as the splice method and shown in FIG. **2**, a first resin material is formed in layers with different lengths, such that a middle layer may have a longer length, and is received in a recess formed between layers, with the second resin material having a shorter length such that the longer length can be received in a recess defined by the shorter length.

[0013] The overlap and/or seam that is created in these prior art solutions is undesirable and can create a part that is overly bulky or lacking in a desirable strength.

[0014] In view of the above, improvements can be made to the construction and reinforcement of composite vehicle wheels.

SUMMARY OF THE DISCLOSURE

[0015] It is an aspect of this disclosure to provide a composite wheel structure with different strength and temperature characteristics in different axial portions of the wheel.

[0016] It is a further aspect of this disclosure to provide a composite wheel structure with a reduced cost.

[0017] It is a further aspect of this disclosure to provide a composite wheel structure formed from a fiber-reinforced molding compound (FRMC) material having different resin chemistries and strength/temperature properties at different axial sections of the wheel.

[0018] It is another aspect of this disclosure to provide a composite wheel structure with a continuous reinforcement layer.

[0019] It is another aspect of this disclosure to provide a method of creating an FRMC material roll having different resin chemistries at different widths or zones, such that the FRMC material can be applied to the wheel mold to provide different FRMC resin chemistries at the different axial locations.

[0020] In one aspect, a single carrier film having multiple resins receives chopped fibers thereon and is impregnated and provided into a roll of multi-resin FRMC material.

[0021] In one aspect, multiple carrier films, each having a different resin, are arranged side-by-side and combined, which receives chopped reinforcement material across the combined width of the carrier films, which are impregnated and combined together into a roll of multi-resin FRMC material.

[0022] In one aspect, multiple single-resin FRMC prepregs are provided and chopped, and deposited in different zones across the width of a single carrier film, and then impregnated and rolled into a roll of multi-resin FRMC material. Alternatively, the chopped prepreg fiber may be deposited directly to a wheel mold, layup aid, or similar tooling, allowing deposition of chopped prepreg fiber of various resin chemistry to different portions of the wheel preform(s).

[0023] In one aspect, a composite wheel structure includes: a wheel body defining an axis of rotation, an axial extent, and a first axial section and a second axial section adjacent the first axial section disposed within the axial extent; at least one layer of composite material extending axially through the first and second axial sections; wherein the composite material is a fiber-reinforced molding compound (FRMC) material having a plurality of fibers distributed randomly along the axial extent through the first and second axial sections; wherein the FRMC material has a first resin chemistry in the first axial section and a second resin chemistry in the second axial section, wherein the first and second resin chemistries are different and have different strength and temperature characteristics.

[0024] In one aspect the composite wheel structure includes at least one oriented fiber reinforcement extending circumferentially through the FRMC material and fully around the axis of rotation.

[0025] In one aspect the composite wheel structure includes at least one continuous fiber reinforcement layer extending circumferentially fully around the axis of rotation and axially through the first and second axial sections.

[0026] In one aspect, the wheel body includes a rim and a wheel center integrally formed with an axial end section of the rim, wherein the wheel center includes at least one layer of FRMC material.

[0027] In another aspect, a method of creating a fiber-reinforced molding compound (FRMC) for use in constructing a composite wheel structure includes the steps of: providing at least one carrier film having an overall lateral width; depositing chopped fibers randomly onto the at least one carrier film; combining the chopped fibers with first and second resins on the at least one carrier film, wherein the first and second resins having different resin chemistries, wherein the first resin is disposed in a first lateral section of the overall lateral width and the second resin is disposed on a second lateral section of the overall lateral width; and impregnating the first and second resins with the chopped fibers and defining a FRMC material.

[0028] In one aspect, the at least one carrier film is a single carrier film having the overall lateral width and the first and second resins are each deposited on the single carrier film.

[0029] In one aspect, the first and second resins are deposited on the single carrier film prior to depositing the chopped fibers onto the single carrier film.

[0030] In one aspect, the at least one carrier film comprises a first carrier film and a second carrier film, wherein the first carrier film defines a first lateral width and the second carrier film defines a second lateral width, wherein the first and second lateral width combine to define at least a portion of the overall lateral width, wherein the first resin is disposed on the first carrier film and the second resin is disposed on the second carrier film.

[0031] In one aspect, the first resin is deposited on the first carrier film prior to depositing the chopped fibers and the second resin is deposited on the second carrier film prior to depositing the chopped fibers.

[0032] In one aspect, the method includes laminating the chopped fibers with at least one further carrier film applied onto the chopped fibers.

[0033] In one aspect, the further carrier film has further first and second resins, wherein the further carrier film is laminated such that the further first resin overlies the first resin, and the further second resin overlies the second resin.

[0034] In one aspect, the chopped fibers are provided from a roll of reinforcement fiber.

[0035] In one aspect, the chopped fibers are provided from a unidirectional prepreg material having unidirectional fibers and the first or second resin, wherein the unidirectional prepreg material is chopped and provides both the chopped fibers and the first or second resin onto the at least one carrier film.

[0036] In one aspect, the FRMC material is formed into a roll after the impregnation step.

[0037] In one aspect, the method includes layering the FRMC material on a wheel mold, such that a first axial section of the wheel mold has the first resin with the chopped fibers and a second axial section of the wheel mold has the second resin with the chopped fibers, and forming a composite wheel having the FRMC material with different resin chemistries in different axial sections of the composite wheel.

[0038] In one aspect, the at least one carrier film is provided as a bare carrier film from a roll without the first and/or second resins, and the first and second resins are deposited on the at least one carrier film in line with the depositing, combining, and impregnating steps.

[0039] In one aspect, the depositing of the chopped fibers onto the at least one carrier film occurs prior to depositing the first and/or second resin.

[0040] In one aspect, the at least one carrier film is provided from a roll with the first and/or second resin pre-deposited on the roll.

[0041] In one aspect, the chopped fibers are deposited randomly and continuously across the overall lateral width of the at least one carrier film.

[0042] In another aspect, a method of constructing a reinforced composite wheel on a mold tool having an axial extent includes the steps of: providing a first unidirectional prepreg material having a first resin chemistry and unidirectional reinforcing fibers; providing a second unidirectional prepreg material having a second resin chemistry and unidirectional reinforcing fibers; slicing and chopping the first unidirectional prepreg material to define a first chopped prepreg; slicing and chopping the second unidirectional prepreg material to define a second chopped prepreg; depositing the first chopped prepreg directly onto a first axial section of the mold tool; depositing the second chopped prepreg directly onto a second axial section of the mold tool; and producing a fiber-reinforced layer of material in the mold tool from the first and second chopped prepregs, wherein the fiber-reinforced layer of material has different resin chemistries at different axial sections of the mold for producing a composite wheel having an axial extent with different resin chemistries at different axial sections.

Description

A BRIEF DESCRIPTION OF THE DRAWINGS

[0043] Other aspects of the present disclosure will be readily appreciated, as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

[0044] FIG. **1** is a schematic view of a prior art system in which multiple matrix materials and multiple reinforcement layers overlap each other;

[0045] FIG. **2** is a schematic view of a prior art system in which multiple matrix materials and multiple reinforcement layers are spliced together;

[0046] FIG. **3** is fragmentary perspective view of a composite wheel having multiple matrix materials across an axial width of the wheel;

[0047] FIG. **4**A is a schematic cross-sectional view illustrating a continuous reinforcement layer having multiple matrix materials, showing the reinforcement layer after consolidating the reinforcement layer and the multiple matrix materials;

[0048] FIG. **4**B is a schematic cross-sectional view illustrating a continuous reinforcement layer having multiple matrix materials, showing the reinforcement layer before consolidating the matrix materials with the continuous reinforcement layer;

[0049] FIG. **5** is a perspective view illustrating multiple matrix films being applied to a single reinforcement layer;

[0050] FIG. **6** is a perspective view of a manufacturing setup illustrating multiple matrix materials being applied to a single substrate for later being applied to a single reinforcement layer;

[0051] FIG. **7** is a schematic view of a composite wheel having at least one layer of FRMC material with different resin chemistries at different axial locations;

[0052] FIG. **8** is a schematic view of a wheel rim portion having at least one layer of FRMC material with different resin chemistries at different axial locations;

[0053] FIG. **9** is a perspective view of a roll of FRMC prepreg material for use in the wheel layup process, having different resin chemistries at different widths or zones;

[0054] FIG. **10**A-B illustrates a method of making the FRMC prepreg material of FIG. **9** by adding chopped reinforcement fibers to a single carrier film having different resins in different widths or zones following by lamination, impregnation, rolling;

[0055] FIG. **11**A-D illustrates another method of making the FRMC prepreg material, including joining multiple separate carrier films having different resins side-by-side and depositing chopped fibers to the combined carrier film; and

[0056] FIG. **12**A-B illustrates another method of making the FRMC prepreg material, including providing multiple single-resin FRMC prepregs, chopping the prepregs, and depositing the chopped prepregs onto a single carrier film, followed by impregnation and rolling into a final FRMC prepreg roll having multiple resin chemistries in different widths or zones.

DESCRIPTION OF THE DISCLOSURE

[0057] Referring to FIG. **3**, a vehicle wheel **10** construction is provided having multiple matrix materials across the axial width of the wheel **10**. The wheel **10** may include a wheel body **12** having multiple axial zones, areas, or portions **12***a*, *b*, *c*, *d*, etc. The body portions may be referred to generally using the reference numeral **12**, with specific zones being referred to as **12***a*, *b*, *c*, *d*, etc.

[0058] The zones **12** may be formed as a continuous fiber layer having different resin materials used in the different zones **12**. As shown in FIG. **1**, a first zone **12***a* may be disposed at and may define an axially inner end portion of the wheel **12**, and may further define an inner bead **14**. A second zone **12***b* may extend generally axially outwardly away from the first zone **12***a*, and may define a generally cylindrical portion **16**. A third zone **12***c* may extend generally axially outwardly from the second zone **12***b*, and may define a curved or tapered cross-section with a diameter that reduces relative to the second zone **12***b* along the axial width of the wheel **10**, which may be described as a curved portion **18** or stepped portion. A fourth zone **12***d* may extend generally axially outwardly from the third zone **12***c*, and may have a diameter that increases relative to the third zone **12***c*. The fourth zone **12***d* may define an outer bead **20**. It will be appreciated that the reference to extending generally axially outwardly refers to the general direction away from the inner bead **14**, and may include tapering or other complex diameter changes, and should not necessarily be interpreted as extending parallel to the rotational axis of the wheel due to the possible tapering and diameter changes.

[0059] It will be appreciated that the illustrated arrangement and number of zones **12** may be modified in accordance with design needs. As further described below, the illustrated zones **12***a*-**12***d* may be tailored to accommodate a particular use environment, such as for temperature resistance or strength at different areas. Of course, given the various temperature and strength needs for different designs, additional zones may be included, or the relative sizes of the illustrated zones **12***a*-**12***d* may be modified. For purposes of further discussion, the number and arrangement of zones **12***a*-**12***d* will be referenced herein.

[0060] The inner bead **14** and the outer bead **20** may be sized and configured to support a tire (not shown) in a traditional manner, such that the tire may be inflated when mounted and sealed to the wheel **10** in a manner known in the art.

[0061] The zones **12** may combine to define an outer surface **22** and an inner surface **24**. The outer surface **22** faces radially outward and combines with a mounted tire to define an interior space within the tire in which pressurized air may be introduced to inflate the tire. The inner surface **24** faces radially inward and toward the axis of the rotation of the wheel. The inner surface **24** may be the surface that interfaces with a vehicle braking mechanism or is disposed near or adjacent a braking mechanism (not shown). The braking mechanism, as is known, will generate a substantial amount of heat during operation. In one approach, the third zone **12***c* that defines the curved portion **18** is the area of the wheel **10** that may interface or be disposed adjacent or near the brake mechanism, and may therefore be the portion of the wheel **10** that receives a large amount of heat from the braking mechanism.

[0062] However, it will be appreciated that other zones of the wheel **10** may be subjected to increased temperature due to braking mechanisms, or the like. Accordingly, it will be appreciated that the zone **12***c* may extend further axial distances to include these areas of increased temperatures. In another aspect, the zone **12***b* illustrated in FIG. **3** may be the zone that is subjected to increased temperature. For the purposes of discussion, the illustrated zone **12***c* is the zone subjected to increased temperature.

[0063] The inner bead **14** and the outer bead **20** have larger outer diameters relative to the cylindrical portion **16** and the curved portion **18**, and are the portions that directly support the tire that is mounted to the wheel **10**. Accordingly, the inner bead **14** and the outer bead **20** are the portions of the wheel **10** that receive the majority of an impact load, for instance when impacting a pothole or other road imperfection or bump. The inner bead **14** and outer bead **20** are therefore preferably constructed with high strength and toughness to resist such loads and to prevent or otherwise limit damage in the wheel **10** that could lead to depressurization of the tires and require replacement.

[0064] Unlike areas of the wheel **10** disposed near braking mechanisms, the inner bead **14** and the outer bead **20** of the wheel **10** do not typically undergo significant temperature increases during operation. Accordingly, the first zone **12***a* and the fourth zone **12***d* may be constructed with a high toughness material but without requiring high temperature performance. Put another way, these zones defining the inner bead **14** and outer bead **20** may have high toughness performance but low temperature performance. In one approach, the resin used for these zones may be an epoxy resin material, but it is understood this may be any polymeric or non-polymeric material. As used herein, the various materials that can be used in the various zones may also be referred to as matrix materials.

[0065] The third zone **12***c* may be the zone that receives a large amount of heat because of its proximity to the brake caliper. In operation, this region of the wheel **10** may undergo temperatures as much as 300 degrees F. above the other zones of the wheel **10**. In one approach, a polymer from a different polymer family relative to the first and fourth zones **12***a* and **12***d* may be used. For example, a polymer from the Bismaleimide family may be used in the third zone **12***c*, while the other zones use an epoxy. In general, the matrix material used in this zone **12***c* may have a higher temperature performance and consequently a lower toughness than the matrix materials used in zones **12***a* and **12***d*. The third zone **12***c* is disposed radially inward relative to the inner bead **14** and the outer bead **20**, and therefore does not undergo substantial impact forces from potholes and the like. Accordingly, the third zone **12***c* may have a relative low toughness performance.

[0066] As used herein, reference to low, high, or the like in toughness performance or temperature performance is intended to refer to performance levels relative to other portions of the wheel **10**. For example, the zone **12***c* having a relative low toughness performance may be understood to mean a lower toughness performance relative to the zones **12***a* and **12***d*. Similarly, the zones **12***a* and **12***d* having a relative high toughness performance may be understood to mean a higher toughness performance than the zone **12***c*.

[0067] The second zone **12***b*, which is disposed axially between the first zone **12***a* (requiring high toughness but allowing low temperature performance) and the third zone **12***c* (requiring high temperature performance but allowing low toughness), may be constructed to have both low toughness and low temperature performance. The second zone **12***b* may have this low toughness and low temperature performance because this zone does not receive substantial impact loads because it is radially recessed relative to the inner bead **14** and the outer bead **20**, and further because it does not undergo substantially high temperatures like the third zone **12***c*. Thus, the second zone **12***b* may be constructed using low cost materials because it does not require these levels of high performance. In this aspect, the second zone **12***b* having low toughness and temperature performance may be understood to mean a lower toughness performance relative to the zones **12***a* and **12***d* and a lower temperature performance relative to zone **12***c*.

[0068] Moreover, it will be understood that different zones both being described as having low toughness performance may have differing levels of toughness performance relative to each other. For example, with both the zones **12***b* and **12***c* having low toughness performance relative to the zones **12***a* and **12***d*, one of the zones **12***b* or **12***c* may have a lower toughness performance than the other of zone **12***b* or **12***c*.

[0069] For the purposes of illustration regarding temperature and strength performance, the following exemplary performance values may be used herein.

[0070] Low temperature performance may have a Tg between 80 C and 120 C. High temperature performance may have a Tg above 180 C. Tg refers to the glass-liquid transition, or glass transition, value. Glass-liquid transition, or glass transition, is the gradual and reversible transition in amorphous materials (or in amorphous regions with semicrystalline materials) from a hard and relatively brittle "glassy" state into a viscous or rubbery state as temperature is increased. The glass-transition temperature Tg of a material characterizes the range of temperatures over which this glass transition occurs. The Tg value is lower than the melting temperature of the crystalline state of the material, if one exists.

[0071] High toughness performance may refer to a fracture toughness of 1000 J/m∧2 to 2000 J/m∧2. Low toughness performance may refer to a fracture toughness of less than 500 J/m∧2.

[0072] With reference to FIG. **4**, the multiple zones of the wheel body **12** may be constructed in a continuous manner, unlike the prior art solutions of overlapping or splicing of reinforcements utilizing different matrix systems and separate fiber reinforcement. Rather, the multiple zones of the body **12** of the wheel **10** may have a continuous single fiber reinforcement layer **30**, but with multiple different matrix or resin materials across the axial width of the reinforcement layer **30**. For example, the single layer **30** may act as the base, skeleton, body, or the like to which the various resin formulations and/or matrix materials are incorporated in the reinforcement layer **30**, which may be in the form of a preform. Incorporating the resin formulations into the preform is performed at the reinforcement level. Alternatively, the incorporation of the resin formulations can be performed at the component level or laminate level. As used herein, it will be appreciated that reference to a "continuous" layer in this disclosure does not require that the fiber itself is continuous, but that the layer of fiber is continuous, with various types of fiber arrangements and distributions possible. For example, chopped fibers of various length may be randomly distributed along the continuous layer of fiber. Longer fibers may be controllably distributed in a woven manner or specifically oriented. In each case, the layer of fiber may be considered continuous, even if the individual fibers used are not themselves continuous across the layer.

[0073] The reinforcement layer **30** may be made from a carbon-fiber fabric, fiberglass, Kevlar, or similar material suitable for acting as a continuous reinforcement layer. The resin materials or formulations that are carried on the reinforcement layer **30** can be joined with the reinforcement layer **30** in different ways. For purposes of discussion, the combined resin materials may be referred to as a resin layer **40**.

[0074] In one approach, the resin or matrix materials, in the form of films or layers, can be fully consolidated with the reinforcement layer **30** before the wheel layup process. When the resin or matrix materials are consolidated with the reinforcement layer **30**, this may be referred to as the reinforcement layer **30** being impregnated. When the matrix materials and reinforcement layer **30** are consolidated and impregnated prior to the wheel layup process, this approach may be referred to as "prepregged," where a consolidated preform is defined that can be applied to a mold during the layup process.

[0075] In another approach, one or more resin films or layers **40** may be defined, having one or more matrix materials carried on a substrate, and can be applied to the mold along with the reinforcement layer **30** during the wheel layup process. The reinforcement layer **30** and the resin film can be then be consolidated on the mold in a resin film infusion molding process, also known as "RFI." In this approach, the layers are not "prepregged" because the impregnating occurs on the mold in response to the RFI process. In another approach, a portion of the resin layer **40** is devoid of resin film, leaving a portion of the reinforcement layer **30** uncovered by the resin film layer **40**. The consolidated reinforcement and resin film layer **50** can be prepregged or utilize the RFI process. During consolidation and cure, the portion of the reinforcement layer **30** devoid of resin can be infused with resin from the adjacent material zones. Alternatively, this portion of the reinforcement layer **30** can be infused with a resin supplied via resin transfer molding or other infusion process during the molding and curing process.

[0076] In either the prepregged process or the RFI process, the matrix materials and the reinforcement layer **30** become consolidated in the consolidated layer **50** in response to the application of heat and pressure.

[0077] The various resin materials that may be used for the different zones **12***a*-**12***d* across the width of the reinforcement layer **30** can be applied as separate films or layers **40** for each material, or as one film or layer **40** with regions of differing resin material. Separate films **40** may be combined with the single reinforcement layer **30** in the prepregged approach or the RFI approach. Similarly, a single layer **40** of multiple resins may be combined with the reinforcement layer **30** in the prepregged approach or the RFI approach. The selection of the prepregged approach vs. the RFI approach can depend on the particular manufacturing capabilities or needs of the user. For example, prepregged layers may require specific handling or storage requirements, and the RFI process may require a specific type of molding equipment.

[0078] In the prepregged approach, the resin layer **40** and the reinforcement layer **30** are heated and partially or completely consolidated together to define the single composite layer **50**, which includes both the reinforcement layer **30** and the resin layer **40**, as shown in FIG. **4**A. The fabric-like structure of the reinforcement layer **30** is embedded within the resin layer **40** when the single composite layer **50** is formed. Multiple composite layers **50** may be prepregged, which may then be applied on a mold for performing the wheel layup process.

[0079] In the RFI approach, the resin layer **40** and reinforcement layer **30** may be separately placed on the wheel mold, and the RFI process is performed that will consolidate and bond the resin layer **40** to the reinforcement layer **30** under heat and pressure, which will impregnate the resin layer **40** with the reinforcement layer **30** on the mold, creating a molded composite layer **50** in the shape of the mold. FIG. **4**A also illustrates the resulting composite layer **50** of the RFI approach having both the reinforcement layer **30** and the resin layer **40** in a single layer.

[0080] In each of the above processes, the resin layer **40** is provided and produced before being applied to the reinforcement layer **30**. As described above, multiple resin materials are used across the width of the reinforcement layer **30**. In the above-described example, there are four zones of the wheel **10** having different toughness or heat requirements and can therefore be four different materials that meet the particular requirements of each zone or region. The resin layer **40** can therefore be provided having multiple materials across its width. The resin layer **40** may include a substrate that may be used to receive the matrix materials, which can later be peeled away.

[0081] The resin layer **40** can be in the form of multiple separate layers **42***a*, **42***b*, etc. (FIG. **5**), or the resin layer can be in the form of a single layer with multiple resin portions **44***a*, **44***b*, **44***c*, etc. (FIG. **4**). It will be appreciated that FIG. **4** may illustrate either a single layer with multiple resin portions or multiple layers laid side-by-side. FIG. **5** shows an example of multiple separate layers. In each of these cases, the resin layer(s) **40** may be produced prior to being applied to the reinforcement material **30**. In the case of separate layers, the resin layer **40** may become a single layer after the separate layers have been consolidated with the reinforcement layer **30**. In each of these cases, the resin or matrix material forming the layers or portions may be applied to a substrate **46**.

[0082] The substrate **46** may be a layer of material on which the resin or matrix materials can be applied, such that the resin layer **40** may be produced and carried on the substrate **46** for later application to the reinforcement layer **30**. The substrate **46** may be a paper, polymeric, or other material suitable to act a substrate for a resin material.

[0083] In one approach, which may be referred to as the multiple film approach and shown in FIG. **5**, the multiple separate resin layers **42***a, b,* etc. each having a different resin material are produced separately and on separate substrates **46**. It will be appreciated that different substrate materials could be used for the separate layers. It will be further appreciated that the same resin materials could be used in separate layers **42***a, b,* etc. and laid adjacent each other or separated by a layer of a different resin material, depending on the desired performance of the resin material along the width of the reinforcement layer **30**. For example, a first resin material may be used for layer **42***a,* a second resin material may be used for layer **42***b,* and the first resin material may be used for layer **42***c.* Or the first material may be used for both zone **42***a* and **42***b,* and a second material may be used for zone **42***c.* The use of different separate layers **42** thereby allows for a modular assembly of resin materials across the width of the reinforcement layer.

[0084] The resin films or layers **42** can be produced using various filming processes. For example, the layers **42***a, b,* etc. may be produced by gravure coating, reverse roll coating, knife-over-roll coating, metering rod coating, slot die coating, curtain coating, all knife coating, spray coating, powder coating, or any other known coating technique. The filming processes, when complete, may therefore produce the multiple separate resin layers **42***a, b,* etc. It will be appreciated that different layers could be made by different coating processes.

[0085] With the multiple layers **42** being produced, they may then be applied to the reinforcement layer **30** for the laminating process. The reinforcement layer **30** and the resin layers **42** may be in the form of a roll of material. The reinforcement layer **30** may be provided, with the separate layers **42** being applied over a surface of the reinforcement layer **30**.

[0086] In one approach, one of the layers **42** may be applied to the reinforcement layer **30** first, thereby covering a portion of the width of the reinforcement layer **30**. The reinforcement layer **30** and the resin layer **42** may then be laminated together, providing a portion of the reinforcement layer **30** in a laminated state. Subsequent resin layers **42** may be applied and laminated in a similar and sequential manner, until the entire width of the reinforcement layer **30** has been covered (or the entire desired amount of the reinforcement layer **30** has been covered). With the multiple matrix materials applied to the reinforcement layer **30**, heat and pressure may be applied to consolidate the layers according to the prepregged approach or the RFI approach.

[0087] In the RFI approach, the reinforcement layer **30** may be placed on the wheel mold separately from the matrix material layers **42**, or the layers may be laminated together and then applied to the mold. In either version of the RFI approach, the layers **42** will be consolidated on the mold to arrive at the consolidated layer **50** illustrated in FIG. **4**A.

[0088] In another approach, each of the layers **42** may be applied to the reinforcement layer **30** side-by-side generally simultaneously or during the same time period. In this approach, the rolls of the layers **42** may be located side by side and the lamination may occur at the same distance along the reinforcement layer **30**. Put another way, at a given longitudinal location along the reinforcement layer **30**, the multiple layers **42** may be applied across the width at the same longitudinal location.

[0089] This approach of applying multiple separate layers **42** to the reinforcement layer **30** can thereby provide a laminated and prepregged composite layer **50** that may be applied to the wheel mold in the wheel layup process, or a laminated assembly of layers that can be consolidated in the RFI approach. In the prepregged approach, heat and pressure are applied to the overlaid reinforcement layer **30** and layers **42**, and the consolidated layer **50** is placed on or in the wheel mold. In the RFI approach, the overlaid layers **30** and **42** are placed on or in the mold prior to applying heat and pressure to create the consolidated layer **50**.

[0090] With reference to FIG. **6**, in another aspect, the resin layer **40**, in the form of a single layer with multiple portions **44***a, b, c,* etc., can be produced and subsequently laminated with the reinforcement layer **30**. In this approach, the resin layer **40** may be produced using a filming process in which multiple resin formulations are applied to the substrate **46** at approximately the same time. An example of such a filming process is shown in FIG. **6**, in which a filming setup **60** for a knife-over-roll process is illustrated.

[0091] In this approach, the substrate **46** may be fed in a first direction toward a lower roller **60***a*, and directed upward toward an upper roller **60***b*. At the upper roller **60***b*, the substrate **46** is directed in a second direction that is opposite the first direction. The substrate **46** may be fed in the second direction toward a doctor blade head **62** having multiple sections **64** with damming **66** disposed between the sections **64**. Each section **64** may include a different resin formulation. Thus, as the substrate **46** passes through the sections **64**, the different resin formulations may be applied to the substrate **46**.

[0092] It will be appreciated that in some aspects, the substrate may be fed toward the doctor blade head **62** in another manner, and not necessarily using the two-roller setup illustrated in FIG. **6**.

[0093] As the substrate **46** passes through the sections **64** and the doctor blade head **62**, the resin layer **40** will be formed having different resin material formulations disposed across the width of the substrate **46**, yielding a single resin layer **40** with multiple zones. The resin layer **40** may then be removed from the setup **60**.

[0094] With the resin layer **40** produced using this process, the resin layer **40** is in the form of a single layer, and may then be combined with the reinforcement layer **30** to create the composite layer **50** in a manner similar to that described above for multiple layers. The single resin layer **40** may be applied to the reinforcement layer **30**, and heat and pressure may be applied to the resin layer **40** and the reinforcement layer **30** to form the prepregged composite layer **50**. The composite layer **50** may then be applied to the mold in the wheel layup process. Alternatively, the single resin layer **40** may be applied to the reinforcement layer, and consolidated as part of an RFI process in the mold.

[0095] It will be appreciated that the single layer **40** having multiple different resin zones may also be combined with additional separate layers, and overlaid with the reinforcement layer **30** in a manner similar to that described above for multiple layers **42**.

[0096] In yet another approach, similar to the above-described approach for forming the single resin layer **40**, the substrate material **46** may be fed through multiple filming stations to apply to the multiple resin formulations to the single substrate **46**, rather than a single filming station where the resin formulation are added at approximately the same longitudinal location. For example, the substrate **46** may be passed through a first filming station, and the resin material may be applied across a portion of the width of the substrate **46**. The substrate **46** may continue to be advanced to a subsequent filming station, where another resin material may be applied across a different portion of the width of the substrate **46**. This process may be continued until the desired width of the substrate **46** is covered with the desired resin materials.

[0097] In yet another approach, one resin material may be applied to a portion of the substrate **46** at a first filming station, and then multiple resin materials may be applied at a subsequent filming station. For example, a first resin formulation may be applied at a first filming station, and then second and third resin formulations may be applied at the same filming station, with regions separated by damming or the like.

[0098] Similar to the above, once all of the desired resin materials have been applied to the substrate **46**, the single resin layer **40** may be removed and then applied to the reinforcement layer **30**, and they can then be combined under heat and pressure to define a prepregged composite layer **50**. The composite layer **50** may then be applied to the wheel mold in the wheel layup process. Attentively, the single resin layer **40** and the reinforcement layer **30** may be consolidated on the mold using an RFI process.

[0099] The above-described methods have related to create a prepregged composite layer **50** that is subsequently applied to the wheel mold or creating an assembly of layers for an RFI process that creates a consolidated layer **50** in the mold. In both cases, a resin layer **40** is produced and then combined with a single reinforcement layer **30** under pressure and heat to consolidate the layers. However, the resin material may be applied in other ways, as well.

[0100] In one aspect, a direct reinforcement coating process may be used to apply the different resin or matrix materials to the single reinforcement layer **30**. In this approach, the substrate material and the separate resin layer may not be used in the manner described above. Instead, the resin material may be applied directly to the reinforcement layer **30**. The reinforcement layer **30** may be optionally placed over a backing material, such as a substrate, table, roller, or the like, to limit the resin coating from seeping through the reinforcement layer **30**.

[0101] Upon coating the reinforcement layer with the resin material directly, the reinforcement layer **30** will include the various resin or matrix materials, and may be placed under heat and pressure to produce the composite layer **50**. The composite layer **50** may then be applied to the wheel mold for use in the wheel layup process.

[0102] In each of the above methods, the resulting single composite layer **50** includes a continuous fiber reinforcement extending across the width of the composite layer **50**. This continuous reinforcement will thereby extend continuously across the width of the wheel **10** that is produced, such that there is no seam or break in the reinforcement layer **30**, or an overlap of matrix materials and reinforcing layers. Accordingly, the different portions of the wheel **10** having different temperature or strength requirements can be accommodated with the desired resin formulation in each region that can suit the specific requirements. In this manner, it is not necessary to compromise on the toughness and heat requirements to find a suitable resin that could be applied to all zones. The ability to select a particular resin for the requirement of a particular zone allows for increased toughness capability, increased temperature capability, and reduced cost.

[0103] The above description has focused on a single consolidated layer of reinforcement material and matrix materials that are consolidated to define a single consolidated layer **50**. It will be appreciated that additional continuous layers can be constructed and layered over each other in the wheel layup process. Unlike the prior art processes, the multiple layers are not spliced together, or overlapping at transitions between matrix materials. Rather, the additional continuous layers can provide additional material to increase the radial thickness of the wheel across its width or at select locations. It is understood a composite single consolidated layer **50** having multiple matrix materials may constitute the entire layer stack or any portion of the layer stack. Equally, the multiple consolidated layers **50** having multiple matrix materials can be positioned anywhere within the entire layer stack.

[0104] The above description has been directed to the use of a continuous fiber layer that is impregnated with various matrix materials across its width to be used in the wheel layup process. This continuous fiber layer can also be impregnated and/or used with other material compositions. For instance, the above described continuous fiber layer may be used with a fiber-reinforced molding compound (FRMC) material having different chemistries at different locations, which may be used in a composite wheel construction to provide a composite wheel with different strength and temperature characteristics at different locations in a manner similar to the above.

[0105] Thus, in another aspect, additionally or alternatively to the continuous fiber reinforcement layer, the layer of material extending along the axial direction of the wheel may be continuously reinforced in the form of fiber-reinforced molding compound, in which multiple randomly distributed chopped fibers are distributed across the width of the material layer that extends along the axis of the wheel, thereby providing reinforcement from one axial side of the wheel to the other. Along this layer of reinforcement, different strengths and temperature characteristics can be provided in a manner similar to the above. The FRMC material distribution thereby provides a generally continuous reinforcement in the axial direction of the wheel.

[0106] FRMC material may refer to both sheet molding compound (SMC) and bulk molding compound (BMC), each of which include glass or carbon fibers integrated with a resin and for use in various molding processes, and which provide increased strength relative to traditional resin formulations.

[0107] FIG. **7** illustrates a one-piece wheel **110** made from a FRMC material sheet **150** with different chemistries at different sections depending on the desired strength or temperature characteristics of the wheel **110**. The one-piece wheel **110** includes a rim portion **112** and a center portion **113**. The cross-section of FIG. **7** cross-sectionally illustrates an upper half of the wheel **110** relative to the center axis A of the wheel **110**. The center portion **113** may include the mounting structure for mounting to the wheel carrier or vehicle axle (not shown).

[0108] FIG. **8** illustrates a similar construction of a wheel rim **112** without a center portion. In both FIGS. **7** and **8**, FRMC material with different resin chemistries at different axial sections is used for the construction. For the purposes of discussion, reference will be made to the wheel **110** and/or rim **112**, but it will be appreciated that reference to either the wheel **110** and/or rim **112** can also apply to the composite rim **112** of FIG. **8** that does not include the center portion.

[0109] As shown in FIG. **7**, the wheel **110** includes different FRMC chemistries at different locations or zones. A first zone **112***a* (or zone **1**) is shown on the left side of FIG. **7**. The first zone **112***a* has a first FRMC resin chemistry. A second zone **112***b* (or zone **2**) is shown in a middle section of the rim **112** and has a second FRMC resin chemistry. A further zone **112***c* is shown on the right side of FIG. **7** at the opposite axial end of the rim **112** from the first zone **112***a*. This further zone **112***c* can have yet another resin chemistry, or may have the same chemistry as zone **1** or zone **2**. The various reasons for selecting a particular resin chemistry for a particular section of the wheel was described previously, but in general the different chemistries may be selected to provide different strength or temperature characteristics in different wheel sections to account for the different requirements at these sections in view of the expected use.

[0110] The center portion **113** can also be made of an FRMC material, and can have the first chemistry, second chemistry, or a further chemistry, and/or multiple different chemistries. In addition to the FRMC material and the associated reinforcement that it provides, additional reinforcement material can also be provided in the center portion **113**, including unidirectional carbon fiber, fiberglass, and/or the like, in a manner consistent with the use of additional reinforcement materials provided in the wheel layup process.

[0111] In addition to the different chemistries at different sections of portions of the wheel **110**, the wheel **110** or rim **112** can also include an embedded oriented fiber reinforcement **115**. The oriented fiber reinforcement **115** may be positioned at various locations where additional strength or reinforcement is desired. The orientation of the fiber reinforcement may be such that it revolves around the axis A in a substantially closed loop circumferentially through the entire wheel, or through circumferential sections, and may be distinct and separate from other fiber reinforcements **115** at different locations. The fiber reinforcement **115** may be in the form of a rod or may be in the form of a sheet. The fiber reinforcements **115** may be added to the sheet of FRMC material during the layup process between layers of the material or otherwise as desired.

[0112] The wheel **110**, and the rim portion **112** and/or center portion **113**, may ultimately be constructed using a traditional lay-up process in which multiple layers are applied into or onto a wheel mold (not shown). Thus, more than one layer of material may be present for a given location or section along the wheel, rim, and/or center structure.

[0113] With regard to the one-piece wheel **110** shown in FIG. **7**, in one aspect, the center portion **113** may be constructed of FRMC material with a resin chemistry resulting in high-temperature resistance. The center portion **113** of the wheel **110** can be exposed to relatively high temperatures, and therefore the FRMC with a resin having high-temperature resistance is desirable.

[0114] Optionally, the center portion **113** may include the continuous fiber reinforcement layer **30** described above in at least one of the material layers of the center portion **113**.

[0115] With regard to the rim portion **112**, at least one of the layers used to construct the rim portion **112** may include a high temperature resistance resin chemistry at one axial location along the rim **112** and a high toughness resin chemistry at another axial location along the rim **112**. The rim **112** includes at least one layer of FRMC material. In one aspect, the FRMC material layer has the multiple resin chemistries that provide the different temperature and toughness levels.

[0116] Similar to the center portion **113**, the rim **112** may also include at least one material layer having the continuous fiber reinforcement layer **30**.

[0117] For the rim **112** shown in FIG. **8**, the above discussion regarding the rim portion **112** is similarly applicable. The rim **112** may include at least one FRMC material layer with different resin chemistries and different strength and temperature characteristics at different axial locations. Optionally, the rim **112** may include at least one layer with the continuous fiber reinforcement layer **30**, as well as the optional oriented fiber reinforcements **115**.

[0118] The FRMC material may be provided in the form of FRMC material **150**, which has different chemistries at different locations across its width. For the purposes of discussion, the width of the sheet shall be interpreted as being the axial direction of the FRMC material **150** when rolled, which generally corresponds to the axial direction of the wheel **110** that will be formed from the sheet **150**.

[0119] FIG. **9** illustrates a roll of the FRMC material **150** following its construction. The FRMC material **150** includes first, second, and third zones **150***a*, **150***b*, and **150***c*. The first zone **150***a* has a first resin chemistry. The second zone **150***b* has a second resin chemistry. The third zone **150***c* has a further resin chemistry, which may be the same or different that the first or second chemistries. Regardless of the specific chemistries used, the FRMC material **150** has different chemistries across its width at different zones or sections. These different chemistries can be selected based on the desired strength and temperature performance of the particular wheel where this FRMC material will be applied. Generally, the width of the FRMC material **150** can correspond to the axial width/axial span of the wheel **110** or rim **112** to be constructed.

[0120] The roll of the FRMC material **150** shown in FIG. **9** may also be referred to as an FRMC prepreg roll, in which the FRMC has been provided into or onto a carrier film (being a combination of resin and fibers on a carrier film) and laminated and impregnated to define the FRMC material **150**. The present disclosure provides various methods for the construction of the prepreg roll of the FRMC material **150** shown in FIG. **9**. In the below described methods, in each case a carrier film is provided, which may include resin pre-deposited on the film or where resin is later deposited, with the resin and fibers ultimately being combined with the carrier film resulting in the FRMC material **150**, which can then be stored as a roll.

[0121] FIG. **10**A illustrates a first method for constructing the FRMC material **150** with multiple resin chemistries. FIG. **10**B illustrates a single carrier film **152** in the form of a multi-resin film **152**, in particular in the form of a plastic carrier film with three different resins **152***a*, **152***b*, **152***c* disposed across the lateral width of the film **152**. FIG. **10**A illustrates the use of two rolls of multi-resin film **152**, which are ultimately disposed above and below the randomly distributed reinforcement fiber.

[0122] As shown, a first roll of the multi-resin film **152**, which may be referred to as film **1521** is provided on the left side of the system. This roll of the film **1521** provides the multi-resin film in a left to right direction in the figure. Downstream from the first roll of film **1521**, a chopper **154** is disposed above the film **1521** that is passing below. The chopper **154** receives reinforcement fiber **156** (which may also be provided on a roll or sheet). The reinforcement fiber **156** is fed into the chopper **154**, which chops up the fiber **156** and distributes the chopped fibers **156***a* onto the film **1521** passing below. The chopped fibers **156***a* are distributed randomly on the film **1521**.

[0123] The fibers **156** may be various types of fibers typically used in FRMC, such as glass fibers or carbon fibers. The fibers **156** may have a length of greater than one inch, in one aspect, which provides for added strength across the multi-resin film.

[0124] The film **1521**, having the chopped fibers **156***a*, proceeds toward a location of a second roll of multi-resin film **1522**. The second multi-resin film **1522** is disposed onto the film **1521** having the chopped fibers **156***a*, creating a lamination **158** above and below the randomly deposited chopped fibers **156***a*. The rolls **1521**, **1522** are arranged such that in the lamination **158**, the same resin chemistry is overlaid with a matching chemistry when the films **1521**, **1522** are brought together to laminate the fibers **156***a*. Put another way, the resins layered together on the left edge match each other, the resins in the middle match each other, etc.

[0125] The lamination **158** proceeds to be fed toward an impregnation station **160**, where the film layers **1521**, **1522** with the resins are impregnated and joined together with the chopped fibers **156***a*, which were deposited between the film layers **1521**, **1522**, and thereby the layers are reinforced with the chopped fibers **156***a*, creating the FRMC material **150**, which is then rolled up to define the roll of FRMC material **150**.

[0126] The above method has been described as using multiple existing pre-deposited carrier films in the form of multi-resin film **152**, which may include the resin materials deposited on a carrier film **151**. However, the multi-resin films **152** can also be created in line with the provision of the chopped fiber onto the multi-resin film. For example, a bare plastic carrier film **151** can be provided at a first stage, with the various resins (**152***a*, **152***b*, etc.) being provided onto the bare carrier film **151**, the combination of which creates multi-resin film **152**, after which the chopped fibers **156** are provided onto the now created multi-resin film **152**.

[0127] In another aspect, chopped fiber **156***a* may be provided onto a bare plastic carrier film **151**, with the multiple resins (**152***a*, **152***b*, etc.) then being provided directly onto and mixed with the chopped fiber **156***a* reinforcement material, which was present on the carrier film **151** prior to the depositing of the resins, with lamination occurring downstream.

[0128] In each case, the method of FIG. **10** generally relates to combining chopped fibers **156***a* with a single multi-resin film **152** above and below. It will be appreciated that the reference to the single film refers to the film either above or below the fibers **156** in the lamination, and that two single films are overlaid in this example.

[0129] In another aspect, FIG. **11**A provides a system and method for producing the FRMC material **150** from separate side-by-side resin films **162**, in contrast to the single multi-resin film **152** that spans across the width of the film roll **150** to be created, which was described above in FIG. **10**.

[0130] The separate films **162** may include first, second, and third resin films **162***a*, **162***b*, and **162***c*, which may be deposited on carrier film **161**, similar to carrier film **151**. For the purposes of discussion, each of these resin films will described as being different resin chemistries, however, it will be appreciated that additional resin films may be used, and that one or more of the various separate resin films being provided may have the same resin chemistry, with the resulting FRMC film roll **150** having a different resin chemistry at one section relative to another.

[0131] Similar to the roll of multi-resin film **152**, the resin films **162***a*, **162***b*, **162***c* may each have a resin disposed on the plastic carrier film **161** and may be provided in the form of a roll. Similar to the multi-resin film **152**, the separate films **162** are paired and layered with matching films to create a lamination **168**. For example, an initial first resin film **1621** is provided, which receives the chopped fibers **156***a*, and a further first resin film **1622** is overlaid on the first film **1621** when creating the lamination **168**.

[0132] As shown in FIG. **11**B-D, each of the films **162***a-c* have a width that is less than the overall width of the resulting finished FRMC sheet **150**. The films **162** are arranged and provided side-by-side and adjacent to each other to generally define the resulting overall width. Each of the films **162** are arranged upstream from the chopper **154**. The films **162** are each provided from their individual rolls, which can occur at different locations along the system, or at generally the same location.

[0133] With the films **162***a-c* each provided and arranged side-by-side to span the width of the resulting roll **150**, and the chopped fiber **156***a* is provided onto the adjacent assembled films **162***a-c*. After the chopped fiber **156** has been provided randomly across the combined width of the first films **1621** having resins from films **162***a-c*, corresponding separate films **1622** are laminated over the chopped fibers **156***a* that were deposited on the underlying films **1621** to create lamination **168**.

The lamination **168** continues toward the impregnation station **160**. The films **1621**, **1622** and chopped fiber **156***a* are impregnated together to define the FRMC material **150**, which is rolled up a roll of FRMC material **150**.

[0134] Similar to the method of FIG. **10**, rather that provide the different separate films **162** in a pre-deposited roll, the films **162** with the resins **162***a-c* can be created in-line with the system, where bare plastic carrier films **161** are provided, and the different resins are provided onto the bare carrier films **161** as they are fed toward the chopper **154** to receive the fibers, and prior to creating the lamination **168**.

[0135] FIG. **12**A-B provides another method of constructing the FRMC roll **150**. As shown in FIG. **12**A multiple rolls of unidirectional prepreg material **172** are provided, which are chopped and deposited on a carrier film **174**. Unlike FIGS. **10** and **11**, the carrier film **174** is not initially provided with the resin material. Rather, the roll of unidirectional prepreg material **172** is formed in an earlier process. For example, in an earlier process, a single resin material is impregnated with unidirectional fibers and formed into the unidirectional prepreg roll **172**, which includes a single resin. These single resin unidirectional prepreg rolls **172** can be chopped up at a chopper disposed at a given location, such that a selected combination of resin and fibers can be selectively deposited at different locations across the carrier film **174**. More particularly, the prepreg material **172** (which includes resin and fiber) is slit, chopped, and deposited on a section of the bare carrier film **174**. In one aspect, the bare carrier film may be paper.

[0136] As shown in FIG. **12**A, the carrier film **174** is distributed from a roll and fed toward a first chopper **154***a* and a second chopper **154***b*. The first chopper **154***a* receives a first unidirectional prepreg material **172***a* (which includes a first resin and a fiber) and chops the unidirectional prepreg material **172***a*, which is deposited onto a section of the carrier film **174**. The first chopper **154***a* is disposed above a specific lateral section the carrier film **174**, such as along an edge section. However, the first chopper **154***a* could also be in the middle of the film **174** or at the right edge, or along some other section along the width of the film. The first chopper **154***a* is disposed upstream of the second chopper **154***b*, but it will be appreciated that different relative locations along the length of the system may be used.

[0137] The second chopper **154***b* receives a second unidirectional prepreg material **172***b* (which includes a combination of resin and fibers) having a different resin chemistry than the first prepreg material **172***a*. Thus, a different section of the carrier film **174** will receive a different resin chemistry. The second chopper **154***b* is arranged at a different lateral section of the carrier film **174** (for example in a middle section, or some other section different from the lateral location of the first chopper **154***a*). Thus, the chopped second prepreg material **172***b* will be deposited adjacent to or in a different lateral section relative to the chopped first material **172***a*.

[0138] The choppers **154***a* and **154***b* are shown at different locations along the length of the system, such that the first chopper **154***a* deposits material before the second chopper **154***b*. However, it will be appreciated that the choppers **154***a* and **154***b* may be at the same location or other different locations along the length of the system relative to each other. Of course, additional choppers may be provided for providing different resins at different sections of the lateral width of the carrier film **174**. With the chopped unidirectional prepreg material **172** disposed on the carrier film **174**, the film **174** is fed through the impregnation station **160**, thereby creating the FRMC material **150** with the different resin chemistries in different lateral sections, which is then rolled up into the roll of FRMC material **150**.

[0139] The unidirectional prepreg material is shown in the form of a roll **172**, having been created in a separate process. However, it will be appreciated that these unidirectional prepreg materials may also be provided in line with the process of FIG. **12**. For example, a bare carrier film (similar to films **151** or **161**) may receive resins, or a film with resin can be provided, upstream, followed by lamination and impregnating the resin film with unidirectional fibers, which is then fed toward the first or second chopper **154***a*, **154***b* for being deposited onto the different sections of the carrier film **174**.

[0140] In another embodiment, the unidirectional prepreg **172** described above can be slit, chopped, and deposited (sprinkled) directly into a cure tool, layup tool, or preforming tool. This allows the making of the FRMC roll **150** to be skipped. Instead, the narrow, chopped prepregs **172** of different resin chemistries can be deposited directly into different lateral sections of a mold tool to lay up the complete part or portions of the part. From these deposited prepregs, a reinforced layer of material can be created in the mold and have different resin chemistries at different lateral sections.

[0141] In each of the above processes of FIGS. **10-12**, a roll of FRMC material **150** with different resin chemistries in different sections results from the process, and can be provided for use in the wheel layup process. This material **150** may be provided onto the wheel layup mold and aligned so that the different resin chemistries are disposed at the desired axial locations of the wheel **110**, rim **112**, and/or center **113**.

[0142] In yet another aspect, an alternative method of using FRMC material in a wheel layup process is provided. In this method, separate sheets of different FRMC material are provided directly to the wheel mold in the layup process. The materials may be arranged adjacent each other, such that one FRMC material is in one axial portion of the rim **112** and another FRMC material is in another axial portion of the rim **112**. Additional FRMC material sheets with the same or different chemistries may be provide in additional locations of the rim **112** or center **113**. In this approach, the separate sheets of the FRMC materials may overlap each other or may abut each other. The wheel layup process, molding, and curing can continue according to the known molding process.

[0143] Each of the above processes regarding the FRMC material may be arranged and/or modified according to the needs of the user. For instance, the reinforcement fibers **156** can be chopped in line with the processes, as shown, or the fibers **156** can be chopped in a separate process and then provided onto the various carriers and/or films.

[0144] In each case, the various resin chemistries may have different toughness characteristics. In each case, the various resin chemistries may have different glass transition temperature properties.

[0145] The resin chemistries can have different resin chemistry types. For example, the resins can be BMI, epoxy, polyurethane, etc.

[0146] The FRMC material, however formed, can be used to form a fiber-reinforced polymer rim preform and/or a fiber-reinforced polymer center preform.

[0147] The FRMC material may be in a sheet format and referred to as sheet molding compound (SMC) and/or may be provided in a non-sheet format and may be referred to as bulk molding compound (BMC).

[0148] In the resulting wheel **110**, rim **112**, and/or center **113**, the outermost ply of the composite may be fabric or FRMC. In this outermost ply, the layer may include UV-stable resin chemistry. The outermost play may utilize a different resin chemistry than the rest of the wheel and/or underlying layers. The outermost layer may have high thermal dissipation properties or insulating properties.

[0149] The various resin chemistries may be developed to have similar or dissimilar rheology properties.

[0150] Obviously, many modifications and variations of the present invention are possible in light of the above teachings and may be practiced otherwise than as specifically described while within the scope of the appended claims. These antecedent recitations should be interpreted to cover any combination in which the inventive novelty exercises its utility.

Claims

1. A composite wheel structure comprising: a wheel body defining an axis of rotation, an axial extent, and a first axial section and a second axial section adjacent the first axial section disposed

within the axial extent; at least one layer of composite material extending axially through the first and second axial sections; wherein the composite material is a fiber-reinforced molding compound (FRMC) material having a plurality of fibers distributed randomly along the axial extent through the first and second axial sections; wherein the FRMC material has a first resin chemistry in the first axial section and a second resin chemistry in the second axial section, wherein the first and second resin chemistries are different and have different strength and temperature characteristics.
2. The composite wheel of claim 1, further comprising at least one oriented fiber reinforcement extending circumferentially through the FRMC material and fully around the axis of rotation.
3. The composite wheel of claim 1, further comprising at least one continuous fiber reinforcement layer extending circumferentially fully around the axis of rotation and axially through the first and second axial sections.
4. The composite wheel of claim 1, wherein the wheel body includes a rim and a wheel center integrally formed with an axial end section of the rim, wherein the wheel center includes at least one layer of FRMC material.
5. A method of creating a fiber-reinforced molding compound (FRMC) for use in constructing a composite wheel structure, the method comprising: providing at least one carrier film having an overall lateral width; depositing chopped fibers randomly onto the at least one carrier film; combining the chopped fibers with first and second resins on the at least one carrier film, wherein the first and second resins having different resin chemistries, wherein the first resin is disposed in a first lateral section of the overall lateral width and the second resin is disposed on a second lateral section of the overall lateral width; and impregnating the first and second resins with the chopped fibers and defining a FRMC material.
6. The method of claim 5, wherein the at least one carrier film is a single carrier film having the overall lateral width and the first and second resins are each deposited on the single carrier film.
7. The method of claim 6, wherein the first and second resins are deposited on the single carrier film prior to depositing the chopped fibers onto the single carrier film.
8. The method of claim 5, wherein the at least one carrier film comprises a first carrier film and a second carrier film, wherein the first carrier film defines a first lateral width and the second carrier film defines a second lateral width, wherein the first and second lateral width combine to define at least a portion of the overall lateral width, wherein the first resin is disposed on the first carrier film and the second resin is disposed on the second carrier film.
9. The method of claim 8, wherein the first resin is deposited on the first carrier film prior to depositing the chopped fibers and the second resin is deposited on the second carrier film prior to depositing the chopped fibers.
10. The method of claim 5 further comprising laminating the chopped fibers with at least one further carrier film applied onto the chopped fibers.
11. The method of claim 10, wherein the further carrier film has further first and second resins, wherein the further carrier film is laminated such that the further first resin overlies the first resin, and the further second resin overlies the second resin.
12. The method of claim 5, wherein the chopped fibers are provided from a roll of reinforcement fiber.
13. The method of claim 5, wherein the chopped fibers are provided from a unidirectional prepreg material having unidirectional fibers and the first or second resin, wherein the unidirectional prepreg material is chopped and provides both the chopped fibers and the first or second resin onto the at least one carrier film.
14. The method of claim 5, wherein the FRMC material is formed into a roll after the impregnation step.
15. The method of claim 5, further comprising layering the FRMC material on a wheel mold, such that a first axial section of the wheel mold has the first resin with the chopped fibers and a second axial section of the wheel mold has the second resin with the chopped fibers, and forming a

composite wheel having the FRMC material with different resin chemistries in different axial sections of the composite wheel.

16. The method of claim 5, wherein the at least one carrier film is provided as a bare carrier film from a roll without the first and/or second resins, and the first and second resins are deposited on the at least one carrier film in line with the depositing, combining, and impregnating steps.

17. The method of claim 16, wherein the depositing of the chopped fibers onto the at least one carrier film occurs prior to depositing the first and/or second resin.

18. The method of claim 5, wherein the at least one carrier film is provided from a roll with the first and/or second resin pre-deposited on the roll.

19. The method of claim 5, wherein the chopped fibers are deposited randomly and continuously across the overall lateral width of the at least one carrier film.

20. A method of constructing a reinforced composite wheel on a mold tool having an axial extent, the method comprising: providing a first unidirectional prepreg material having a first resin chemistry and unidirectional reinforcing fibers; providing a second unidirectional prepreg material having a second resin chemistry and unidirectional reinforcing fibers; slicing and chopping the first unidirectional prepreg material to define a first chopped prepreg; slicing and chopping the second unidirectional prepreg material to define a second chopped prepreg; depositing the first chopped prepreg directly onto a first axial section of the mold tool; depositing the second chopped prepreg directly onto a second axial section of the mold tool; and producing a fiber-reinforced layer of material in the mold tool from the first and second chopped prepregs, wherein the fiber-reinforced layer of material has different resin chemistries at different axial sections of the mold for producing a composite wheel having an axial extent with different resin chemistries at different axial sections.