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FORCE OPTIMIZATION ON GRAIN CLEANING DRIVE SYSTEM OF COMBINE HARVESTER

Abstract

A grain cleaning system for a combine harvester includes a chaffer and a sieve positioned below the chaffer. A first link includes a first end and a second end coupled to the chaffer. A second link includes a first end and a second end coupled to the sieve. A drive shaft is driven by a drive system to rotate about a shaft axis, wherein rotation of the drive shaft drives the first link to reciprocate the chaffer and drives the second link to reciprocate the sieve. The drive system is configured to control reciprocating motion of the chaffer and sieve with the goals of (i) minimizing vibrations of the cleaning system, (ii) minimizing destructive forces on the bearings (and other components) of cleaning system, and (iii) minimizing the power required to reciprocate the chaffer and sieve back and forth.

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Background/Summary

FIELD OF THE INVENTION

[0001] The present invention relates to a combine harvester agricultural machine, and more particularly, to a drive for a grain cleaning system of a combine harvester.

BACKGROUND OF THE INVENTION

[0002] Combines are used to harvest agricultural crops such as corn, soybeans, wheat and other grain crops. As the combine is driven through crop fields, the combine cuts the crop, separates the desired crop from the undesired waste, stores the crop, and discards the waste.

[0003] In a typical combine, a header is mounted to the front of the combine to gather the crop and feed the crop into the combine for processing. As the combine is driven through the field, the crop material is collected by the header and deposited into a feeder housing. The crop material is then transported upwardly and into the combine by a feed elevator located within the feeder housing. The crop material then passes through a threshing and separating mechanism. In a rotary combine, the threshing and separating mechanism includes a rotor, a threshing concave, a rotor cage, and a separating grate. As crop material passes between the rotor, the threshing concave and the separating grate, the crop material is impacted and/or rubbed, thereby causing the grain to separate from the stalk material. The stalk material that is separated from the grain is commonly referred to as material other than grain (MOG). Other types of combines are also known that perform similar functions using different mechanisms.

[0004] After passing through the threshing and separating assembly, the grain and MOG are deposited onto a grain cleaning system. The grain cleaning system of a typical combine includes a plurality of adjustable cleaning sieves including a chaffer sieve, a shoe sieve, and (optionally) a pre-cleaning sieve. These sieves are typically reciprocated back and forth in opposite directions. This motion has the tendency to separate the grain from the MOG. To further separate the grain from the MOG, a cleaning fan or blower is positioned so as to blow air up through the cleaning sieves. This flow of air tends to blow the MOG, which is typically lighter than grain, rearwardly and out the back of the combine. Grain, which is heavier than MOG, is allowed to drop through the openings in the sieve.

[0005] The clean grain that falls through the cleaning sieves is deposited on a collection panel positioned beneath the cleaning sieves. The collection panel is angled so as to permit the grain to flow, under the influence of gravity, into an auger trough positioned along the lowermost edge of the collection panel. The auger trough is typically positioned near the forward end of the cleaning sieves and extends along the width of the sieves. The grain collected in the auger trough is then moved by an auger towards the side of the combine where it is raised by a grain elevator and deposited into a storage tank or grain tank.

[0006] Turning back to the grain cleaning system, that system can be subject to high peak forces as the sieves are reciprocated back and forth, which forces can be destructive to the cleaning system. While it is possible to increase the size and thickness of the grain cleaning system components to handle the higher peak forces, the space for accommodating those components is limited and it has been found that using larger components could have a negative impact on the structural and/or functional geometry of the cleaning system. Described herein is a system that is designed for reducing the aforementioned forces, while also minimizing the power required to reciprocate the sieves. Minimizing the power required to reciprocate the sieves results in either conservation of that power or the ability to use that power for other systems of the combine harvester.

SUMMARY OF THE INVENTION

[0007] According to one example, a grain cleaning system for a combine harvester is provided. The combine harvester includes a chassis and a header for harvesting agricultural material. The grain cleaning system comprises:
[0008] a chaffer configured to be supported for movement relative to the chassis between a chaffer front dead point (FDP) and a chaffer rear dead point (RDP); [0009] a sieve positioned below at least a portion of the chaffer, the sieve configured to be supported for movement relative to the chassis between a sieve FDP and a sieve RDP; [0010] a first link including a first end and a second end coupled to the chaffer; [0011] a second link including a first end and a second end coupled to the sieve; and [0012] a drive shaft driven to rotate about a shaft axis, the rotation of the drive shaft driving the first link to reciprocate the chaffer and driving the second link to reciprocate the sieve, [0013] wherein either (i) when the sieve is positioned at the sieve FDP, the chaffer is positioned at a location between the chaffer RDP and a chaffer midpoint (MP) position that is defined between the chaffer RDP and chaffer FDP, or (ii) when the sieve is positioned at the sieve RDP, the chaffer is positioned at a location between the chaffer FDP and the chaffer MP.
[0014] According to another alternative, when the sieve is positioned in the sieve RDP or the sieve FDP, the chaffer is positioned at a chaffer midpoint (MP) that is defined between the chaffer RDP and chaffer FDP.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0015] The above-mentioned and other features and advantages of this invention, and the manner of attaining them, will become more apparent and the invention will be better understood by reference to the following description of embodiments of the invention taken in conjunction with the accompanying drawings, wherein:
[0016] FIG. **1** is a side view of an embodiment of an agricultural combine harvester, in accordance with an exemplary embodiment of the present invention.
[0017] FIG. **2** is a cross-sectional view of a grain cleaning system of the combine of FIG. **1**, the grain cleaning system being shown schematically.
[0018] FIG. **3** is an isometric view of the grain cleaning system of FIG. **2**.
[0019] FIG. **4** is an elevation view of the grain cleaning system of FIG. **3**.
[0020] FIG. **5** is an isometric and exploded view of a drive mechanism for the cleaning system.
[0021] FIG. **6** is an end view of the drive shaft, the chaffer cam and the sieve cam.
[0022] FIG. **7** depicts a schematic view of the chaffer and sieve paths.
[0023] Corresponding reference characters indicate corresponding parts throughout the several views. The exemplifications set out herein illustrate embodiments of the invention and such exemplifications are not to be construed as limiting the scope of the invention in any manner.
DETAILED DESCRIPTION OF THE INVENTION
[0024] The terms “grain”, “straw” and “tailings” are used principally throughout this specification for convenience but it is to be understood that these terms are not intended to be limiting. Thus “grain” refers to that part of the crop material which is threshed and separated from the discardable part of the crop material, which is referred to as non-grain crop material, MOG or straw. Incompletely threshed crop material is referred to as “tailings”. Also the terms “forward”, “rearward”, “left” and “right”, when used in connection with the agricultural harvester and/or components thereof are usually determined with reference to the direction of forward operative travel of the combine harvester, but again, they should not be construed as limiting. The terms “longitudinal” and “transverse” are determined with reference to the fore-and-aft direction of the agricultural harvester and are equally not to be construed as limiting.
[0025] Referring now to the drawings, and more particularly to FIG. **1**, there is shown an

agricultural harvester in the form of a combine **10**, which generally includes a chassis **12**, ground engaging wheels **14** and **16**, a header **18**, a feeder housing **20**, an operator cab **22**, a threshing and separating system **24**, a grain cleaning system **26**, a grain tank **28**, and an unloading auger **30**. Motive force is selectively applied to front wheels **14** through a power plant in the form of a diesel engine **32** and a transmission (not shown). It should be appreciated that while the agricultural harvester is shown as combine **10**, the agricultural harvester can be any type of construction that allows for crop material to be harvested such as a conventional combine (which does not have a rotor), rotary combine, hybrid combine, chopper harvester, etc.

[0026] The header **18** is mounted to the front of the combine **10** and includes a cutter bar **34** for severing crops from a field during forward motion of the combine **10**. A rotatable reel **36** feeds the crop into the header **18**, and a double auger **38** feeds the severed crop laterally inwardly from each side toward the feeder housing **20**. The feeder housing **20** conveys the cut crop to the threshing and separating system **24**, and is selectively vertically movable using appropriate actuators, such as hydraulic cylinders (not shown).

[0027] The threshing and separating system **24** generally includes a rotor **40** at least partially enclosed by and rotatable within a corresponding perforated concave **42**. The cut crops are threshed and separated by the rotation of the rotor **40** within the concave **42**, and larger elements, such as stalks, leaves and the like are discharged from the rear of the combine **10**. Smaller elements of crop material including grain and non-grain crop material, including particles lighter than grain, such as chaff, dust and straw, are discharged through perforations of the concave **42**.

[0028] Grain which has been separated by the rotor **40** and perforated concaves **42** falls onto a main grain pan **44** and is conveyed toward grain cleaning system **26**. The grain cleaning system **26** may include an optional pre-cleaning sieve **46**, an upper sieve **48** (also known as a chaffer sieve), a lower sieve **50** (also known as a shoe sieve), and a cleaning fan **52**. Grain on the sieves **46**, **48** and **50** is subjected to a cleaning action by the fan **52** which provides an airflow through the sieves to remove chaff and other impurities such as dust from the grain by making this material airborne for discharge from straw hood **54** of the combine **10**. The main grain pan **44** and the pre-cleaning sieve **46** oscillate or reciprocate in a fore-to-aft manner to transport the grain and finer non-grain crop material to the upper surface of the upper sieve **48**. The upper sieve **48** and the lower sieve **50** are vertically arranged relative to each other, and likewise oscillate in a fore-to-aft manner to spread the grain across the sieves **48**, **50**, while permitting the passage of cleaned grain by gravity through the openings of the sieves **48**, **50**.

[0029] Clean grain falls to a clean grain auger **56** positioned crosswise below and in front of the lower sieve **50**. The clean grain auger **56** receives clean grain from each sieve **48**, **50** and from a bottom pan **58** of the grain cleaning system **26**. The clean grain auger **56** conveys the clean grain laterally to a generally vertically arranged elevator **60**, which can also be referred to as a grain elevator, for transport to the grain tank **28**. Tailings from the grain cleaning system **26** fall to a tailings auger on pan **62**. The tailings are transported via a tailings auger **64** and a return auger **66** to the upstream end of the grain cleaning system **26** for repeated cleaning action. A pair of grain tank augers **68** at the bottom of the grain tank **28** convey the clean grain laterally within the grain tank **28** to the unloading auger **30** for discharge from combine **10**. The non-grain crop material proceeds through a residue handling system **70**. The residue handling system **70** may include a chopper, counter knives, a windrow door and a residue spreader.

[0030] Referring now to FIG. **2**, a grain cleaning system **26**, which forms part of the threshing and separating system **24**, is shown in cross-section. Prior to reaching the grain cleaning system **26**, the rotor **40** and perforated concave **42** (not shown in FIG. **2**) operate to create a mat of the crop material and pass it through a narrow gap between the rotor **40** and the perforated concave **42** to thresh or separate the grains from the larger elements of MOG such that a flow of the grain will be discharged into the grain cleaning system **26**. This flow of grain will include some smaller elements of MOG, and falls on the main grain pan **44**. A reciprocating motion causes the mixture of grain and residual MOG to move rearwardly until it passes over a fall step **100**. The mixture then falls on the pre-cleaning sieve **46**, where a certain volume of the mixture of grain and residual MOG are separated, again under reciprocal motion of the pre-cleaning sieve. Excess volume of the mixture of grain and residual MOG passes over the pre-cleaning sieve **46** onto the upper or chaffer sieve **48**. The grain cleaned by pre-cleaning sieve **46** and upper sieve **48** then falls through to lower or shoe sieve **50** for further cleaning, also under reciprocal motion.

[0031] Throughout this movement of the mixture of grain and residual MOG, a cleaning fan **52** blows air up past the ends of the main grain pan **44** and the grain transfer pan **72**, and up through the pre-cleaning sieve **46**, the upper sieve **48**, and the lower sieve **50**, by way of fan main outlet **122** leading to a fan upper outlet **106** and a fan lower outlet **110**, guided by fan outlet air guide **112**. Further details in connection with cleaning system **26** are described in U.S. Pat. No. 10,039,236, which is incorporated by reference in its entirety and for all purposes.

[0032] Turning now to FIGS. **3** and **4**, and is described in U.S. Pat. No. 9,844,186, which is incorporated by reference herein in its entirety, the chaffer **48** includes a first end **138** positioned proximate the fan **52** and a second end **142** positioned away from the fan **52**. The chaffer **48** is positioned below a portion of the concave **42**. In the illustrated embodiment, the harvester **10** also includes conveyor augers **146** positioned within grain pan **44**. Grain that is separated by the forward portion of the concave **42** falls into troughs **150** of grain pan **44**, where the augers **146** convey the grain to the first end **138** of the chaffer **48**.

[0033] The (optional) pre-cleaning sieve **46** may be positioned above a portion of the chaffer **42** proximate the second end **142**. The sieve **46** is linked to the chaffer **48** for reciprocating movement by a connecting arm **154**. The sieve **46** collects grain from the concave **42** and deposits it onto the chaffer **48**.

[0034] The shoe sieve **50** is positioned below the chaffer sieve **48**. The sieve **50** reciprocates independently of the chaffer **48**. The chaffer **48** and the sieve **50** each include louvers or slots (not shown) through which grain passes. The slots can be selectively opened and closed depending on the type and size of grain that is being harvested.

[0035] Turning now to FIGS. **4** and **5**, the cleaning system **26** further includes a drive system **162** for reciprocating the chaffer **48** and sieve **50**. The drive system **162** includes a drive shaft **166**, a first link or chaffer link **170**, and a second link or sieve link **174**. The drive shaft **166** rotates about a shaft axis **178** (FIG. **6**). In the illustrated embodiment, the drive system **162** also includes a pulley or sheave **182** coupled to the drive shaft **166** and a belt **186** wrapped around a portion of the sheave **182**. The belt **186** may be driven by a motor (not shown) to rotate the sheave **182** and the shaft **166**. In other embodiments, another type of drive system may be used.

[0036] As shown in FIG. **5**, the drive system **162** also includes a first cam or chaffer cam **194** eccentrically coupled to the shaft **166** and a second cam or sieve cam **198** eccentrically coupled to the shaft **166**. In the illustrated embodiment, each cam **194**, **198** is secured against rotation relative to the shaft **166** by a key **200** formed on the shaft **166**. The chaffer link **170** includes a first end **202** coupled to the chaffer cam **194** and a second end **206** coupled to the connecting arm **154**, which is in turn coupled to the sieve **46** as well as a center of gravity point of chaffer **48**. The sieve link **174** includes a first end **210** coupled to the sieve cam **198** and a second end **214** coupled at or near a center of gravity point of the sieve **50**. Connections to the respective center of gravity points are not necessarily shown in all of the figures.

[0037] In the illustrated embodiment, the chaffer link **170** and sieve link **174** are each formed as Pitman arms. The first ends **202**, **210** each include flanges **218** that extend around the respective cams **194**, **198**. Although one side of the drive system **162** is shown in FIGS. **4** and **5**, it is understood that another chaffer link **170**, another sieve link **174**, similar cams **194**, **198**, and/or an additional sheave/flywheel may be provided on the opposite end of the drive shaft **166**. It should be understood that the details of the drive system **162** can vary greatly.

[0038] Turning now to FIG. **6**, the chaffer cam **194** and the sieve cam **198** may be angularly offset

from one another with respect to the shaft axis **178** by a phase angle **230**. Stated another way, a first reference line **238** extends between the shaft axis **178** and a point on the chaffer cam **194** that is furthest from the shaft axis **178**, and a second reference line **242** extends between the shaft axis **178** and a point on the sieve cam **198** that is furthest from the shaft axis **198**. The phase angle **230** is defined as the angle between the first reference line **238** and the second reference line **242**. The phase angle **230** provides a phase difference between the reciprocation of the chaffer link **170** and the reciprocation of the sieve link **174**. The motions of the chaffer link **170** and the sieve link **174** are out of phase relative to each other, thereby causing the motions of the chaffer **48** and the sieve **50** to be out of phase relative to one another.
[0039] It should be understood that the design is not limited to any particular phase angle **230**. The value of the phase angle **230** can vary depending upon the design of the cleaning system (e.g., component shapes, center of gravity, etc.). The phase angle may be selected to optimize a particular performance characteristic or support a limiting factor of the design, for example. The phase angle **230** may be 80 to 120 degrees, for example.
[0040] Turning now to FIG. **7**, both the chaffer **48** and sieve **50** reciprocate between a front dead point (FDP) and a rear dead point (RDP). In the FDP, the respective sieve cannot move further forward along its path, and, in the RDP, the respective sieve cannot move further rearward along its path. The path may be arcuate, curved, straight, ovular, eye-shaped, vertical, circular, and so forth. A midpoint (MP) is defined between the FDP and RDP. The drive system **162** is specially designed to control reciprocating motion of chaffer **48** and sieve **50** between the RDP and FDP with the goals of (i) minimizing vibrations of the cleaning system, (ii) minimizing destructive forces on the bearings (and other components) of cleaning system **26**, and (iii) minimizing the power required to reciprocate the chaffer **48** and sieve **50** back and forth.
[0041] Specifically, to meet the aforementioned goals, the drive system **162** may be operated such that when the sieve **50** is in its RDP, the chaffer **48** is maintained at a location between its MP and FDP. Alternatively, to meet the aforementioned goals, the drive system **162** may be operated such that when the sieve **50** is in its FDP, the chaffer **48** is maintained at a location between its MP and RDP. Such operation is seen as a compromise or optimization (and referred to herein as an optimized arrangement) between a first arrangement in which the destructive forces are minimized and a second arrangement in which the power required to move the sieves is minimized. As background, in the first arrangement, when the sieve **50** is in its RDP, the chaffer **48** is in its FDP. And, in the second arrangement, when the sieve **50** is in its RDP or FDP, the chaffer is at its MP. It has been discovered that the optimized arrangement described above may be preferred because it results in (i) minimized vibrations of the cleaning system, (ii) minimized destructive forces on the bearings (and other components) of cleaning system **26**, and (iii) minimized power required to reciprocate the chaffer **48** and sieve **50** back and forth. Alternatively, the above-described second arrangement, in which the power required to move the sieves is minimized, may be viewed as preferred. As another alternative, the above-described first arrangement may be viewed as preferred.
[0042] While this invention has been described with respect to at least one embodiment, the present invention can be further modified within the spirit and scope of this disclosure. This application is therefore intended to cover any variations, uses, or adaptations of the invention using its general principles. Further, this application is intended to cover such departures from the present disclosure as come within known or customary practice in the art to which this invention pertains and which fall within the limits of the appended claims.

Claims

1. A grain cleaning system for a combine harvester, the combine harvester including a chassis and a header for harvesting agricultural material, said grain cleaning system comprising: a chaffer sieve

configured to be supported for movement relative to the chassis between a chaffer sieve front dead point (FDP) and a chaffer sieve rear dead point (RDP); a shoe sieve positioned below at least a portion of the chaffer sieve, the shoe sieve configured to be supported for movement relative to the chassis between a shoe sieve FDP and a shoe sieve RDP; a first link including a first end and a second end coupled to the chaffer sieve; a second link including a first end and a second end coupled to the shoe sieve; and a drive shaft driven to rotate about a shaft axis, the rotation of the drive shaft driving the first link to reciprocate the chaffer sieve and driving the second link to reciprocate the shoe sieve, wherein either (i) when the shoe sieve is positioned at the shoe sieve FDP, the chaffer sieve is positioned at a location between the chaffer sieve RDP and a chaffer sieve midpoint (MP) position that is defined between the chaffer sieve RDP and chaffer sieve FDP, or (ii) when the shoe sieve is positioned at the shoe sieve RDP, the chaffer sieve is positioned at a location between the chaffer sieve FDP and the chaffer sieve MP.
2. The grain cleaning system of claim 1, wherein the second end of the first link is coupled to the chaffer sieve at a point on the chaffer sieve that constitutes a center of gravity of the chaffer sieve.
3. The grain cleaning system of claim 1, wherein the second end of the second link is coupled to the shoe sieve at a point on the shoe sieve that constitutes a center of gravity of the shoe sieve.
4. The grain cleaning system of claim 1, wherein when the shoe sieve is positioned at the shoe sieve FDP, the chaffer sieve is positioned at a location between the chaffer sieve RDP and the chaffer sieve MP.
5. The grain cleaning system of claim 1, when the shoe sieve is positioned at the shoe sieve RDP, the chaffer sieve is positioned at a location between the chaffer sieve FDP and the chaffer sieve MP.
6. The grain cleaning system of claim 1, the drive shaft including a first cam and a second cam, the first cam coupled to the first end of the first link, the second cam coupled to the first end of the second link, wherein the second cam is angularly offset relative to the first cam by a phase angle.
7. The grain cleaning system of claim 6, wherein the phase angle is selected so as to minimize vibrations of the cleaning system.
8. The grain cleaning system of claim 6, wherein the phase angle is selected so as to minimize destructive forces on bearings and/or other components of the cleaning system.
9. The grain cleaning system of claim 6, wherein the phase angle is selected so as to minimize a power required to reciprocate the chaffer and shoe sieves back and forth.
10. The grain cleaning system of claim 1, wherein in the shoe sieve RDP and the chaffer sieve RDP, neither the shoe sieve nor the chaffer sieve can move further rearward along their respective paths, and, in the shoe sieve FDP and the chaffer sieve FDP, neither the shoe sieve nor the chaffer sieve can move further forward along their respective paths.
11. A combine harvester comprising the grain cleaning system of claim 1.
12. A grain cleaning system for a combine harvester, the combine harvester including a chassis and a header for harvesting agricultural material, said grain cleaning system comprising: a chaffer sieve configured to be supported for movement relative to the chassis between a chaffer sieve front dead point (FDP) and a chaffer sieve rear dead point (RDP); a shoe sieve positioned below at least a portion of the chaffer sieve, the shoe sieve configured to be supported for movement relative to the chassis between a shoe sieve FDP and a shoe sieve RDP; a first link including a first end and a second end coupled to the chaffer sieve; a second link including a first end and a second end coupled to the shoe sieve; and a drive shaft driven to rotate about a shaft axis, the rotation of the drive shaft driving the first link to reciprocate the chaffer sieve and driving the second link to reciprocate the shoe sieve, wherein when the shoe sieve is positioned in the shoe sieve RDP or the shoe sieve FDP, the chaffer sieve is positioned at a chaffer sieve midpoint (MP) that is defined between the chaffer sieve RDP and chaffer sieve FDP.
13. The grain cleaning system of claim 12, wherein in the shoe sieve RDP and the chaffer sieve RDP, neither the shoe sieve nor the chaffer sieve can move further rearward along their respective paths, and, in the shoe sieve FDP and the chaffer sieve FDP, neither the shoe sieve nor the chaffer

sieve can move further forward along their respective paths.
14. The grain cleaning system of claim 12, the drive shaft including a first cam and a second cam, the first cam coupled to the first end of the first link, the second cam coupled to the first end of the second link, wherein the second cam is angularly offset relative to the first cam by a phase angle.
15. A combine harvester comprising the grain cleaning system of claim 12.