This disclosure describes new construction for rotary elements that find use in compressor devices, e.g., centrifugal compressors and blowers. This construction utilizes composite materials (e.g., carbon fiber composites) that require less machine time and reduce the weight of the rotary element, while meeting the operational characteristics of compressor devices for use in a wide range of industrial applications. In one embodiment, the rotary element has a bifurcated material design, which uses a first material (e.g., carbon fiber) to form blades and other features of an impeller and a second material (e.g., metal) to form a sleeve with properties that can securely affix the impeller to a drive shaft of the compressor device.
ROTOR ELEMENT AND COMPRESSOR DEVICE COMPRISSED THEREOF

BACKGROUND

[0001] The subject matter disclosed herein relates to rotary elements (e.g., impellers) for use in turbomachines.

[0002] Centrifugal compressors, blowers, and like compressor devices often include an impeller (also “rotor”) that rotates to change the pressure of a working fluid (e.g., gas and liquid). The impeller has blades (also “vanes”) with geometry that can raise the energy of the working fluid. This geometry describes complex shapes and profiles, which in turn define operating characteristics (e.g., operating speed, operating pressure, etc.) for the compressor device.

[0003] The shape of the blades can dictate construction and/or manufacture of the impeller. Use of computer-aided machining tools and similar fabrication techniques, for example, are generally necessary to form the impeller with the appropriate profiles for the blades. These techniques can generate impellers from a single piece of material. In alternative construction, the blades are separate pieces that secure to the impeller, e.g., by welding.

[0004] Conventional impeller designs comprise metals (e.g., aluminum, steel, stainless steel, etc.) compatible with use of the impeller in the compressor device. For example, impellers made of metal can withstand the high pressure and operating speeds of the compressor device. These materials are also resistant to corrosion and other chemically aggravated failure modes due to properties of the working fluid.

[0005] On the other hand, while metals and like materials offer some advantages, these materials can impede progress as relates to compressor performance and cost management. Metals introduce weight constraints that can limit operating speeds for the compressor devices. These weight constraints can also dictate size and/or shapes for impeller, which can narrow the range of applications that require impellers of metal design. Moreover, metals have material properties (e.g., hardness) that can slow manufacture time. These material properties may require extensive machine time because the machining tools must run at slower speeds to render the profiles and other features found on the impeller.

BRIEF DESCRIPTION OF THE INVENTION

[0006] This disclosure describes new construction for rotary elements that find use in compressor devices, e.g., centrifugal compressors and blowers. This construction utilizes composite materials (e.g., carbon fiber composites) that require less machine time and reduce the weight of the rotary element as compared to conventional metal (e.g., steel) designs, while meeting the operational characteristics of compressor devices for use in a wide range of industrial applications. In one embodiment, the rotary element has a bifurcated material design, which uses a first material (e.g., carbon fiber) to form blades and other features of an impeller and a second material (e.g., metal) to form a sleeve with properties that can securely affix the impeller to a drive shaft of the compressor device.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Reference is now made briefly to the accompanying drawings, in which:

[0008] FIG. 1 depicts a schematic diagram of an exemplary embodiment of a rotary element as part of a compressor device;

[0009] FIG. 2 depicts a detail, cross-section view of the rotary element of FIG. 1, which shows an exemplary construction of the rotary element;

[0010] FIG. 3 depicts a perspective view of an exemplary embodiment of a rotary element as part of a compressor device;

[0011] FIG. 4 depicts a perspective view of the rotary element in exploded assembly form;

[0012] FIG. 5 depicts a side, cross-section view of the rotary element of FIG. 4 in assembled form;

[0013] FIG. 6 depicts a front view of the rotary element of FIGS. 4 and 5; and

[0014] FIG. 7 depicts a detail, cross-section view of the rotary element of FIG. 8, which shows an exemplary material layer disposed on a surface of the rotary element.

[0015] Where applicable like reference characters designate identical or corresponding components and units throughout the several views, which are not to scale unless otherwise indicated.

DETAILED DESCRIPTION

[0016] FIG. 1 illustrates an exemplary embodiment of a rotary element 100 that facilitates movement of a working fluid (e.g., gas and liquids). The rotary element 100 includes a body element 102 and a sleeve element 104 that aligns on a rotary axis 106. As shown in schematic form in FIG. 1, the rotary element 100 is part of a compressor device 108, e.g., a centrifugal compressor and/or blower. The compressor device 108 includes a drive unit 110 with a drive shaft 112. The compressor device 108 also has a flow housing 114 with an outlet 116 and an inlet 118 that houses at least part of the rotary element 100 therein. In one implementation, the rotary element 100 secures to the drive shaft 112 via the sleeve element 104. This configuration transfers rotary motion from the drive unit 110 to rotate the rotary element 100, as generally indicated by the arrow enumerated by the numeral 120.

[0017] Broadly, construction of the rotary element 100 uses a bifurcated material design that improves the physical characteristics of the rotary element 100 as compared to conventional, single material designs. This bifurcated design includes a first material and a second material to construct, respectively, the body element 102 and the sleeve element 104. In one embodiment, the second material is different from the first material. The second material can comprise metals (e.g., steel, stainless steel, etc.) and other materials with material properties (e.g., material hardness) that afford the sleeve element 104 with characteristics to couple securely with the drive shaft 112. For example, the second material can withstand loading (e.g., torque loading) that can occur during operation of the compressor device 108. Moreover, the second material can facilitate installation and assembly of the rotary element 100 on the compressor device 108. For example, the second material is amenable to removal of portions, e.g., by drilling and/or machining of material. This feature is helpful to balance the rotary element 100 during fit-up and assembly on the compressor device 108.

[0018] The first material can comprise a composite that provides the body element 102 with characteristics that benefit robust designs of the rotary element 100 for a broad range of applications. Examples of the first material can comprise fiber-reinforced materials, e.g., carbon-fiber reinforced mate-
rials and similar composites and derivations thereof. These types of composites are often chemically inert and/or resis-
tant to corrosive working fluids and, thus, amenable to appli-
cations not often suitable for conventional metal impellers. 
These composites are also amenable to manufacturing pro-
cesses (e.g., machining, turning, milling, etc.) that can shape 
blocks and/or billets of material into the body element 102, 
e.g., with grooves, blades and fins, and other features. This 
characteristic can reduce costs to manufacture the rotary ele-
ment 100. For example, composites may take less machining 
time to form the features of the body element 102 as com-
pared to conventional impellers made of metals. Moreover, 
the ability to manufacture the features of the body element 
102 from a single piece of material, e.g., via machining, 
eliminates certain assembly steps (e.g., welding) and second-
ary processes (e.g., heat treatment) necessary for construction 
of some types of impellers, e.g., found on closed impeller 

pumps.

The first material also affords the rotary element 100 with 
favorable physical properties. Examples of the first 
material can make the rotary element 100 lighter and stiffer 
than impellers made from metals. Carbon fibers and other 
select materials, for example, may reduce the weight of the 
rotary element 100 by 60% or more, e.g., with respect to 
impellers made of steel. Increasing the stiffness of the rotary 

element 100 can raise the modal frequency of the rotary 
element 100. This feature can prevent vibration, e.g., at reso-
nance frequency, and other problems that can limit operating 
speeds for the compressor device 108. The first material 
can also reduce deflection of the body element 102. During operation 
of the compressor device 108, this feature can minimize 
leakage of the working fluid about the periphery of the body 


element 102 by reducing the clearance necessary to allow the 
body element 102 to rotate without interference in the inlet 

118.

The first material can also reduce the weight of the 
rotary element 100, which effectively reduces loading on the 
shaft 112. The resulting loading can, in turn, require smaller 
and/or more compact bearings (e.g., journal bearings) on the 
compressor device 108. The changes in bearing size can 
reduce parasitic losses and, ultimately, improve performance 
of the compressor device 108. In some implementations, 

favorable weight characteristics of the rotary element 100 can 
permit configurations (e.g., larger sizes) of the rotary element 
100 to expand the operating envelope of the compressor 
device 108 to accommodate a broader range of operating 
parameters (e.g., higher speeds and higher pressures) as com-
pared to compressors that use conventional metal impellers. 
Moreover, the lighter weight of the rotary element 100 
increases the bending mode, which in turn can result in con-
figurations of the rotary element 100 that can achieve aerody-
namically optimal length for use in multi-stage compressor 

applications.

FIG. 2 illustrates a schematic diagram of a cross-
section of the rotary element 100 to illustrate one exemplary 
construction of the body element 102. This construction uti-
lizes a composition 122 with one or more components (e.g., 
a matrix component 124 and a woven component 126). The 
unwoven component 126 includes a plurality of fiber compo-
nents (e.g., a first fiber component 128, a second fiber com-
ponent 130, and a third fiber component 132), which include, 
respectively, a first set of fibers, a second set of fibers, and a 
third set of fibers. As shown in FIG. 2, the fiber components 
128, 130, 132 form a multi-layer structure 134 with a plurality 
of layers (e.g., a first layer 136, a second layer 138, a third 
layer 140, and a fourth layer 142).

Broadly, examples of the components 124, 126 are 
found in carbon-fiber reinforced polymers, carbon-fiber rein-
forced thermoplastics, and similar materials that provide 

excellent physical properties (e.g., light weight) and 
mechanical properties (e.g., high strength and stiffness). In 
one example, the composition 122 is generally homogenous 
throughout the body element 102. This homogeneity affords 
the rotary element 100 with uniform properties throughout 
the body element 102 and/or throughout the constituent com-
ponents (e.g., blades and fins) of the body element 102.

The matrix component 124 can comprise a resin of 
one or more polymers, e.g., epoxy, polyester, vinly ester, 
and/or nylon. Selection of the resin may depend on one or 
more operating characteristics of the compressor device 108 
(FIG. 1). These operating characteristics include fluid tem-
perature and fluid pressure. For example, devices that operate 
at high temperatures may require resins that can withstand 
prolonged operation and exposure in those environments. To 
this end, exemplary resins can exhibit properties that with-
stand operating temperatures (e.g., fluid temperatures in the 
compressor device 108 of FIG. 1) of at least about 350°F or 
more.

As mentioned above, the woven component 126 
embodies a three-dimensional (3D) fiber pattern. Examples of 
this fiber pattern arranges the fiber components 128, 130, 
132 in different directions (e.g., a first direction, a sec-
dond direction, and a third direction) to form and to interlock one or 
more of the layers 136, 138, 140, 142 to one another. As 
shown in FIG. 2, the directions can assume mutually orthog-
nonal directions, e.g., an x-direction (the first direction of the 
fiber component 128), a y-direction (the second direction of 
the fiber component 130), and a z-direction (the third 
direction of the fiber component 132). Positioning the fiber 
components 128, 130, 132 in the different directions can make the 
resulting woven component 126 less susceptible to damage 
and failure modes, e.g., where adjacent layers pull apart, or 
delaminate, from one another. These failure modes would 
likely render other fiber-based compositions that do not use 
the interlocking pattern of fibers as ineffective for use, e.g., 
as impellers in the compressor device 108 of FIG. 1.

Fibers in the woven component 126 can include 
carbon fibers, although the present disclosure contemplates 
other fibers that have different material compositions. The 
material composition can determine the physical and 
mechanical properties of the body element 102. Use of carbon 
fibers (and compositions and derivations thereof), for 
example, can reduce the weight, increase the stiffness, and 

improve uniformity of the body element 102 as compared to 
elements that use metals. In one example, the fibers can vary in 
stiffness (also “modulus”), with one example of the fiber 
components 128, 130, 132 utilizing carbon fibers of standard 
and/or intermediate modulus. This disclosure contemplates 
other constructions that may utilize low modulus and high 
modulus fibers, as well as combinations of fibers having 
relatively different modulus (e.g., intermediate and high 
modulus) within the fiber component 126.

FIG. 3 depicts another exemplary embodiment of a 
rotary element 200 that resides in the inlet 218 of the 
compressor device 208. In FIG. 3, the flow housing 214 forms a 
volute 244 that terminates at the outlet 216. During operation, 
the drive unit 210 rotates the drive shaft 212, which rotates the 
rotating element 200. Rotation of the rotating element 200
draws a working fluid (e.g., gas and/or liquid) into the inlet 218. The rotary element 200 compresses the working fluid. The compressed working fluid flows through the volute 244. In one embodiment, the compressor device 208 couples with industrial piping at the outlet 216 to expel the working fluid under pressure and/or with certain designated flow parameters as desired. The flow parameters may correspond to the setting and/or industry that implements the compressor device 200. Examples of these industries include automotive industries, electronics industries, aerospace industries, oil and gas industries, power generation industries, petrochemical industries, and the like.

[0027] FIGS. 4, 5, 6, and 7 illustrate various details of the rotary element 200. FIG. 4 shows the rotary element 200 in exploded form. The body element 202 includes a base 246 and a plurality of blades 248 disposed annularly about the rotary axis 206. The body element 202 also has a first bore 250 with a first bore inner surface 252 that extends through the base 246. The sleeve element 204 has an elongated body 254 with an outer sleeve surface 256.

[0028] Broadly, the body element 202 and the sleeve element 204 integrate with one another to allow the rotary element 200 to operate in the compressor device 208 (FIG. 3). Dimensions for the first bore 250 of the body element 202 and the elongated body 254 allow the elongated body 254 to fit inside of the first bore 250. This fit may cause the first bore inner surface 252 to engage the outer sleeve surface 256, e.g., to form a press fit and/or interference fit of varying frictional contact. In one embodiment, the rotary element 200 may include unidirectional carbon tape and/or pre-impregnated composite fibers (also “prepreg”). These materials may be disposed on the outer sleeve surface 256 along the axis of the elongated body 254. Curing of the tape and/or prepreg can form a mechanical fit or interlocking between the outer sleeve surface 256 and the first bore 250.

[0029] In one embodiment, the rotary element 200 may include one or more fasteners (e.g., screws, bolts, etc.) that penetrate one or more of the body element 202 and the sleeve element 204. These fasteners can help couple the body element 202 with the sleeve element 204, and vice versa. To further enhance engagement, and/or in lieu of the fasteners, the rotary element 200 may include a first material layer (also “first coating”) disposed between, for example, the first bore inner surface 252 and the outer sleeve surface 256. Examples of the first material layer can include adhesives, bonding agents, and/or carbon prepreg tapes, e.g., that adhere to the first material (e.g., carbon-fiber composites) and the second material (e.g., stainless steel).

[0030] FIG. 5 illustrates a cross-section, assembled view of the rotary element 200 (e.g., taken at line 5-5 of FIG. 6). The sleeve element 204 has a second bore 258 with several bore sections (e.g., a first bore section 260, a second bore section 262, a third bore section 264, and a fourth bore section 266). The sleeve element 204 also has one or more puller holes 268. Configurations of the puller holes 268 permit engagement with the rotary element 200 with a tool and/or other implement. This feature allows a technician to remove the rotary element 200 from the compressor device.

[0031] Examples the body element 202 can have a monolithic and/or contiguous structure that integrates the blades 248 with the base 246. As discussed above, use of the first material (e.g., carbon fiber composite) can permit machining of the contours, surface profiles, and features of the blades 248 and the base 246 from a single, block of material. In one example, the block of material comprises a preform of the first material. Preparation of the preform can utilize carbon fibers of standard modulus and/or glass fibers to form a fiber component (e.g., the fiber component 126 of FIG. 2). The fiber component is infused and cured with a matrix component (e.g., the matrix component 124 of FIG. 2). In one example, the matrix component utilizes one or more of an epoxy and phenolic resin, e.g., using resin transfer molding (RTM) and/or vacuum assisted resin transfer molding (VARTM). Examples of the preform can have a diameter in a range from about 125 mm to about 400 mm and a length in a range from about 1500 mm to about 5000 mm. In one implementation, processing of the preform can include cutting the preform into one or more pre-determined blocks of desired length and carbonizing (e.g., at about 800° C.). Further processing can include machining the pre-determined block with a desired geometry, surfaces profiles, and features, e.g., on a multi-axis CNC machining center.

[0032] Turning now to the sleeve element 204, the second bore 258 allows the rotary element 200 to receive and secure to a shaft (e.g., shaft 212 of FIG. 3). The configuration of the bore sections 260, 262, 264, 266 correspond to one or more features on the shaft. For example, as best shown in FIG. 6, which shows a front view of the rotary element 200 taken at line 6-6 of FIG. 5, the second bore section 262 can form a locking profile 270. Examples of the locking profile 270 can match a corresponding profile found on a shaft (e.g., shaft 212 of FIG. 3) found on a drive unit (e.g., drive unit 210 of FIG. 3).

[0033] FIG. 7 illustrates details of the body element 202 taken at the detail of FIG. 5. This diagram illustrates an example of a material layer 270 that is disposed on one or more surfaces of the body element 202. The material layer 270 can seal pores, frays, and other defects in the body element 202 to prevent, for example, penetration of working fluid into the material. Examples of the material layer 270 can include metals coatings (e.g., chrome nickel) and similar coatings some of which are amenable to deposition using various techniques, e.g., sputtering and chemical vapor deposition (CVD).

[0034] As used herein, an element or function recited in the singular and proceeded with the word “a” or “an” should be understood as not excluding plural said elements or functions, unless such exclusion is explicitly recited. Furthermore, references to “one embodiment” of the claimed invention should not be interpreted as excluding the existence of additional embodiments that also incorporate the recited features.

[0035] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal language of the claims.

What is claimed is:

1. An impeller, comprising a body element comprising a first material and having a blade disposed thereon, the first material comprising a woven component with a first fiber and a second fiber
forming a first fiber layer and a second fiber layer and a third fiber coupling the first fiber layer and the second fiber layer; and a sleeve element disposed in the body element, the sleeve element comprising a second material that is different from the first material.

2. The impeller of claim 1, wherein the first fiber, the second fiber, and the third fiber are disposed in, respectively, a first direction, a second direction, and a third direction in the woven component, and wherein the first direction is different from the second direction and the third direction.

3. The impeller of claim 2, wherein the first direction, the second direction, and the third direction are mutually orthogonal to one another.

4. The impeller of claim 1, wherein the first fiber, the second fiber, and the third fiber comprise carbon fibers.

5. The impeller of claim 1, wherein the first fiber, the second fiber, and the third fiber are disposed in a resin.

6. The impeller of claim 1, wherein the first material is homogenous throughout the body element.

7. The impeller of claim 1, wherein the second material comprises a metal.

8. The impeller of claim 1, further comprising a first material layer disposed on a surface of the body element and a surface of the sleeve element.

9. The impeller of claim 1, further comprising a second material layer disposed on a surface of the body element.

10. The impeller of claim 9, wherein the second material layer comprises chrome nickel metal.

11. An impeller, comprising:
   a body element having a rotary axis and a plurality of blades disposed circumferentially about the rotary axis, the body element comprising a composite having a resin and a plurality of fibers disposed in the resin, the plurality of fibers comprising a first set of fibers in a first direction, a second set of fibers in a second direction, and a third set of fibers in a third direction, and wherein the first direction, the second direction, and the third direction are mutually orthogonal to one another.

12. The impeller of claim 11, wherein fibers in the first set of fibers and fibers in the second set of fibers interweave with one another to form a first fiber layer and a second fiber layer.

13. The impeller of claim 12, wherein fibers in the third set of fibers interweave with the fibers in the first layer and the second layer.

14. The impeller of claim 11, wherein the plurality of blades are formed integrally with the body element.

15. The impeller of claim 14, wherein the composite is homogenous throughout the body element and the plurality of blades.

16. The impeller of claim 11, further comprising a coating disposed on one or more of the body element and the plurality of blades, wherein the coating is different from the composite.

17. A compressor device, comprising:
   a rotary element having a body element and a sleeve element disposed in the body element, the body element comprising a first material and the sleeve element comprising a second material that is different from the first material, wherein the first material comprises a carbon fiber composite with a first set of fibers and a second set of fibers disposed orthogonally to the first set of fibers to form a first fiber layer and a second fiber layer adjacent the first fiber layer and a third set of fibers disposed orthogonally to the first set of fibers and the second set of fibers.

18. The compressor device of claim 17, wherein the third set of fibers couple the first fiber layer and the second fiber layer.

19. The compressor device of claim 17, further comprising a drive unit with a drive shaft, wherein the sleeve element comprises a bore with a section that has a locking profile that matches a profile on the drive shaft.

20. The compressor device of claim 17, wherein the carbon fiber composite is homogenous throughout the body element.