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(54) **LINEAR COMPRESSOR AND INTERNAL COLLISION BUFFERING**

(57) A linear compressor or an operation method comprises: driving a motor of the linear compressor to a reference current, and detecting a sampled current during driving the motor. The linear compressor or the method may further specify: calculating the variance of the

current by using the sampled current, determining that the calculated variance exceeds a variance threshold; and limiting the reference current on the basis of determining that the calculated variance exceeds the variance threshold.

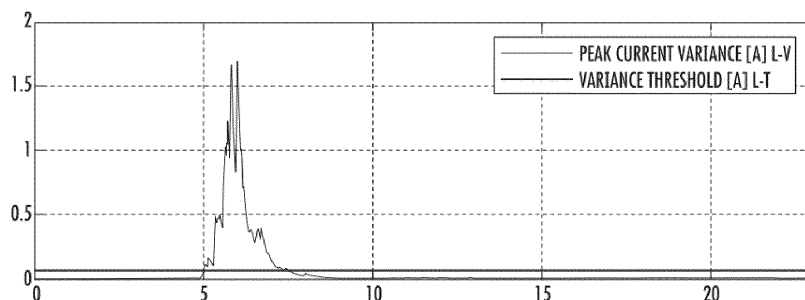


FIG. 6

Description

FIELD OF THE INVENTION

[0001] The present subject matter relates generally to a compressor for an appliance, such as a refrigerator appliance.

BACKGROUND OF THE INVENTION

[0002] Certain refrigerator appliances include sealed systems for cooling chilled chambers of the refrigerator appliance. The sealed systems generally include a compressor that generates compressed refrigerant during operation of the sealed system. The compressed refrigerant flows to an evaporator where heat exchange between the chilled chambers and the refrigerant cools the chilled chambers and food items located therein.

[0003] Recently, certain refrigerator appliances have included linear compressors for compressing refrigerant. Linear compressors generally include a piston and a driving coil housed, and may be housed within a sealed shell. The driving coil generates a force for sliding the piston forward and backward within a chamber. During motion of the piston within the chamber, the piston compresses refrigerant. Motion of the piston within the chamber is generally controlled such that the compressor does not crash into the inner shell (i.e., as an internal collision). Such internal collisions can damage various components of the linear compressor and can be extremely loud or bothersome to nearby users.

[0004] Even when a linear compressor is operating appropriately (e.g., to avoid inducing a crash from the piston motion), it is possible for a series of internal collisions to be caused by a sizeable impact, such as a refrigerator door being slammed or the linear compressor being tipped. Unfortunately, a single collision can be followed by a series of internal collisions as the linear compressor moves within the shell, creating sudden changes in the back-EMF of a motor, which makes controlling the linear compressor difficult. Nonetheless, it can be difficult to predict or quickly determine when such a series of internal collisions is occurring. Adding sensors configured to detect significant movement or noise from the linear compressor may permit extensive collisions to occur before the system is able to detect and stop such the collisions. Additionally or alternatively, adding such sensors may undesirably increase the complexity or expense of an appliance. This may, in turn, lead to a poor user experience, reduce reliability, or unacceptably increase the cost of the linear compressor.

[0005] As a result, it would be useful to provide a linear compressor design or method of operation for quickly detecting or mitigating internal collisions of the linear compressor against an inner surface of a surrounding shell. In particular, it would be advantageous to provide a system or method for detecting or mitigating internal collisions without requiring a separate sensor.

BRIEF DESCRIPTION OF THE INVENTION

[0006] Aspects and advantages of the invention will be set forth in part in the following description, or may be obvious from the description, or may be learned through practice of the invention.

[0007] In one exemplary aspect of the present disclosure, a method of operating a linear compressor to correct an internal collision between a linear compressor and a shell enclosing the linear compressor is provided. The method may include driving a motor of the linear compressor to a reference current and detecting a sampled current during driving the motor. The method may also include calculating a variance in current using the sampled current, determining the calculated variance exceeds a variance threshold, and restricting the reference current based on determining the calculated variance exceeds the variance threshold.

[0008] In another exemplary aspect of the present disclosure, a method of operating a linear compressor to correct an internal collision between a linear compressor and a shell enclosing the linear compressor is provided. The method may include driving a motor of the linear compressor to a reference current over a plurality of electrical cycles and detecting a sampled current. Detecting the sampled current may include detecting a discrete sampled current value for each electrical cycle of the plurality of electrical cycles. The method may further include calculating a variance in current using the sampled current, determining the calculated variance exceeds a variance threshold, and restricting the reference current based on determining the calculated variance exceeds the variance threshold independent of a piston position of the motor.

[0009] These and other features, aspects and advantages of the present invention will become better understood with reference to the following description and appended claims. The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] A full and enabling disclosure of the present invention, including the best mode thereof, directed to one of ordinary skill in the art, is set forth in the specification, which makes reference to the appended figures.

FIG. 1 is a front elevation view of a refrigerator appliance according to exemplary embodiments of the present disclosure.

FIG. 2 is a schematic view of certain components of the exemplary refrigerator appliance of FIG. 1 with respective exemplary oil cooling circuits according to exemplary embodiments of the present disclosure.

FIG. 3 provides a section view of an exemplary linear

compressor according to exemplary embodiments of the present disclosure.

FIG. 4 provides a section view of the exemplary linear compressor of FIG. 3, illustrating a flow path according to exemplary embodiments of the present disclosure.

FIG. 5 provides an exemplary chart of experimental electrical motor parameter estimates.

FIG. 6 provides an exemplary chart of experimental electrical motor parameter estimates.

FIG. 7 provides a flow chart illustrating a method of operating a linear compressor according to exemplary embodiments of the present disclosure.

DETAILED DESCRIPTION

[0011] Reference now will be made in detail to embodiments of the invention, one or more examples of which are illustrated in the drawings. Each example is provided by way of explanation of the invention, not limitation of the invention. In fact, it will be apparent to those skilled in the art that various modifications and variations can be made in the present invention without departing from the scope of the invention. For instance, features illustrated or described as part of one embodiment can be used with another embodiment to yield a still further embodiment. Thus, it is intended that the present invention covers such modifications and variations as come within the scope of the appended claims and their equivalents.

[0012] As used herein, the terms "first," "second," and "third" may be used interchangeably to distinguish one component from another and are not intended to signify location or importance of the individual components. The terms "upstream" and "downstream" refer to the relative flow direction with respect to fluid flow in a fluid pathway. For example, "upstream" refers to the flow direction from which the fluid flows, and "downstream" refers to the flow direction to which the fluid flows. The term "or" is generally intended to be inclusive (i.e., "A or B" is intended to mean "A or B or both").

[0013] Turning now to the figures, FIG. 1 depicts a refrigerator appliance 10 that incorporates a sealed refrigeration system 60 (FIG. 2). It should be appreciated that the term "refrigerator appliance" is used in a generic sense herein to encompass any manner of refrigeration appliance, such as a freezer, refrigerator/freezer combination, and any style or model of conventional refrigerator. In addition, it should be understood that the present disclosure is not limited to use in refrigerator appliances. Thus, the present subject matter may be used for any other suitable purpose, such as vapor compression within air conditioning units or air compression within air compressors.

[0014] In the illustrated exemplary embodiment shown in FIG. 1, the refrigerator appliance 10 is depicted as an upright refrigerator having a cabinet or casing 12 that defines a number of internal chilled storage compartments. In particular, refrigerator appliance 10 includes

upper fresh-food compartments 14 having doors 16 and lower freezer compartment 18 having an upper drawer 20 and a lower drawer 22. The drawers 20 and 22 are "pull-out" drawers in that they can be manually moved into and out of the freezer compartment 18 on suitable slide mechanisms.

[0015] FIG. 2 provides schematic views of certain components of refrigerator appliance 10, including a sealed refrigeration system 60 of refrigerator appliance 10. In particular, FIG. 2 provides exemplary oil cooling circuit with sealed refrigeration system 60 according to exemplary embodiments of the present disclosure. It should be understood that, except as otherwise indicated, the exemplary oil cooling circuit of FIG. 2 may be modified or used in or with any suitable appliance in alternative exemplary embodiments. For example, the exemplary oil cooling circuit of FIG. 2 may be used in or with heat pump dryer appliances, heat pump water heater appliance, air conditioner appliances, etc.

[0016] A machinery compartment of refrigerator appliance 10 may contain components for executing a known vapor compression cycle for cooling air. The components include a compressor 64, a condenser 66, an expansion device 68, and an evaporator 70 connected in series and charged with a refrigerant. As will be understood by those skilled in the art, refrigeration system 60 may include additional components (e.g., at least one additional evaporator, compressor, expansion device, or condenser). As an example, refrigeration system 60 may include two evaporators.

[0017] Within refrigeration system 60, refrigerant generally flows into compressor 64, which operates to increase the pressure of the refrigerant. This compression of the refrigerant raises its temperature, which is lowered by passing the refrigerant through condenser 66. Within condenser 66, heat exchange with ambient air takes place so as to cool the refrigerant. A condenser fan 72 is used to pull air across condenser 66 so as to provide forced convection for a more rapid and efficient heat exchange between the refrigerant within condenser 66 and the ambient air. Thus, as will be understood by those skilled in the art, increasing air flow across condenser 66 can, for example, increase the efficiency of condenser 66 by improving cooling of the refrigerant contained therein.

[0018] An expansion device (e.g., a valve, capillary tube, or other restriction device) 68 receives refrigerant from condenser 66. From expansion device 68, the refrigerant enters evaporator 70. Upon exiting expansion device 68 and entering evaporator 70, the refrigerant drops in pressure. Due to the pressure drop or phase change of the refrigerant, evaporator 70 is cool relative to compartments 14 and 18 of refrigerator appliance 10. As such, cooled air is produced and refrigerates compartments 14 and 18 of refrigerator appliance 10. Thus, evaporator 70 is a type of heat exchanger which transfers heat from air passing over evaporator 70 to refrigerant flowing through evaporator 70.

[0019] Collectively, the vapor compression cycle components in a refrigeration circuit, associated fans, and associated compartments are sometimes referred to as a sealed refrigeration system operable to force cold air through compartments 14, 18 (FIG. 1). The refrigeration system 60 depicted in FIG. 2 is provided by way of example only. Thus, it is within the scope of the present disclosure for other configurations of the refrigeration system to be used as well.

[0020] In some embodiments, an oil cooling circuit 200 according to exemplary embodiments of the present disclosure is shown with refrigeration system 60. Compressor 64 of refrigeration system 60 may include or be provided within a shell 302 (FIG. 3) that also holds a lubrication oil therein. The lubrication oil may assist with reducing friction between sliding or moving components of compressor 64 during operation of compressor 64. For example, the lubrication oil may reduce friction between a piston and a cylinder of compressor 64 when the piston slides within the cylinder to compress refrigerant, as discussed in greater detail below.

[0021] During operation of compressor 64, the lubrication oil may increase in temperature. Thus, oil cooling circuit 200 is provided to assist with rejecting heat from the lubrication oil. By cooling the lubrication oil, an efficiency of compressor 64 may be improved. Thus, oil cooling circuit 200 may assist with increasing the efficiency of compressor 64 (e.g., relative to a compressor without oil cooling circuit 200) by reducing the temperature of the lubrication oil within compressor 64.

[0022] In optional embodiments, oil cooling circuit 200 includes a heat exchanger 210 spaced apart from at least a portion of compressor 64. A lubrication oil conduit 220 extends between compressor 64 and heat exchanger 210. Lubrication oil from compressor 64 may flow to heat exchanger 210 via lubrication oil conduit 220. As shown in FIG. 2, lubrication oil conduit 220 may include a supply conduit 222 and a return conduit 224. Supply conduit 222 extends between compressor 64 and heat exchanger 210 and is configured for directing lubrication oil from compressor 64 to heat exchanger 210. Conversely, return conduit 224 extends between heat exchanger 210 and compressor 64 and is configured for directing lubrication oil from heat exchanger 210 to compressor 64.

[0023] Within heat exchanger 210, the lubrication oil may reject heat to ambient air about heat exchanger 210. From heat exchanger 210, the lubrication oil flows back to compressor 64 via lubrication oil conduit 220. In such a manner, lubrication oil conduit 220 may circulate lubrication oil between compressor 64 and heat exchanger 210, and heat exchanger 210 may reduce the temperature of lubrication oil from compressor 64 before returning the lubrication oil to compressor 64. Thus, oil cooling circuit 200 may remove lubrication oil from compressor 64 via lubrication oil conduit 220 and return the lubrication oil to compressor 64 via lubrication oil conduit 220 after cooling the lubrication oil in heat exchanger 210.

[0024] In some embodiments, heat exchanger 210 is positioned at or adjacent fan 72. For example, heat exchanger 210 may be positioned and oriented such that fan 72 pulls or urges air across heat exchanger 210 so as to provide forced convection for a more rapid and efficient heat exchange between lubrication oil within heat exchanger 210 and ambient air about refrigeration system 60. In certain exemplary embodiments, heat exchanger 210 may be disposed between fan 72 and condenser 66. Thus, heat exchanger 210 may be disposed downstream of fan 72 and upstream of condenser 66 relative to a flow of air from fan 72. In such a manner, air from fan 72 may heat exchange with lubrication oil in heat exchanger 210 prior to heat exchange with refrigerant in condenser 66.

[0025] In additional or alternative embodiments, heat exchanger 210 is positioned at or on condenser 66. For example, heat exchanger 210 may be mounted to condenser 66 such that heat exchanger 210 and condenser 66 are in conductive thermal communication with each other. Thus, condenser 66 and heat exchanger 210 may conductively exchange heat. In such a manner, heat exchanger 210 and condenser 66 may provide for heat exchange between lubrication oil within heat exchanger 210 and refrigerant within condenser 66.

[0026] In certain exemplary embodiments, heat exchanger 210 may be a tube-to-tube heat exchanger 210 integrated within or onto condenser 66 (e.g., a portion of condenser 66). For example, heat exchanger 210 may be welded or soldered onto condenser 66. In optional embodiments, heat exchanger 210 is disposed on a portion of condenser 66 between an inlet and an outlet of condenser 66. For example, refrigerant may enter condenser 66 at the inlet of condenser 66 at a first temperature (e.g., one hundred and fifty degrees Fahrenheit (150° F)), and heat exchanger 210 may be positioned on condenser 66 downstream of the inlet of condenser 66 such that refrigerant immediately upstream of the portion of condenser 66 where heat exchanger 210 is mounted may have a second temperature (e.g., ninety degrees Fahrenheit (90° F)).

[0027] Heat exchanger 210 may also be positioned on condenser 66 upstream of the outlet of condenser 66 such that refrigerant immediately downstream of the portion of condenser 66 where heat exchanger 210 is mounted may have a third temperature (e.g., one hundred and five degrees Fahrenheit (105° F)), and refrigerant may exit condenser 66 at the outlet of condenser 66 at a fourth temperature (e.g., ninety degrees Fahrenheit (90° F)). Thus, refrigerant within condenser 66 may increase in temperature at the portion of condenser 66 where heat exchanger 210 is mounted during operation of compressor 64 in order to cool lubrication oil within heat exchanger 210. However, the portion of condenser 66 downstream of heat exchanger 210 may assist with rejecting heat to ambient air about condenser 66.

[0028] Turning now to FIGS. 3 and 4, various sectional views are provided of a linear compressor 300 according

to an exemplary embodiments of the present disclosure. As discussed in greater detail below, linear compressor 300 is operable to increase a pressure of fluid within a chamber 312 of linear compressor 300. Linear compressor 300 may be used to compress any suitable fluid, such as refrigerant. In particular, linear compressor 300 may be used in a refrigerator appliance, such as refrigerator appliance 10 (FIG. 1) in which linear compressor 300 may be used as compressor 64 (FIG. 2). As may be seen in FIG. 3, linear compressor 300 defines an axial direction A and a radial direction R. Linear compressor 300 may be enclosed within a hermetic or air-tight shell 302. In other words, linear compressor 300 may be enclosed within an internal volume 303 defined by shell 302. For instance, linear compressor may be supported within internal volume 303 by one or more mounting springs 305, which may generally dampen oscillations or movement of linear compressor 300 relative to shell 302. When assembled, hermetic shell 302 hinders or prevents refrigerant or lubrication oil from leaking or escaping refrigeration system 60 (FIG. 2).

[0029] Linear compressor 300 includes a casing 308 that extends between a first end portion 304 and a second end portion 306 (e.g., along the axial direction A). Casing 308 includes various relatively static or non-moving structural components of linear compressor 300. In particular, casing 308 includes a cylinder assembly 310 that defines a chamber 312. Cylinder assembly 310 may be positioned at or adjacent second end portion 306 of casing 308. Chamber 312 may extend longitudinally along the axial direction A.

[0030] In some embodiments, a motor mount mid-section 314 (e.g., at the second end portion 306) of casing 308 supports a stator of the motor. As shown, the stator may include an outer back iron 364 and a driving coil 366 sandwiched between the first end portion 304 and the second end portion 306. Linear compressor 300 may also include one or more valves (e.g., a discharge valve assembly 320 at an end of chamber 312) that permit refrigerant to enter and exit chamber 312 during operation of linear compressor 300.

[0031] In some embodiments, a discharge valve assembly 320 is mounted to the casing 308 (e.g., at the second end portion 306). Discharge valve assembly 320 may include a muffler housing 322, a valve head 324, and a valve spring 338.

[0032] Muffler housing 322 may include an end wall 326 and a cylindrical side wall 328. Cylindrical side wall 328 is mounted to end wall 326, and cylindrical side wall 328 extends from end wall 326 (e.g., along the axial direction A) to cylinder assembly 310 of casing 308. A refrigerant outlet conduit 330 may extend from or through muffler housing 322 and through shell 302 (e.g., to or in fluid communication with condenser 66-FIG. 2) to selectively permit refrigerant from discharge valve assembly 320 during operation of linear compressor 300.

[0033] Muffler housing 322 may be mounted or fixed to casing 308, and other components of discharge valve

assembly 320 may be disposed within muffler housing 322. For example, a plate 332 of muffler housing 322 at a distal end of cylindrical side wall 328 may be positioned at or on cylinder assembly 310, and a seal (e.g., O-ring or gasket) may extend between cylinder assembly 310 and plate 332 of muffler housing 322 (e.g., along the axial direction A) in order to limit fluid leakage at an axial gap between casing 308 and muffler housing 322. Fasteners may extend through plate 332 into casing 308 to mount muffler housing 322 to casing 308.

[0034] In some embodiments, valve head 324 is positioned at or adjacent chamber 312 of cylinder assembly 310. Valve head 324 may selectively a passage that extends through the cylinder assembly 310 (e.g., along the axial direction A). Such a passage may be contiguous with chamber 312. When assembled, valve spring 338 may be coupled to muffler housing 322 and valve head 324. Valve spring 338 may be configured to urge valve head 324 towards or against cylinder assembly 310 (e.g., along the axial direction A).

[0035] A piston assembly 316 with a piston head 318 may be slidably received within chamber 312 of cylinder assembly 310. In particular, piston assembly 316 may be slidable along the axial direction A within chamber 312. During sliding of piston head 318 within chamber 312, piston head 318 compresses refrigerant within chamber 312. As an example, from a top dead center position, piston head 318 can slide within chamber 312 towards a bottom dead center position along the axial direction A (i.e., an expansion stroke of piston head 318). When piston head 318 reaches the bottom dead center position, piston head 318 changes directions and slides in chamber 312 back towards the top dead center position (i.e., a compression stroke of piston head 318). As, or immediately prior to, piston head 318 reaching the top dead center position, expansion valve assembly 320 may open. For instance, valve head 324 may be urged away from cylinder assembly 310, permitting refrigerant from chamber 312 and through discharge valve assembly 320 to refrigerant outlet conduit 330.

[0036] It should be understood that linear compressor 300 may include an additional piston head or additional chamber at an opposite end of linear compressor 300 (e.g., proximal to first end portion 304). Thus, linear compressor 300 may have multiple piston heads in alternative exemplary embodiments.

[0037] In certain embodiments, linear compressor 300 includes an inner back iron assembly 352. Inner back iron assembly 352 is positioned in the stator of the motor. In particular, outer back iron 364 or driving coil 366 may extend about inner back iron assembly 352 (e.g., along a circumferential direction). Inner back iron assembly 352 also has the outer surface. At least one driving magnet 362 is mounted to inner back iron assembly 352 (e.g., at the outer surface of inner back iron assembly 352). Driving magnet 362 may face or be exposed to driving coil 366. In particular, driving magnet 362 may be spaced apart from driving coil 366 (e.g., along the radial direction

R by an air gap). Thus, the air gap may be defined between opposing surfaces of driving magnet 362 and driving coil 366. Driving magnet 362 may also be mounted or fixed to inner back iron assembly 352 such that the outer surface of driving magnet 362 is substantially flush with the outer surface of inner back iron assembly 352. Thus, driving magnet 362 may be inset within inner back iron assembly 352. In such a manner, the magnetic field from driving coil 366 may have to pass through only a single air gap between outer back iron 364 and inner back iron assembly 352 during operation of linear compressor 300.

[0038] As may be seen in FIG. 3, driving coil 366 extends about inner back iron assembly 352 (e.g., along the circumferential direction). Generally, driving coil 366 is operable to move the inner back iron assembly 352 along the axial direction A during operation of driving coil 366. As an example, a current may be induced in driving coil 366 by a current source (e.g., included with or in connection with a controller 367) to generate a magnetic field that engages driving magnet 362 and urges piston assembly 316 to move along the axial direction A in order to compress refrigerant within chamber 312, as described above. In particular, the magnetic field of driving coil 366 may engage driving magnet 362 in order to move inner back iron assembly 352 and piston head 318 the axial direction A during operation of driving coil 366. Thus, driving coil 366 may slide piston assembly 316 between the top dead center position and the bottom dead center position during operation of driving coil 366.

[0039] In optional embodiments, linear compressor 300 includes various components for permitting or regulating operation of linear compressor 300. In particular, linear compressor 300 includes a controller 367 that is configured for regulating operation of linear compressor 300. The controller 367 is in, for example, operative, communication with the motor (e.g., driving coil 366 of the motor). Thus, the controller 367 may selectively activate driving coil 366, for example, by supplying current to driving coil 366, in order to compress refrigerant with piston assembly 316 as described above. In some embodiments, controller 367 directs or regulates current according to a predetermined control loop. For instance, as would be understood, such a control loop may regulate the supply voltage [e.g., peak voltage or root mean square (RMS) voltage] of a supplied current to a desired reference voltage. To that end, controller 367 may include a suitable component for measuring or estimating a supply current, such as an ammeter. Additionally or alternatively, controller 367 may be configured to detect or mitigate an internal collision (e.g., according to one or more programmed methods, such as method 700).

[0040] The controller 367 includes memory and one or more processing devices such as microprocessors, CPUs or the like, such as general or special purpose microprocessors operable to execute programming instructions or micro-control code associated with operation of linear compressor 300. The memory can represent

random access memory such as DRAM, or read only memory such as ROM or FLASH. The processor executes programming instructions stored in the memory. The memory can be a separate component from the processor or can be included onboard within the processor. Alternatively, the controller 367 may be constructed without using a microprocessor (e.g., using a combination of discrete analog or digital logic circuitry; such as switches, amplifiers, integrators, comparators, flip-flops, AND gates, and the like) to perform control functionality instead of relying upon software.

[0041] Linear compressor 300 also includes one or more spring assemblies 340, 342 mounted to casing 308. In certain embodiments, a pair of spring assemblies (i.e., a first spring assembly 340 and a second spring assembly 342) bounds driving coil 366 along the axial direction A. In other words, a first spring assembly 340 is positioned proximal to the first end portion 304 and a second spring assembly 342 is positioned proximal to the second end portion 306.

[0042] In some embodiments, each spring assembly 340 and 342 includes one or more planar springs that are mounted or secured to one another. In particular, planar springs may be mounted or secured to one another such that each planar spring of a corresponding assembly 340 or 342 are spaced apart from one another (e.g., along the axial direction A).

[0043] Generally, the pair of spring assemblies 340, 342 assists with coupling inner back iron assembly 352 to casing 308. In some such embodiments, a first outer set of fasteners 344 (e.g., bolts, nuts, clamps, tabs, welds, solders, etc.) secure first and second spring assemblies 340, 342 to casing 308 (e.g., a bracket of the stator) while a first inner set of fasteners 346 that are radially inward (e.g., closer to the axial direction A along a perpendicular radial direction R) from the first outer set of fasteners 344 secure first spring assembly 340 to inner back iron assembly 352 at first end portion 304. In additional or alternative embodiments, a second inner set of fasteners 350 that are radially inward (e.g., closer to the axial direction A along the radial direction R) from the first outer set of fasteners 344 secure second spring assembly 342 to inner back iron assembly 352 at second end portion 306.

[0044] During operation of driving coil 366, the spring assemblies 340, 342 support inner back iron assembly 352. In particular, inner back iron assembly 352 is suspended by the spring assemblies 340, 342 within the stator or the motor of linear compressor 300 such that motion of inner back iron assembly 352 along the radial direction R is hindered or limited while motion along the axial direction A is relatively unimpeded. Thus, the spring assemblies 340, 342 may be substantially stiffer along the radial direction R than along the axial direction A. In such a manner, the spring assemblies 340, 342 can assist with maintaining a uniformity of the air gap between driving magnet 362 and driving coil 366 (e.g., along the radial direction R) during operation of the motor and movement

of inner back iron assembly 352 on the axial direction A. The spring assemblies 340, 342 can also assist with hindering side pull forces of the motor from transmitting to piston assembly 316 and being reacted in cylinder assembly 310 as a friction loss.

[0045] In optional embodiments, inner back iron assembly 352 includes an outer cylinder 354 and a sleeve 360. Sleeve 360 is positioned on or at the inner surface of outer cylinder 354. A first interference fit between outer cylinder 354 and sleeve 360 may couple or secure outer cylinder 354 and sleeve 360 together. In alternative exemplary embodiments, sleeve 360 may be welded, glued, fastened, or connected via any other suitable mechanism or method to outer cylinder 354.

[0046] When assembled, sleeve 360 may extend about the axial direction A (e.g., along the circumferential direction). In exemplary embodiments, a first interference fit between outer cylinder 354 and sleeve 360 may couple or secure outer cylinder 354 and sleeve 360 together. In alternative exemplary embodiments, sleeve 360 is welded, glued, fastened, or connected via any other suitable mechanism or method to outer cylinder 354. As shown, sleeve 360 extends within outer cylinder 354 (e.g., along the axial direction A) between first and second end portions 304 and 306 of inner back iron assembly 352 130. First and second spring assemblies 340, 342 and are mounted to sleeve 360 (e.g., with inner set of fasteners 346 and 350).

[0047] Outer cylinder 354 may be constructed of or with any suitable material. For example, outer cylinder 354 may be constructed of or with a plurality of (e.g., ferromagnetic) laminations. The laminations are distributed along the circumferential direction in order to form outer cylinder 354 and are mounted to one another or secured together (e.g., with rings pressed onto ends of the laminations). Outer cylinder 354 defines a recess that extends inwardly from the outer surface of outer cylinder 354 (e.g., along the radial direction R). Driving magnet 362 may be positioned in the recess on outer cylinder 354 (e.g., such that driving magnet 362 is inset within outer cylinder 354).

[0048] In some embodiments, a piston flex mount 368 is mounted to and extends through inner back iron assembly 352. In particular, piston flex mount 368 is mounted to inner back iron assembly 352 via sleeve 360 and spring assemblies 340, 342. Thus, piston flex mount 368 may be coupled (e.g., threaded) to sleeve 360 in order to mount or fix piston flex mount 368 to inner back iron assembly 352. A coupling 370 extends between piston flex mount 368 and piston assembly 316 (e.g., along the axial direction A). Thus, coupling 370 connects inner back iron assembly 352 and piston assembly 316 such that motion of inner back iron assembly 352 (e.g., along the axial direction A) is transferred to piston assembly 316. Coupling 370 may extend through driving coil 366 (e.g., along the axial direction A).

[0049] Piston flex mount 368 may define at least one passage 369. Passage 369 of piston flex mount 368 ex-

tends (e.g., along the axial direction A) through piston flex mount 368. Thus, a flow of fluid, such as air or refrigerant, may pass through piston flex mount 368 via passage 369 of piston flex mount 368 during operation of linear compressor 300. As shown, one or more refrigerant inlet conduits 331 may extend through shell 302 to return refrigerant from evaporator 70 (or another portion of sealed system 60) (FIG. 2) to compressor 300.

[0050] Piston head 318 also defines at least one opening (e.g., selectively covered by a head valve). The opening of piston head 318 extends (e.g., along the axial direction A) through piston head 318. Thus, the flow of refrigerant may pass through piston head 318 via the opening of piston head 318 into chamber 312 during operation of linear compressor 300. In such a manner, the flow of fluid (that is compressed by piston head 318 within chamber 312) may flow through piston flex mount 368 and inner back iron assembly 352 to piston assembly 316 during operation of linear compressor 300.

[0051] As shown, linear compressor 300 may include features for directing oil through linear compressor 300 and oil cooling circuit 200 (FIG. 2). One or more oil inlet conduits 380 or oil outlet conduits 382 may extend through shell 302 to direct oil to/from oil cooling circuit 200.

[0052] Optionally, oil inlet conduit 380 may be coupled to return conduit 224 of oil cooling circuit 200 (FIG. 2). Thus, from heat exchanger 210, lubrication oil may flow to linear compressor 300 via oil inlet conduit 380. Optionally, oil inlet conduit 380 may be positioned at or adjacent sump 376. Thus, lubrication oil to linear compressor 300 at oil inlet conduit 380 may flow into sump 376. As discussed above, oil cooling circuit 200 may cool lubrication oil from linear compressor 300. After such cooling, the lubrication oil is returned to linear compressor 300 via oil inlet conduit 380. Thus, the lubrication oil in oil inlet conduit 380 may be relatively cool and assist with cooling lubrication oil in sump 376.

[0053] In some embodiments, linear compressor 300 includes a pump 372. Pump 372 may be positioned at or adjacent a sump 376 of shell 302 (e.g., within a pump housing 374). Sump 376 corresponds to a portion of shell 302 at or adjacent a bottom of shell 302. Thus, a volume of lubrication oil 377 within shell 302 may pool within sump 376 (e.g., because the lubrication oil is denser than the refrigerant within shell 302). During use, pump 372 may draw the lubrication oil from the volume 377 within sump 376 to pump 372 via a supply line 378 extending from pump 372 to sump 376. For instance, a pair of check valves within a pump housing 374 at opposite ends of pump 372 may selectively permit/release oil to/from pump housing 374 as pump 372 oscillates within pump housing 374 (e.g., as motivated by oscillations of casing 308). Additionally or alternatively, the volume of lubrication oil 377 may be maintained at a predetermined level (e.g., even with a vertical midpoint of pump 372) while pump 372 is actively oscillating.

[0054] An internal conduit 384 may extend from pump

372 (e.g., pump housing 374) to an oil reservoir 386 defined within casing 308. In some embodiments, oil reservoir 386 is positioned radially outward from the chamber 312 of cylinder assembly 310. For instance, oil reservoir 386 may be defined to extend along the circumferential direction (e.g., about the axial direction A) as an annular chamber around chamber 312 of cylinder assembly 310.

[0055] Generally, lubrication oil may be selectively directed to cylinder assembly 310 from oil reservoir 386. In particular, one or more passages (e.g., radial passages) may extend from oil reservoir 386 to the chamber 312. Such radial passages may terminate at a portion of the sliding path of piston head 318 (e.g., between top dead center and bottom dead center relative to the axial direction A). As piston head 318 slides within chamber 312, a sidewall of piston head 318 may receive lubrication oil. In optional embodiments, the radial passages terminate at a groove 388 defined by the cylinder assembly 310 within the chamber 312. Thus, the groove 388 may be open to the chamber 312. Lubrication oil from oil reservoir 386 may flow into chamber 312 of cylinder assembly 310 (e.g., via radial passages to the groove 388) in order to lubricate motion of piston assembly 316 within chamber 312 of cylinder assembly 310.

[0056] Along with the chamber 312 and oil reservoir 386, casing 308 may define an oil exhaust 390. In some embodiments, oil exhaust 390 extends from oil reservoir 386. For example, oil exhaust 390 may extend through casing 308 outward from oil reservoir 386. Oil exhaust 390 may thus be in fluid communication with oil reservoir 386. During use, at least a portion of the lubrication oil urged to oil reservoir 386 may flow to the oil exhaust 390 (e.g., as motivated by pump 372). From oil exhaust 390, lubrication oil may exit the casing 308 (and linear compressor 300 generally). In certain embodiments, oil exhaust 390 is connected in fluid communication to the oil outlet conduit 382. Thus, pump 372 may generally urge lubrication oil from the internal volume 303, through casing 308, and to the oil outlet conduit 382. Oil outlet conduit 382 may be coupled to supply conduit 222 of oil cooling circuit 200 (FIG. 2). Thus, pump 372 may urge lubrication oil from sump 376 into supply conduit 222. In such a manner, pump 372 may supply lubrication oil to oil cooling circuit 200 in order to cool the lubrication oil from linear compressor 300, as discussed above.

[0057] Separate from or in addition to oil exhaust 390, casing 308 may define a gas vent 392. In particular, gas vent 392 extends through from oil reservoir 386 to the internal volume 303. As shown, gas vent 392 is defined in fluid parallel with oil exhaust 390. Thus, fluid is separately directed through gas vent 392 and oil exhaust 390. Generally, gas vent 392 may be sized to restrict fluid more than oil exhaust 390. For example, the minimum diameter of gas vent 392 may still be smaller than the minimum diameter of the oil exhaust 390. Optionally, the minimum diameter of gas vent 392 may be less than two millimeters while the minimum diameter of oil exhaust is

greater than four millimeters. Along with being smaller in diameter, the gas vent 392 may further be shorter in length than oil exhaust 390. Under typical pumping operations, a greater volume of lubrication oil may be motivated through oil exhaust 390 than gas vent 392. Nonetheless, gas (e.g., produced during an outgassing within oil reservoir 386) may be permitted to internal volume 303 through gas vent 392 while permitting the continued flow of lubrication oil from oil reservoir 386 to oil exhaust 390 or chamber 312.

[0058] Gas vent 392 may be defined at an upper portion of casing 308 (e.g., at an upper end of oil reservoir 386). Additionally or alternatively, gas vent 392 may extend above the discharge valve assembly 320 (e.g., parallel to the axial direction A). Gas vent 392 may further be located below (e.g., lower along a vertical direction V than) oil exhaust 390. In some embodiments, gas vent 392 is located at the second end portion 306 of casing 308. Fluid from gas vent 392 may be directed forward into internal volume 303.

[0059] In some embodiments, an oil shield 394 is provided in front of gas vent 392. As shown, oil shield 394 may be disposed on casing 308 (e.g., at second end portion 306). Between oil shield 394 and, for example, muffler housing 322, a drip passage may be defined. Between oil shield 394 and, for example, muffler housing 322, a drip passage may be defined. For instance, oil shield 394 may extend outward from casing 308 to a curved or inward-extending wall portion 396. Additionally or alternatively, oil shield 394 may extend about a portion of muffler housing 322. For instance, oil shield 394 may extend 180° along a top side of muffler housing 322. During use, lubrication oil discharged through gas vent 392 may be directed downward to the sump 376. During use, oil shield 394 may prevent lubrication oil from striking shell 302 (e.g., at a high velocity, which might otherwise cause atomizing of lubrication oil within internal volume 303).

[0060] Turning now to FIGS. 5 and 6, during use of a linear compressor (e.g., linear compressor 300-FIG. 3), it is possible for the linear compressor to be suddenly shifted or inadvertently struck, such as when the door to the corresponding appliance (e.g., refrigerator appliance 10-FIG. 1) is slammed shut. Such a shift or strike may cause the linear compressor to collide repeatedly with an enclosing shell. For instance, with respect to the exemplary embodiments of FIG. 3, muffler housing 328 may collide with an internal surface of shell 302. Such internal collisions may be repeated as linear compressor 300 rocks or oscillates on support springs 305.

[0061] FIGS. 5 and 6 provide a pair of exemplary charts that illustrate experimental electrical motor parameter estimates obtained during an internal collision event and resulting changes in one or more control parameters (e.g., reference current according to a disclosed method of operation). In particular, FIG. 5 illustrates a detected line L-S and a reference line L-R over a span of time (e.g., measured in seconds or according to discrete elec-

trical cycles of the motor). FIG. 6 illustrates a calculated variance line L-V and a variance threshold line L-T over the same span of time.

[0062] Generally, detected line L-S charts changes, over time, in a detected supply current (e.g., at or to the motor of linear compressor 300). Reference line L-R charts changes, over time, in a reference current, which may be used as a control parameter of a control loop for the motor of linear compressor 300 (e.g., adjusted in response to changes in the detected supply current). Calculated variance line L-V charts changes, over time, in variance values calculated from the values of the detected line. Generally, a variance threshold value may remain constant (e.g., as a predetermined value) and, thus, variance threshold line L-T is flat over time. As will be described in detail below, values of the reference current may be changed based on (e.g., in response to) one or more determinations that one or more calculated variance values exceed the variance threshold value. Notably, changes in the reference current may be independent of the position of the piston within the linear compressor (e.g., such that an internal collision can be detected without prohibiting a separate monitoring sequence for determine a hard or soft crash of the piston within the motor). It is noted that although detected supply current values, reference current values, and calculated variance values are illustrated as a peak current values, another suitable value (e.g., RMS) of current may be similarly used.

[0063] Turning now to FIG. 7, exemplary methods (e.g., method 700) of operating a linear compressor are illustrated. Such methods may be applied to any suitable linear compressor (e.g., linear compressor 300) to detect or correct an internal collision of the linear compressor against an enclosing shell (e.g., shell 302), as would be understood in light of the present disclosure. In some embodiments, the belowdescribed methods may be initiated or directed by controller 367 (e.g., as or as part of a software program that the controller 367 is configured to initiate).

[0064] Advantageously, methods described herein may permit the corresponding linear compressor to quickly detect or mitigate internal collisions of the linear compressor against an inner surface of a surrounding shell. Additionally or alternatively, such methods may advantageously be performed without requiring an additional or detected sensor assembly.

[0065] At 710, the method 700 includes driving a motor of a linear compressor to a reference current. For instance, a variable reference current may be used to induce a current in the driving coil of the motor and motivate movement of the piston within the linear compressor, as described above. Moreover, the motor may be driven in a generally continuous or uninterrupted manner such that 710 extends over a plurality of electrical cycles (e.g., represented on a sine wave of current, as would be understood).

[0066] Generally, the motor may be driven according

to any suitable reference current control loop. As an example, a supply voltage may be directed to the motor to activate the motor. Subsequently, the supply voltage may be adjusted to reduce a difference or error between a sample current (e.g., peak current or RMS current) supplied to linear compressor and the reference current (e.g., reference peak current or reference RMS current). The sample current may be measured or estimated using any suitable method or mechanism. For example, an ammeter may be used to measure the sample current as a peak current. A voltage selector of the controller may operate as a proportional-integral (PI) controller in order to reduce the error between the sample current and the reference current. At a start of 710, the reference current may be a default value (e.g., a default peak current value or peak RMS value) that may subsequently be adjusted (e.g., increased or decreased) during subsequent steps of the method 700, as discussed in greater detail below, such that method 700 reverts to (or otherwise continues with) driving the motor in order to adjust the amplitude of the supply voltage and reduce the error between the current supplied to linear compressor and the adjusted reference current.

[0067] At 720, the method 700 includes detecting a sampled current during 710. In other words, as the motor is being driven, the current being supplied to the motor may be sampled (e.g., as a peak supply current value or an RMS current value). In some embodiments, 720 includes detecting discrete sampled values over time. Thus, as the motor continues to be driven, sampled values of supply current to the motor may continue to be detected. In optional embodiments, a discrete sampled current value is detected for each electrical cycle. Thus, as least one sampled value may be obtained for a corresponding electrical cycle. The sampled value may be detected, for instance by detecting a maximum value of current during each electrical cycle. Additionally or alternatively, the sampled current value may include a maximum absolute value of current for each corresponding electrical cycle such that the sampled current value is detected in terms of magnitude of the supplied current.

[0068] In certain embodiments, 720 may include detecting a predetermined-number set of sampled current values. For instance, the set may include a window of sequential current values to be stored in the controller. Thus, as a new sampled current value is detected, it may be stored within the set or window. This may continue until the set or window is full (i.e., the predetermined number of sampled current values are obtained). Optionally, the set or window may be a rolling set such that a new sampled current value may displace the oldest previously sampled current value within the set.

[0069] At 730, the method 700 includes calculating a variance in current using the sampled current. The calculated variance may be a recursive variance and, thus, be representative of sampled current values detected over time (e.g., over a plurality of electrical cycles even when no previous sampled current values are maintained

or stored in memory). Generally, the sampled current may be used within a programmed variance formula. Such variance formulas are known, and the programmed variance formula may be provided as or include the same. As an example, the programmed variance formula ($Var[X]$) may be or include

$$Var(X) = \frac{1}{n} \sum_{i=1}^n (x_i - \mu)^2$$

wherein x_i are the detected sampled current values, n is the number of samples for which the variance is calculated, and μ is the mean of the values for x_i (e.g., calculated as rolling average, moving average, weighted average, etc.). Optionally, the variance may be calculated from the predetermined number set. In some such embodiments, n is the predetermined number and the values of the predetermined-number set are used for the samples x_i . Thus, 730 may include calculating a mean value of the predetermined-number of set of sampled current values.

[0070] Optionally, 730 may include calculating the variance from a change in sampled values (ΔX). Thus, 730 may include calculating a difference in a previously sampled current and the sampled current (i.e., contemporary sampled current), and calculating variance based on the difference in a previously sampled current and the sampled current. As an example, the programmed variance formula may be or include

$$Var(\Delta X) = \frac{1}{n} \sum_{i=1}^n (\Delta x_i - \mu)^2$$

wherein Δx_i are the samples of the calculated difference in sampled current values, n is the number of samples for which the variance is calculated, and μ is the mean of the values for Δx_i (e.g., calculated as rolling average, moving average, weighted average, etc.). Advantageously, anomalous changes in variance between individual sampled current values may be prevented from affecting large changes in any control parameters based on the calculated variance.

[0071] At 740, the method 700 includes determining the calculated variance exceeds a variance threshold. For instance, the calculated variance value of 730 may be compared to a predetermined variance threshold value (e.g., current peak threshold value or current RMS value) and it may be determined that the calculated variance value of 730 is greater than the variance threshold value. Optionally, this may be repeated such that multiple (e.g., sequential) calculated variance values may be determined to exceed the variance threshold value.

[0072] At 750, the method 700 includes restricting the reference current based on 740. Specifically, in response

to one or more determinations that the calculated variance exceeds the variance threshold, the reference current used to drive the motor may be decreased. This may be done independent of the piston position of the motor (e.g., as noted above).

[0073] Optionally, the decrease may be a reduction of the reference current (e.g., the reference current value at the moment of the determination at 740) by a predetermined reduction value. Additionally or alternatively, a reduction formula may be provided to make variable reductions to the reference current (e.g., based on the magnitude of the reference current value at the moment of the determination at 740).

[0074] In certain embodiments, 750 requires the calculated variance to repeatedly exceed the variance threshold. Thus, 750 may be contingent on (e.g., prompted by) determining multiple calculated variance values exceed the predetermined variance. In some such embodiments, the multiple calculated variance values may require a set number (e.g., count or instances) of the calculated variance exceeding the variance threshold. Additionally or alternatively, the determinations may all be required to occur within a set time period or number of cycles.

[0075] After the reference current is restricted, the restricted or decreased reference current may be used to drive the motor. If subsequent electrical cycles (e.g., a set number of cycles or predetermined period of time) elapse without further determinations that the calculated variance exceeds the reference threshold, the reference current may be increased (e.g., incrementally) until the adjusted reference current is equal to the default reference current value (or another predetermined reference current value).

[0076] 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 include 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 languages of the claims.

Claims

1. A method of operating a linear compressor to correct an internal collision between a linear compressor and a shell enclosing the linear compressor, the method comprising:

driving a motor of the linear compressor to a reference current;

- detecting a sampled current during driving the motor;
calculating a variance in current using the sampled current;
determining the calculated variance exceeds a variance threshold; and
restricting the reference current based on determining the calculated variance exceeds the variance threshold.
2. The method of claim 1, wherein the sampled current comprises a peak supply current value, and wherein the reference current comprises a reference peak current value.
3. The method of claim 1, wherein the sampled current comprises a root mean square (RMS) current value, and wherein the reference current comprises a reference RMS current value.
4. The method of claim 1, wherein the calculated variance is a recursive variance.
5. The method of claim 1, wherein calculating variance comprises
calculating a difference in a previously sampled current and the sampled current, and
calculating variance based on the difference in a previously sampled current and the sampled current.
6. The method of claim 1, wherein driving the motor comprises driving the motor over a plurality of electrical cycles, and wherein detecting the sampled current comprises detecting a discrete sampled current value for each electrical cycle of the plurality of electrical cycles.
7. The method of claim 6, wherein the sampled current value is a maximum absolute value of current for a corresponding electrical cycle.
8. The method of claim 1, wherein detecting the sampled current comprises detecting a predetermined-number set of sampled current values, and wherein calculating variance comprises calculating variance of the predetermined-number set of sampled current values.
9. The method of claim 8, wherein calculating variance comprises calculating a mean value of the predetermined-number of set of sampled current values.
10. The method of claim 1, wherein determining the calculated variance exceeds the variance threshold comprises determining multiple calculated variance values exceed the predetermined variance, and
- wherein restricting the reference current is contingent on determining multiple calculated variance values exceed the predetermined variance.
11. A method of operating a linear compressor to correct an internal collision between a linear compressor and a shell enclosing the linear compressor, the method comprising:
driving a motor of the linear compressor to a reference current over a plurality of electrical cycles;
detecting a sampled current, detecting the sampled current comprising detecting a discrete sampled current value for each electrical cycle of the plurality of electrical cycles;
calculating a variance in current using the sampled current;
determining the calculated variance exceeds a variance threshold; and
restricting the reference current based on determining the calculated variance exceeds the variance threshold independent of a piston position of the motor.
12. The method of claim 11, wherein the sampled current comprises a peak supply current value, and wherein the reference current comprises a reference peak current value.
13. The method of claim 11, wherein the sampled current comprises a root mean square (RMS) current value, and wherein the reference current comprises a reference RMS current value.
14. The method of claim 11, wherein the calculated variance is a recursive variance.
15. The method of claim 11, wherein calculating variance comprises
calculating a difference in a previously sampled current and the sampled current, and
calculating variance based on the difference in a previously sampled current and the sampled current.
16. The method of claim 11, wherein the sampled current value is a maximum absolute value of current for a corresponding electrical cycle.
17. The method of claim 11, wherein detecting the sampled current comprises detecting a predetermined-number set of sampled current values, and wherein calculating variance comprises calculating variance of the predetermined-number set of sampled current values.

18. The method of claim 17, wherein calculating variance comprises calculating a mean value of the predetermined-number of set of sampled current values.

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19. The method of claim 11, wherein determining the calculated variance exceeds the variance threshold comprises determining multiple calculated variance values exceed the predetermined variance, and wherein restricting the reference current is contingent on determining multiple calculated variance values exceed the predetermined variance.

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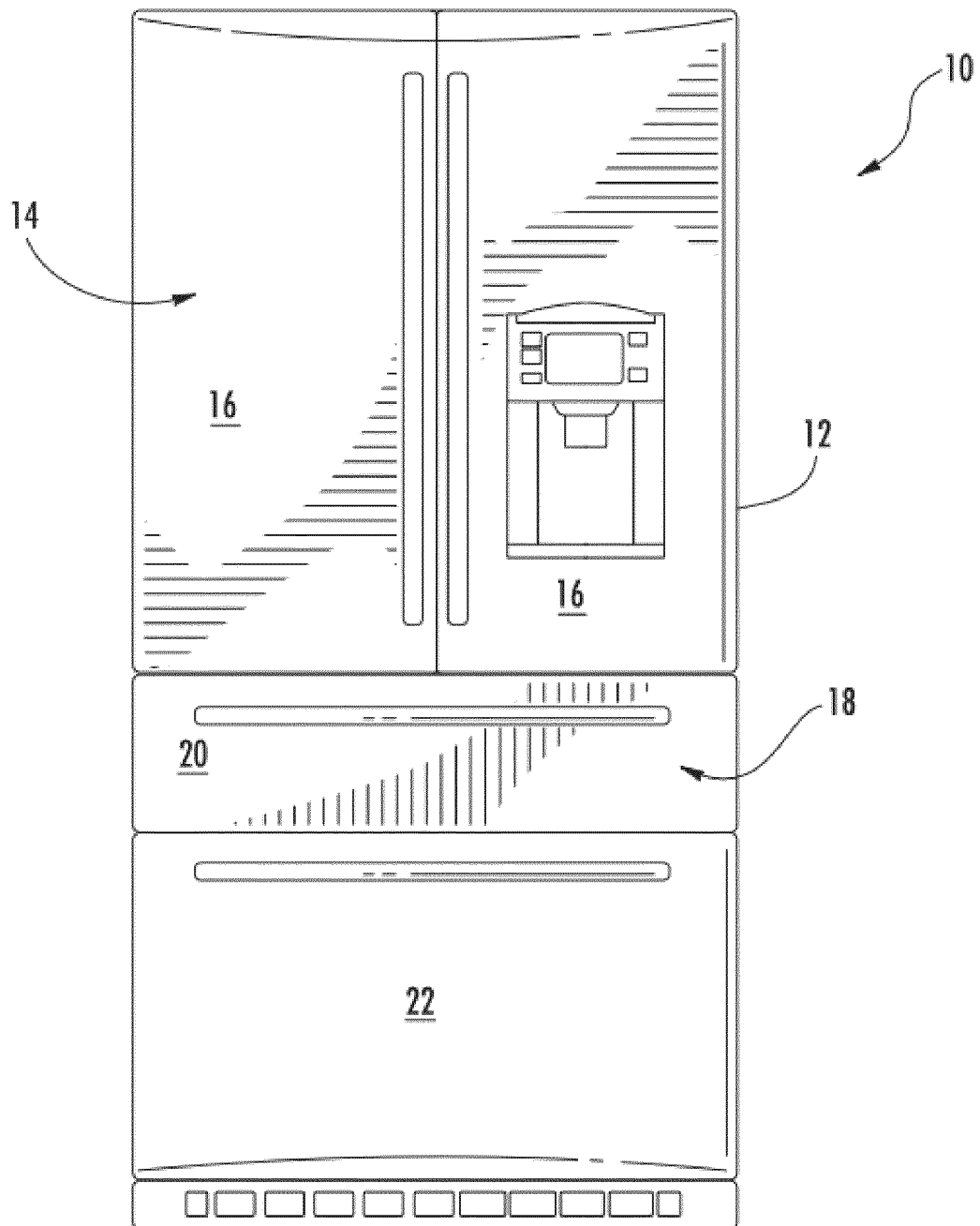


FIG. 1

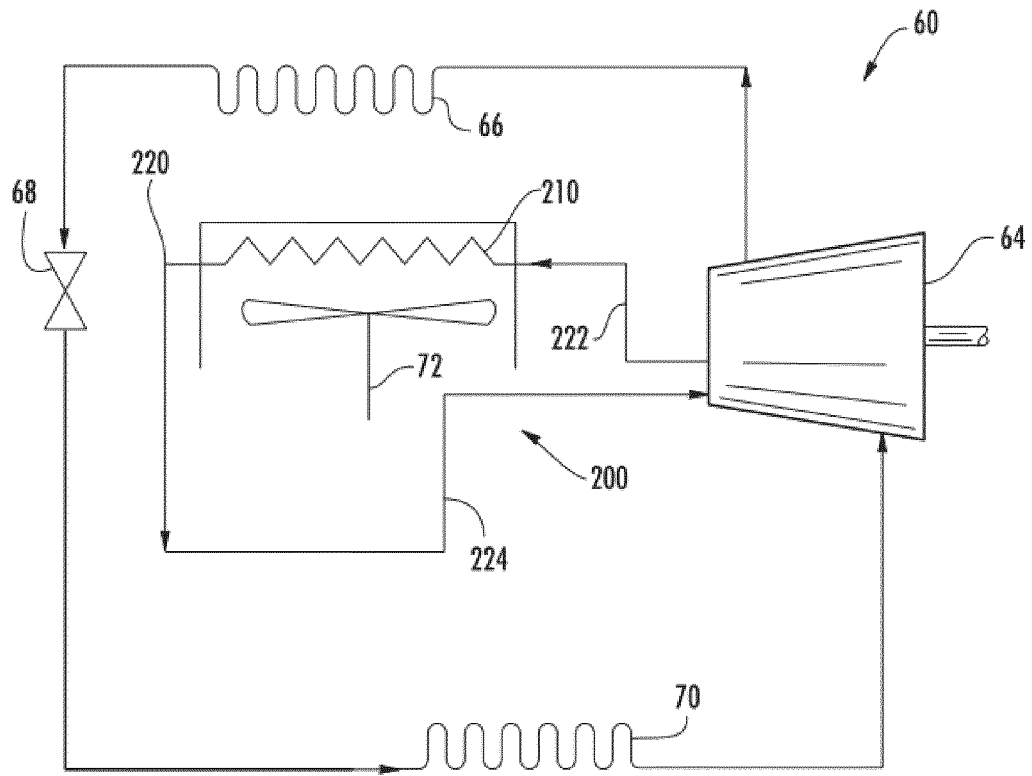


FIG. 2

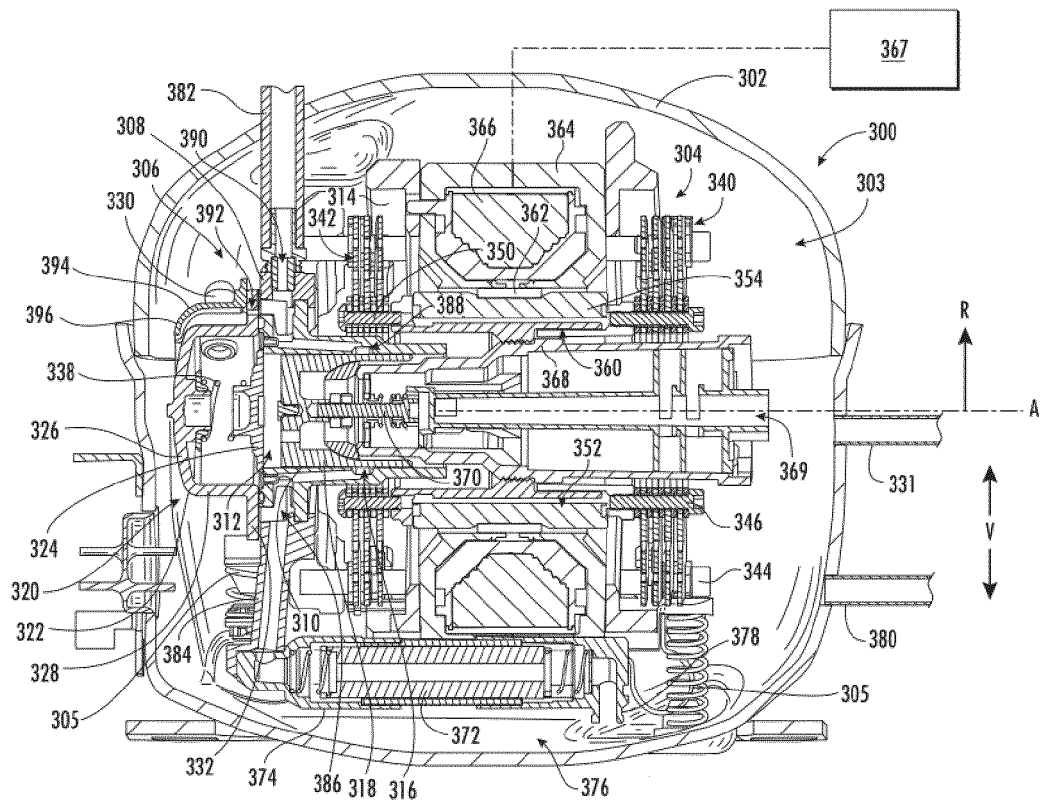


FIG. 3

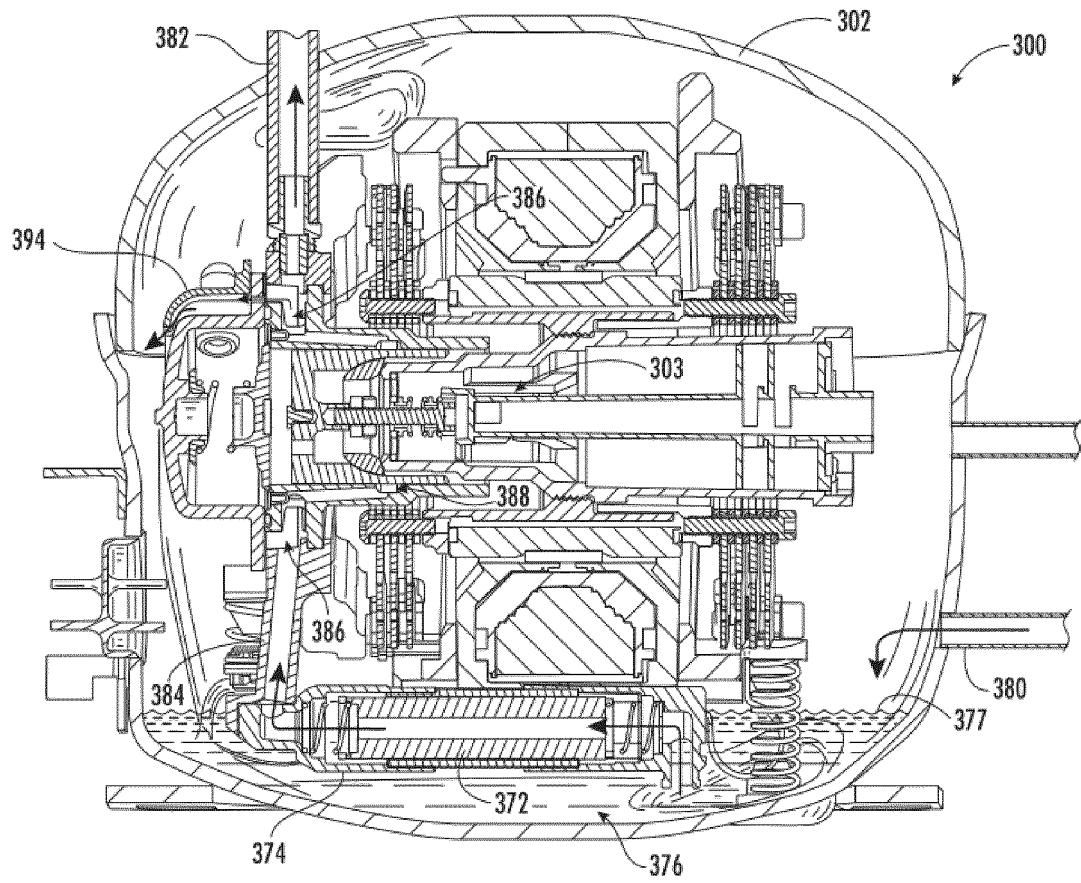


FIG. 4

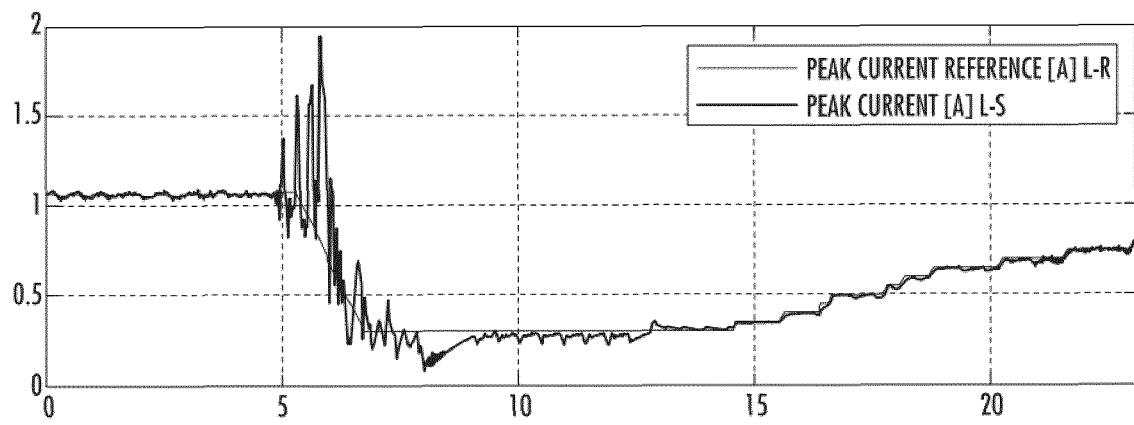


FIG. 5

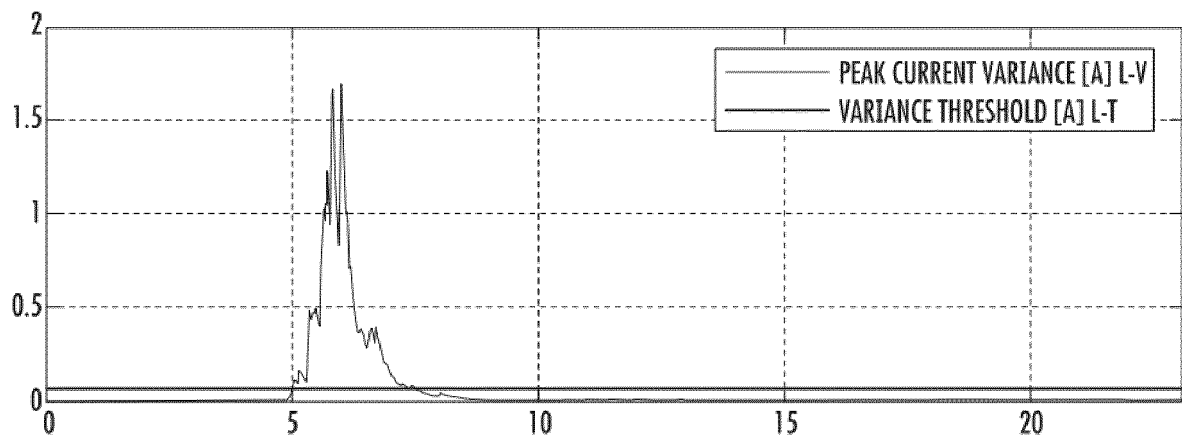


FIG. 6

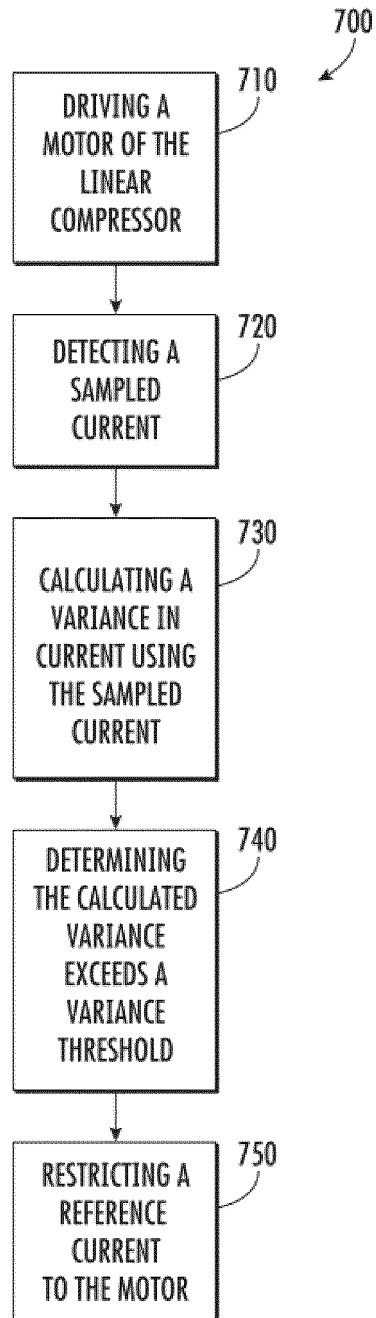


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2021/131455

5	A. CLASSIFICATION OF SUBJECT MATTER F04B 49/06(2006.01)i; G01R 19/00(2006.01)i According to International Patent Classification (IPC) or to both national classification and IPC		
10	B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) F04B; G01R Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
15	Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) CNPAT, EPODOC, WPI, CNKI: 压缩机, 线性, 直线, 活塞, 电机, 马达, 摆, 碰撞, 撞击, 壳, 电流, 方差, 阈值, 比较, 检测, 监测, 校正, 调, compressor, linear, piston, motor, crash+, collid+, collis+, correct+, detect+, adjust+, current, variance, compare		
20	C. DOCUMENTS CONSIDERED TO BE RELEVANT		
25	Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
30	A	JP 2004100640 A (FUJI ELECTRIC SYSTEMS CO., LTD.) 02 April 2004 (2004-04-02) description, paragraphs 20-33, and figures 1-2	1-19
35	A	CN 101952593 A (WHIRLPOOL SA) 19 January 2011 (2011-01-19) entire document	1-19
40	A	CN 106568498 A (WUHU ABAUR MECHANICAL & ELECTRICAL CO., LTD.) 19 April 2017 (2017-04-19) entire document	1-19
45	A	CN 106452270 A (NO. 719 RESEARCH INSTITUTE, CHINA SHIPBUILDING INDUSTRY CORP.) 22 February 2017 (2017-02-22) entire document	1-19
50	A	CN 107654359 A (QINGDAO HAIER INTELLIGENT TECHNOLOGY RESEARCH AND DEVELOPMENT CO., LTD.) 02 February 2018 (2018-02-02) entire document	1-19
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60	A	US 2017122309 A1 (GENERAL ELECTRIC COMPANY) 04 May 2017 (2017-05-04) entire document	1-19
65	☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
70	* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "I" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
75	Date of the actual completion of the international search		Date of mailing of the international search report
80	28 January 2022		15 February 2022
85	Name and mailing address of the ISA/CN		Authorized officer
90	China National Intellectual Property Administration (ISA/CN) No. 6, Xitucheng Road, Jimenqiao, Haidian District, Beijing 100088, China		
95	Facsimile No. (86-10)62019451		Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2021/131455

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Information on patent family members

International application No.

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		EP 3238887 A3	15 November 2017
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