United States Patent Application Publication 20250264103
Kind Code A1
Publication Date August 21, 2025
Inventor(s) Stratman; Taylor

SCAVENGE LOSS LIMITER FOR A ROTARY COMPRESSOR

Abstract

A fluid compressor system has a scavenge loss limiter that increases the efficiency of the fluid compressor system by reducing the compressed working fluid recirculated into the airend through a scavenge flow. The scavenge loss limiter includes a scavenge hole positioned at a discharge end face of a rotor cavity of the compressor housing. As a rotor of the compressor system rotates, the rotor may intermittently restrict the free-flowing scavenge flow returning from a lubricant separation tank. The rotor may be a male rotor having a plurality of male lobes. As the discharge end clearance between the rotor and the discharge end face is tightly controlled and monitored, a better control of the scavenge flow returning to the rotor cavity is achieved.

Inventors: **Stratman; Taylor (Quincy, IL)**

Applicant: **Ingersoll-Rand Industrial U.S., Inc.** (Davidson, NC)

Family ID: **1000008361597**

Appl. No.: **19/012547**

Filed: **January 07, 2025**

Related U.S. Application Data

parent US continuation 18581865 20240220 parent-grant-document US 12215692 child US 19012547

Publication Classification

Int. Cl.: **F04C29/02** (20060101); **F04C18/16** (20060101); **F04C29/00** (20060101)

U.S. Cl.:

CPC **F04C29/026** (20130101); **F04C18/165** (20130101); **F04C29/0028** (20130101); **F04C29/028** (20130101); F04C2210/1005 (20130101); F04C2210/14 (20130101);

F04C2240/30 (20130101); F04C2240/50 (20130101)

Background/Summary

BACKGROUND

[0001] Fluid compressor systems are widely used in a variety of industries such as in construction, manufacturing, agriculture, energy production, etc. As fluid compressors compress a working fluid, heat is produced as a result of the pressure increase in the working fluid. To reduce the heat produced by the compression process and lubricate mechanical components, compressor systems may inject a lubricant (e.g., oil, etc.) into the compressor airend. These compressors are known as contact-cooled compressors.

Description

DRAWINGS

[0002] The Detailed Description is described with reference to the accompanying figures. The use of the same reference numbers in different instances in the description and the figures may indicate similar or identical items.

[0003] FIG. **1** is an isometric view illustrating a rotary compressor with a scavenge loss limiter in accordance with example embodiments of the present disclosure.

[0004] FIG. **2** is a cross-sectional side view of a rotary compressor, as shown in FIG. **1** along line **2-2**, the rotary compressor having a male root scavenge limiter in accordance with example embodiments of the present disclosure.

[0005] FIG. **3** is a cross-sectional front view of the rotary compressor shown in FIG. **2** along line **3-3**, having a scavenge limiter orifice in accordance with example embodiments of the present disclosure.

[0006] FIG. **4** is a cross-sectional isometric view of a rotary compressor, as shown in FIG. **1**, the rotary compressor having a shaft scavenge limiter in accordance with example embodiments of the present disclosure.

[0007] FIG. **5** is a cross-sectional top view of the rotary compressor as shown in FIG. **4**, the rotary compressor having a shaft scavenge limiter in accordance with example embodiments of the present disclosure.

[0008] FIG. **6** is an isometric view of a rotor shaft, as shown in FIG. **4**, the rotor shaft having a shaft scavenge groove in accordance with example embodiments of the present disclosure.

[0009] FIG. **7** is a cross-sectional front view of the rotary compressor shown in FIG. **5** along line **7-7**, showing a bearing return passage connecting a bearing assembly with a rotor cavity in accordance with example embodiments of the present disclosure.

[0010] FIG. **8** is a cross-sectional side view of a rotary compressor, as shown in FIG. **1**, the rotary compressor having a rotor orifice scavenge limiter in accordance with example embodiments of the present disclosure.

[0011] FIG. **9** is an isometric view of the rotor shown in FIG. **8**, the rotor having a rotor scavenge orifice in accordance with example embodiments of the present disclosure.

[0012] FIG. **10** is a cross-sectional isometric view of a rotary compressor, as shown in FIG. **1**, a rotor of the rotary compressor having a blind-orifice scavenge limiter in accordance with example embodiments of the present disclosure.

[0013] FIG. **11** is a cross-sectional side view of the rotary compressor of FIG. **10**, along line **11-11**, the rotary compressor having a bearing return passage connecting a bearing assembly with a rotor cavity in accordance with example embodiments of the present disclosure.

[0014] FIG. **12** is a partial cross-sectional top view of the rotary compressor of FIG. **11** along line **12-12**, showing a rotor blind-orifice and a bearing lubrication passage in accordance with example embodiments of the present disclosure.
[0015] FIG. **13** is a schematic view of a compressor system including a contact-cooled rotary compressor and a separator tank in accordance with example embodiments of the present disclosure.

DETAILED DESCRIPTION

[0016] For the purposes of promoting an understanding of the principles of the subject matter, reference will now be made to the embodiments illustrated in the drawings and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of the subject matter is thereby intended. Any alterations and further modifications in the described embodiments, and any further applications of the principles of the subject matter as described herein are contemplated as would normally occur to one skilled in the art to which the subject matter relates.

Overview

[0017] Contact-cooled compressors, such as rotary screw compressors, separate the working fluid (e.g., air, gas, etc.) from the lubricant and other undesired particles in a separator process. The separation process starts in an oil sump in a separator tank, where a majority of the lubricant (around 95%) is separated from the compressed working fluid. The compressed working fluid is then directed to a coalescing-type filter. The coalescing-type filter intercepts and coalesces the remaining aerosol lubricant stream in the compressed working fluid as it exits the initial inertial separation process within the oil sump.
[0018] The coalescing-type filter includes a scavenge tube configured to take in the lubricant separated in the coalescing-type filter and recirculates it back into the compressor airend. The scavenge tube includes an orifice that controls the amount of lubricant and compressed working fluid that is returned or recirculated back into the compressor. This scavenge flow that is recirculated represents a loss in compressed working fluid delivered to the end-user. This scavenge loss is especially significant in small and variable speed compression systems (5 hp to 60 hp). The scavenge loss is even more significant when these small and variable speed compressors are running at their respective minimum speeds.
[0019] Less than one percent (1%) of scavenge flow corresponds to the lubricant, and almost the entirety of the scavenge flow corresponds to a loss of compressed working fluid. Typical compressors may include a scavenge return hole disposed on a rotor housing, located radially from an axis of rotation of a female rotor. There is a need for a compressor that limits compressed working fluid loss through scavenge flow, hereinafter referred to as scavenge loss.
[0020] Accordingly, the present disclosure is directed to a fluid compressor system having a scavenge loss limiter that increases the efficiency of the fluid compressor system by reducing the compressed working fluid recirculated into the airend. The scavenge loss limiter includes a scavenge orifice positioned at a discharge end of the compressor housing, for example, at an end face of a rotor cavity. As a rotor of the compressor system rotates, the rotor may intermittently restrict the free-flowing scavenge flow returning from the coalescent-type filter. The rotor may be a male rotor having a plurality of male lobes or a female rotor having a plurality of female lobes. As the discharge end clearance between the rotor and the discharge end face is tightly controlled and monitored, a better control of the scavenge flow returning to the rotor cavity is achieved.
[0021] The compressor system can be used with any type of fluid compression device and should not be limited to the illustrative fluid compressor system shown in any of the accompanying figures. The term “fluid” should be understood to include any compressible fluid medium that can be used in the fluid compressor system as disclosed herein. It should be understood that air is a typical working fluid, but different fluids or mixtures of fluid constituents can be used and remain within the teaching of the present disclosure. Therefore, terms such as fluid, air, compressible gas,

etc. can be used interchangeably in the present disclosure. For example, in some embodiments it is contemplated that ambient air, a hydrocarbon gaseous fuel including natural gas or propane, or inert gases including nitrogen or argon may be used as a primary working fluid. The fluid compressor system may include a compressor with multi-stage compression or a compressor with single stage compression. Other forms and configurations of compression devices are also contemplated herein. The fluid compressor system may include a rotary screw compressor. However, it is contemplated that other types of contact-cooled compressor systems may be used in different embodiments.

Detailed Description of Example Embodiments

[0022] Referring generally to FIGS. **1** through **13**, a compressor system **1000** having a contact-cooled airend or compressor **100** with a scavenge loss limiter is described. Compressor **100** includes a compressor housing **102** having a first end **104** and a second end **106**. The compressor housing **102** defines an inlet **101** configured to receive a working fluid (e.g., air, gas, etc.) for compressing. A rotor cavity **116** is defined between the first end **104** and the second end **106**. The compressor housing **102** further includes a first interior wall **118** located proximate to the first end **104**. In example embodiments, the first end **104** is a discharge end of the compressor **100**.

[0023] The compressor housing **102** houses at least one rotor configured to rotate around a rotor axis. For example, a first rotor **110** includes a rotor shaft **108** having a first plurality of helically disposed lobes **112**, a rotor end face **111**, and a rotor root **113** between adjacent lobes **112**. The compressor **100** further includes a bearing assembly **130** disposed within a bearing cavity **134** positioned by the first end **104** of the housing **102**. The bearing assembly **130** supports the rotor shaft **108** of the first rotor **110**. The bearing assembly **130** may include at least one bearing, for example a needle roller bearing, a ball bearing, an angular contact ball bearing, or a combination thereof.

[0024] As the compressor **100** runs, the rotor shaft **108** rotates around a rotor axis **108**X. The rotor axis **108**X extends from the first end **104** to the second end **106**. In the example embodiment shown, the first plurality of lobes **112** is a plurality of male lobes. The lobes **112** have a maximum radius R.sub.max with respect to the rotor axis **108**X. The rotor root **113** has a radius R.sub.O from the rotor axis **108**X.

[0025] The compressor housing **102** may also house a second rotor **114** configured to rotate around a second axis, where the second axis is parallel to the rotor axis **108**X. In other embodiments, the rotor axis **108**X and the second axis may be disposed at an angle greater than zero degrees (0°). The second rotor **114** includes a second plurality of lobes **115** configured to intermesh with the first plurality of lobes **112** to compress the working fluid. In the embodiment shown, the second plurality of lobes **115** is a plurality of female lobes having a thinner profile than the plurality of male lobes **112**.

[0026] The working fluid is injected with a lubricant for cooling and lubrication of the rotors and other mechanical components of the compressor **100**. The working fluid is then compressed as it travels from the second end **106** to the first end **104**. A compressed working fluid/lubricant mixture is discharged into a separator tank **200**. The separator tank **200** is configured to separate the lubricant from the compressed working fluid prior to delivery of the compressed working fluid. The separator tank **200** is in fluid communication with a coalescent-type filter **300** configured to further separate lubricant droplets from the working fluid. As the lubricant droplets collect at the bottom of the coalescent-type filter **300**, a scavenge pipe **302** absorbs the collected lubricant along with compressed working fluid and recirculates it back into the compressor **100** through a scavenge tube **304**.

[0027] To minimize compressed work fluid losses recirculated into the scavenge flow, the compressor **100** includes a scavenge flow limiter **120** connected to the scavenge tube **304**. The scavenge flow limiter **120** includes a scavenge passage **122** and a scavenge orifice **124**. The scavenge passage **122** is disposed within the first interior wall **118** on the discharge end of the compressor **100**. The scavenge passage **122** receives the scavenge flow from the scavenge tube **304** and releases the scavenge flow into the rotor cavity **116** through the scavenge orifice **124**.

[0028] In the embodiment shown in FIGS. **2** and **3**, the scavenge orifice **124** is positioned above a root **113** of the rotor **110**, between adjacent rotor lobes **112**. The scavenge orifice **124** may be positioned at an orifice radius R.sub.Y from the rotor axis **108**X, where the orifice radius R.sub.Y is greater than the rotor root radius R.sub.O and less than the rotor lobe **112** maximum radius R.sub.max.

[0029] As the first rotor **110** rotates, the rotor end face **111** of the plurality of lobes **112** intermittently cover and uncover the scavenge orifice **124**, opening and closing the scavenge orifice **124** to the rotor cavity **116**. In example embodiments, the rotor end face **111** and the first interior wall **118** are adjacent to each other and have a discharge end clearance (DEC) ranging from fifteen to twenty-five micrometers (15-25 μm). In example embodiments, the DEC is twenty micrometers (20 μm). The clearance between the first interior wall **118** and the rotor end face **111** allows the rotor lobes **112** to block the scavenge flow recirculating back into the rotor cavity **116** until the rotor **110** rotates to uncover the scavenge orifice **124**. The scavenge orifice may have a diameter between one-half millimeter and two millimeters (0.5-2 mm). In example embodiments, the scavenge orifice has a diameter of one millimeter (1 mm). In the embodiment shown in FIGS. **2** and **3**, the rotor **110** blocks the scavenge orifice **124** for most of the compression cycle while still allowing the scavenge flow to recirculate into the rotor cavity **116**.

[0030] FIGS. **4** through **7** show an example embodiment of the compressor **100** having a shaft scavenge loss limiter, where the rotor **110** has at least one scavenge groove **128** machined into the surface of the rotor shaft **108**. The scavenge passage **122** may direct the scavenge flow into the at least one scavenge groove **128** once per revolution of the rotor shaft **108**. The scavenge groove **128** fluidly connects the scavenge orifice **124** with the bearing assembly **130**. Once the scavenge flow flows into the scavenge groove **128**, the scavenge flow is directed to and lubricates the bearing assembly **130**. The scavenge flow may then be directed back into the rotor cavity **116** through a return passage **126**. In example embodiments, the scavenge loss limiter **120** includes a lubrication passage disposed between and fluidly connecting the scavenge groove **128** and the bearing assembly **130**.

[0031] In other embodiments, such as the one shown in FIGS. **8** and **9**, the scavenge orifice **124** is located at a radius R.sub.Y that is less than or equal to the rotor root radius R.sub.O. The scavenge groove **128** is machined in the rotor end face **111** at the rotor root **113** and is open to the rotor cavity **116**. As the rotor **110** rotates, the scavenge orifice **124** is blocked and the scavenge flow is restricted from entering the rotor cavity **116** until the scavenge groove **128** is aligned with the scavenger orifice **124**.

[0032] In other embodiments, as shown in FIGS. **10** through **12**, where the scavenge orifice **124** is located at a radius R.sub.Y that is less than the rotor root radius R.sub.O, the scavenge groove **128** may be machined in the rotor end face **111** below the rotor root **113**. In this embodiment, the scavenge groove **128** is not open to the rotor cavity **116**. The scavenge groove **128** may be a blind hole configured to act as a scavenge flow storage pocket, wherein the scavenge flow discharged from the scavenge orifice **124** is stored in the scavenge groove **128** until the rotor **110** rotates and aligns the scavenge groove **128** with a lubrication passage **132**. The scavenge groove **128** vents the scavenge flow stored into the lubrication passage **132**.

[0033] The lubrication passage **132** may direct the scavenge flow into the bearing assembly **130**. After passing through the bearing assembly **130**, the scavenge flow is redirected into the rotor cavity **116** through a return passage **126** as shown in FIG. **7**. The scavenge flow may be routed to the bearing assembly **130** to assist with the draining of the stored scavenge flow in the scavenge groove **128** and to help circulate any oil accumulating in the bearing cavity **134** back into the rotor cavity **116**.

[0034] As shown in FIG. **13** the compression system **1000** may include one contact-cooled airend or compressor **100**. In other embodiments, the compression system may include a plurality of compressors **100** in fluid communication with a separator tank **200** and a coalescent-type filter **300**. The compression system **1000** may further include a check valve **306** coupled between the scavenge tube **304** and the compressor **100**. The check valve **306** is configured to prevent backflow of the scavenge flow into the separator tank **200** and the coalescent-type filter **300** upon unit stoppage.

[0035] The storage tank **200** is coupled to an oil line **202** redirecting the lubricant pooled at the bottom of the separator tank **200** to recirculate the lubricant into the compressor **100**. The oil line **202** may include a cooling fan **204** and a filter element **206** configured to respectively cool and filter the recirculating lubricant prior to injecting into the rotor cavity **106**. The coalescing-type filter **300** is coupled to an after-cooler **402** that cools the compressed working fluid prior to it being delivered. The compression system **1000** may also include an air dryer **400** connected to the after-cooler **402**.

[0036] While the subject matter has been illustrated and described in detail in the drawings and foregoing description, the same is to be considered as illustrative and not restrictive in character, it being understood that only the preferred embodiments have been shown and described and that all changes and modifications that come within the spirit of the subject matters are desired to be protected. It should be understood that while the use of words such as preferable, preferably, preferred or more preferred utilized in the description above indicate that the feature so described may be more desirable, it nonetheless may not be necessary and embodiments lacking the same may be contemplated as within the scope of the subject matter, the scope being defined by the claims that follow. In reading the claims, it is intended that when words such as “a,” “an,” “at least one,” or “at least one portion” are used there is no intention to limit the claim to only one item unless specifically stated to the contrary in the claim. When the language “at least a portion” and/or “a portion” is used the item can include a portion and/or the entire item unless specifically stated to the contrary. Unless specified or limited otherwise, the terms “mounted,” “connected,” “supported,” and “coupled” and variations thereof are used broadly and encompass both direct and indirect mountings, connections, supports, and couplings. Further, “connected” and “coupled” are not restricted to physical or mechanical connections or couplings.

[0037] Although the subject matter has been described in language specific to structural features and/or process operations, it is to be understood that the subject matter defined in the appended claims is not necessarily limited to the specific features or acts described above. Rather, the specific features and acts described above are disclosed as example forms of implementing the claims.

Claims

1. A rotary compressor comprising: a housing having a rotor cavity and an interior wall; a rotor housed within the rotor cavity and rotating about a rotor axis, the rotor having a plurality of lobes; and a scavenge loss limiter disposed within the interior wall, the scavenge loss limiter comprising a scavenge passage and a scavenge orifice; wherein the scavenge loss limiter is configured to recirculate scavenge flow from an oil separator into the rotor cavity as the rotation of the rotor intermittently covers and uncovers the scavenge orifice.

2. The rotary compressor of claim 1, wherein the rotor comprises a rotor root radius and a lobe maximum radius from the rotor axis, and wherein the scavenge orifice is disposed at an orifice radius from the rotor axis, where the orifice radius is greater than the rotor root radius and less than the lobe maximum radius.

3. The rotary compressor of claim 1, wherein the housing comprises a bearing assembly, and wherein the scavenge passage is configured to direct a scavenge flow through the bearing assembly prior to recirculating the scavenge flow into the rotor cavity.

4. The rotary compressor of claim 3, wherein the rotor includes a scavenge groove configured to

receive the scavenge flow from the scavenge passage.
5. The rotary compressor of claim 4, wherein the scavenge groove is disposed in a rotor shaft of the rotor.
6. The rotary compressor of claim 4, wherein the bearing assembly comprises a bearing cavity, and wherein the scavenge groove directs the scavenge flow to the bearing cavity, the bearing cavity configured to be lubricated by the scavenge flow.
7. The rotary compressor of claim 4, wherein the rotor comprises a rotor end face, and wherein the scavenge groove is disposed on the rotor end face.
8. The rotary compressor of claim 7, wherein the scavenge groove is open to the rotor cavity.
9. A rotary compressor comprising: a housing having a rotor cavity and an interior wall; a rotor housed within the rotor cavity, rotating about a rotor axis; and a scavenge loss limiter disposed within the interior wall, the scavenge loss limiter including a scavenge passage and a scavenge orifice, the scavenge orifice connecting the scavenge passage with the rotor cavity; wherein the scavenge loss limiter is configured to recirculate scavenge flow from an oil separator into the rotary rotor cavity as the rotation of the rotor intermittently opens and closes the scavenge orifice.
10. The rotary compressor of claim 9, further comprising a second rotor housed within the rotor cavity.
11. The rotary compressor of claim 9, wherein the scavenge orifice is disposed at an orifice radius from the rotor axis, where the orifice radius is greater than a rotor root radius and less than a rotor lobe maximum radius.
12. The rotary compressor of claim 9, wherein the scavenge passage is configured to direct a scavenge flow through a bearing assembly prior to recirculating the scavenge flow into the rotor cavity.
13. The rotary compressor of claim 12, wherein the rotor includes a scavenge groove configured to receive the scavenge flow from the scavenge orifice.
14. The rotary compressor of claim 13, wherein the scavenge groove is disposed in a rotor shaft of the rotor.
15. The rotary compressor of claim 13, wherein the scavenge groove directs the scavenge flow to a bearing cavity, the bearing cavity configured to be lubricated by the scavenge flow.
16. The rotary compressor of claim 13, wherein the scavenge groove is disposed on a rotor end face.
17. The rotary compressor of claim 16, wherein the scavenge groove is open to the rotor cavity.
18. A compressor system comprising: an airend configured to compress a working fluid, the airend including: a housing having a rotor cavity and an interior wall; a rotor housed within the rotor cavity, rotating about a rotor axis; and a scavenge loss limiter disposed within the first interior wall, the scavenge loss limiter including a scavenge passage and a scavenge orifice, the scavenge orifice connecting the scavenge passage with the rotor cavity; and a lubricant separator configured to separate a lubricant from the working fluid, the lubricant separator delivering a scavenge flow to the airend; wherein the scavenge loss limiter is configured to recirculate the scavenge flow into the rotary rotor cavity as the rotation of the rotor intermittently opens and closes the scavenge orifice.
19. The compressor system of claim 18, wherein the scavenge orifice is disposed at an orifice radius from the rotor axis, where the orifice radius is greater than a rotor root radius and less than a rotor maximum lobe radius.
20. The compressor system of claim 18, wherein the scavenge passage is configured to direct a scavenge flow through a bearing assembly prior to recirculating the scavenge flow into the rotor cavity.