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Combine harvester with weed seed destruction

Abstract

Weed seeds are destroyed in the chaff from a combine harvester by repeated high speed impacts caused by a rotor mounted in one of a pair of side by side housings which accelerate the discarded seeds in a direction centrifugally away from the rotor onto a stator including angularly adjustable stator surfaces around the axis. Thus the discarded seeds rebound back and forth between the rotor and the stator to provide a plurality of impacts. The seeds are carried axially of the rotor by a controlled airstream so that they move to an axial discharge location where a discharge fan is mounted. The angle of the discharge around the rotor axis can be changed to direct the seeds to the side of the combine away from a straw chopper, towards the guide fins of the tailboard of the chopper, or into the housing of the straw chopper.

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Background/Summary

(1) This application is a continuation of application Ser. No. 17/150,181 filed Jan. 15, 2021 which is a continuation of application Ser. No. 16/654,162 filed Oct. 16, 2019 which is a divisional application of application Ser. No. 16/016,827 filed Jun. 25, 2018 which issued as U.S. Pat. No. 10,485,178 on Nov. 26, 2019, which is a continuation of application Ser. No. 15/701,096 filed Sep. 11, 2017 which issued as U.S. Pat. No. 10,492,369 on Dec. 3, 2019, which is a continuation in part of application Ser. No. 15/209,151 filed Jul. 13, 2016 which is issued as U.S. Pat. No. 10,004,176 on Jun. 26, 2018. (2) This application claims the benefit under 35 USC 119 (e) of Provisional application 62/192,111 filed Jul. 14, 2015.

(1) This invention relates to a weed seed destructor which can be attached to a combine harvester so that weed seeds in the discharged chaff can be devitalized before being spread onto the ground.

BACKGROUND OF THE INVENTION

(2) Combine harvesters harvest cereal grain crops, such as wheat, oats, rye, barley, corn, soybeans and flax. Grain and straw are separated in a combine harvester. Following the separation process, waste straw and chaff is supplied to a chopper for shredding and distributing back over the field in

an even spread pattern.

(3) During the harvesting process weed seeds and grain seed are discharged with the residue into the chopper and spread back onto the field. The combine is then effectively acting as a seeder to evenly spread the seed back onto the field. In a number of areas of the world herbicides are used heavily to control the weed seeds however this has led to weed and grain seed that has become resistant to the herbicide.

(4) It is known that if the seed can be removed or destroyed before the combine spreads it back onto the field the cycle can be stopped. Research has shown that, with three consecutive cycles of weed and grain removal, significant reductions in herbicide can be obtained providing huge saving for farmers.

(5) One recent approach is shown in WO 2014/127408 published Aug. 28, 2014 and assigned to Grains Research Development Corporation Australia which shows that a plurality of impacts at relatively high speed of the seeds with a stationary object causes breakdown of the seed sufficient to prevent germination. Thus they have developed a cage mill which is integrally mounted inside the combine harvester so as to receive waste material (discarded seeds and chaff) from the sieve. The cage mill assembly includes at least one rotating ring carrying a plurality of blades and a series of outer stationary rings or fixed blades. Thus the seeds are accelerated outwardly by escaping centrifugally from the rotating blades into the surrounding stationary blades of the outer rings where a series of impacts occur as the seeds move outwardly into and through the fixed blades. The seeds are released outwardly under the centrifugal force from the stationary blades and escape outwardly into a peripheral channel for discharge.

(6) The document shows evidence that four impacts at relatively high speed are sufficient to cause the required breakdown of the seeds, for example to obtain a 95% kill rate.

(7) However the cage mill shown is large and complex with numerous rings running in opposite directions. Should a rock, or other hard material enter the mill, the entire cage mill would need to be replaced. Thus the system may function to destroy the seeds but has practical difficulties as it is without consideration of other obstacles passing through the assembly. The assembly runs at a very high rotational speed, so the precision in manufacturing is critical. Although this is believed that this arrangement is closer to commercialization a number of problems remain with the design.

(8) U.S. Pat. No. 3,448,933 (Roy) issued Jun. 10, 1969 describes a cone style grinding shear mill used to process weed seed. All excess chaff and weed seed is processed by the unit. However it is a permanently fixed grinder without a means to bypass material other than residue. It would also allow passage of small fine seeds as it would need to be set to the average seed size to allow adequate throughput.

(9) U.S. Pat. No. 5,059,154 (Reyenga) issued Oct. 22, 1991 discloses a pair of rollers to mill seeds smaller than grain that are in the clean grain auger. This does not address seeds thrown over the back of the sieve and would not work if placed behind the sieve as today's combines the chaff stream is often 6 inches thick which would cushion the seeds and allow the spread of live seed back onto the field.

(10) In AU Published Application 2001/038781 an additional sieve is added to remove more of the chaff before milling, and separate the weed seed from the grain. However this is not practical with today's combines. All combines throw out some grain and farmers want the herbicide tolerant grain removed as well.

(11) U.S. Pat. No. 8,152,610 (Harrington) issued Apr. 10, 2012 discloses an arrangement which processes all the chaff coming off of the sieves and blows it to a trailing cart to pulverize all of the residue. The cart requires a second engine running in the dust of the combine and the mill requires a significant amount of power to pulverize and discharge the residue back onto the field. The cage mill disclosed is large and complex with numerous rings running in opposite directions. Again, the rings have not removable parts so should a rock, or other hard material enter it the entire cage mill would need to be replaced. The cost of this system will limit its commercial viability.

(12) The term weed seed destruction used herein is used somewhat colloquially in that the seeds are not annihilated but are devitalized or rendered so that they cannot germinate. It will of course also be appreciated that not necessarily each and every seed is destroyed but that the intention is that a significant number will be incapable of germination so as to reduce the number of emerging seeds in the growing season.

SUMMARY OF THE INVENTION

(13) According to the invention there is provided an apparatus for use in a combine harvester which includes a separation system for separating from harvested crop a first material comprising straw and a second material comprising chaff and weed seeds, the apparatus comprising:

(14) a weed seed destructor section arranged to be mounted on the combine harvester at a location to receive the second material comprising:

(15) a housing having at least one inlet for receiving the second crop residue material from the second discharge location and at least one outlet for discharging the second crop residue material after passage through the housing;

(16) two or more rotors located in the housing each for rotation about a respective axis where the axes are parallel, each rotor comprising a plurality of radially extending impact members;

(17) said at least one outlet of the housing being axially spaced from said at least one inlet of the housing;

(18) and one or more fan members arranged to urge the crop residue material to move through the housing from said at least one inlet to said at least one outlet;

(19) wherein the plurality of radially extending impact members are configured to rotate with said two or more rotors and impact against the crop residue material as the crop residue material passes through the housing.

(20) Preferably in one embodiment the fan members, the impact members and the housing are configured so that less dense material of the second crop residue material defined by the chaff is subjected to less impacts and denser material of the second crop residue material defined by the weed seeds is subjected to relatively more impacts.

(21) Preferably in one embodiment the fan member is in the form of a paddle of a spreader located at an outlet end of the housing.

(22) Preferably in one embodiment the housing is shaped so that it approximates the outer dimensions of the rotors.

(23) Preferably in one embodiment the housing is shaped so that it substantially follows an orbit of a tip of each of the impact members and wherein the impact members are arranged in two parallel rows.

(24) Preferably in one embodiment the impact members rotate with velocity so as to damage weed seeds in the crop residue upon impact.

(25) Preferably in one embodiment the apparatus is configured so that the denser material comprising weed seeds which are retained in the housing until the weed seeds are sufficiently impacted so as to damage a substantial amount of weed seed in the second crop residue material before it exits the outlet and the less dense material is the remainder of the crop residue which has received fewer impacts than the seeds within the housing when it exits the outlet.

(26) Preferably in one embodiment the housing comprises an inwardly directed annulus at the outlet between the housing and said one or more fan members.

(27) Preferably in one embodiment the less dense material of the second crop residue material is more influenced by the air flow and the denser material of the second crop residue material is more influenced by a centrifugal force imparted by said two or more rotors.

(28) Preferably in one embodiment the housing includes means for returning the material impacted thereon back toward the said two or more rotors.

(29) Preferably in one embodiment the rotors and the housing arranged such that the weed seeds rebound back and forth between said two or more rotors and the housing to provide a plurality of

impacts on the weed seeds to destroy at least some of the weed seeds.

(30) Preferably in one embodiment the discharge opening is at a location different from the housing so that said weed seeds discharged from the rotor through said discharge opening do not exit through the housing.

(31) Preferably in one embodiment the rotors rotate around an axis so as to direct the weed seeds centrifugally outwardly, and the housing surrounds the axis so as to rebound the weed seeds back toward the axis and the discharge opening is arranged such that the discarded seeds discharge axially from within the housing.

(32) Preferably in one embodiment the housing is arranged to be mounted directly under the second discharge location of the combine harvester with the rotor axis generally upright so that the second crop residue material falls directly into the top of the housing on to said two or more rotors along the axial direction of the rotors.

(33) Preferably in one embodiment the second crop residue material enters the housing axially of said two or more rotors at one end and discharges axially from the opposite end of the housing.

(34) Preferably in one embodiment the fan members is arranged to direct the second crop residue material radially outwardly relative to the axis of the rotor.

(35) Preferably in one embodiment the housing comprises a stator including one or more stator surfaces for engaging the weed seeds when accelerated by said two or more rotors.

(36) Preferably in one embodiment the stator surfaces are arranged at an angle to a tangent of an imaginary cylindrical surface surrounding the axis.

(37) Preferably in one embodiment the angle of the stator surfaces to the tangent is adjustable.

(38) Preferably in one embodiment the stator surfaces and/or the rotor surfaces are arranged to pivot so as to increase the spacing therebetween to allow the passage of foreign objects between the rotor and stator.

(39) Preferably in one embodiment the stator surfaces are readily removable for replacement when damaged or worn.

(40) Preferably in one embodiment the velocity of air generated by said one or more fan members is adjustable to change the number of impacts a seed encounters during its passage.

(41) Preferably in one embodiment the impact members of said two or more rotors include a generally flat surface having a first end edge spaced axially of a second edge so that the surface when rotated provides a width between the first and second end edges for engaging the weed seeds.

(42) The embodiments disclosed hereinafter provide a number of further features and aspects. One of these is directed to an apparatus for destroying weed seeds comprising:

(43) a housing arranged to be mounted at a location on a combine harvester for receiving from the location a feed material containing separated chaff and weed seeds separated by the combine harvester from harvested crop;

(44) a rotor mounted in the housing for rotation about an axis and including rotor surfaces thereon for engaging the feed material and for accelerating the feed material in a direction outwardly from the axis of the rotor;

(45) a stator arranged at a location along the direction and including one or more stator surfaces for engaging the weed seeds in the accelerated feed material;

(46) said stator and said one or more stator surfaces of the stator being arranged such that the weed seeds impact on said one or more stator surfaces and do not pass through the stator along said direction but instead are rebounded therefrom back toward the rotor;

(47) the rotor and stator being arranged such that the weed seeds rebound back and forth between the rotor and the stator to provide a plurality of impacts on the accelerated feed material to destroy at least some of the weed seeds;

(48) wherein the housing includes a discharge opening for discharge of the feed material after the plurality of impacts, where the discharge opening is at a location different from the stator so that said weed seeds discharged from the rotor through said discharge opening do not pass through the

stator.

- (49) Preferably therefore the discharge opening for discharge of the feed material after the plurality of impacts the discarded seeds discharge from the rotor and do not pass through the stator but instead are rebounded away from the stator to discharge at a different location. In this way, any foreign bodies are not trapped in the stator to cause damage but instead can escape to the discharge.
- (50) In the preferred arrangement described in detail hereinafter, the rotor rotates around an axis so as to direct the discarded seeds centrifugally outwardly, and the stator surrounds the axis so as to rebound the discarded seeds back toward the axis and the discharge opening is arranged such that the discarded seeds discharge axially from within the stator.
- (51) In one arrangement the rotor is mounted directly under the first discharge location of the combine harvester with the rotor axis generally upright so that the feed material fold directly into the top of the housing on to the rotor along the axial direction of the rotor.
- (52) As an alternate embodiment the apparatus comprises a horizontal rotor defined by a horizontally rotating tube or shaft, with auger fighting in the middle of the shaft, moving the feed material or chaff to an impact zone at each end of the horizontal rotor. The discharge zone is then at the end and is arranged to expel into the straw chopper of the combine harvester.
- (53) Preferably as a feature of independent importance the feed material enters the housing axially of the rotor at one end and discharges axially from the opposite end of the rotor.
- (54) Preferably as a feature of independent importance there is provided a fan component for driving the discarded seeds from the opposite end radially outwardly.
- (55) Preferably as a feature of independent importance the stator includes a plurality of stator surfaces spaced angularly around the axis.
- (56) Preferably as a feature of independent importance the stator surfaces are arranged at an angle to a tangent of an imaginary cylindrical surface surrounding the axis.
- (57) Preferably as a feature of independent importance the angle of the stator surfaces to the tangent is adjustable.
- (58) Preferably as a feature of independent importance the stator surfaces and/or the rotor surfaces are arranged to pivot so as to increase the spacing therebetween to allow the passage of foreign objects between the rotor and stator.
- (59) Preferably as a feature of independent importance the stator surfaces are readily removable for replacement when damaged or worn.
- (60) Preferably as a feature of independent importance the stator surfaces include one or more fins extending generally around the axis.
- (61) Preferably as a feature of independent importance the housing when viewed in plan longitudinal of the axis of the rotor is of polygonal shape to define a plurality of apexes at angularly spaced positions around the axis and the stator surface in plan view includes a plurality of pairs of stator surfaces which form a V shape converging to a respective one of the apexes.
- (62) Preferably as a feature of independent importance the rotational speed of the rotor is adjustable to change the number of impacts a seed encounters during its passage.
- (63) Preferably as a feature of independent importance the velocity of air along the rotor is adjustable to change the number of impacts a seed encounters during its passage.
- (64) Preferably as a feature of independent importance the rotor and the stator are arranged so that the impacts act to move the discarded seeds along the rotor so as to change the position along the rotor at which the impacts of the discarded seeds occurs.
- (65) Preferably as a feature of independent importance there is provided two housings each including a rotor and stator arranged side by side across the width of the discharge location.
- (66) Preferably as a feature of independent importance each of the housings is rotatable about the axis of the respective rotor to change an angle of the discharge around the axis.
- (67) According to one feature described herein, there is provided an apparatus for destroying weed seeds for use in a combine harvester where the combine harvester comprises a separation system

for separating from harvested crop at a first discharge location feed material including chaff and said weed seeds and at a second discharge location straw, the apparatus comprising:

(68) a straw chopper section comprising: a chopper housing for mounting at the second location on the combine harvester for receiving from the first discharge location a feed material containing separated straw separated by the combine harvester from harvested crop; a chopper rotor mounted in the housing for chopping the straw for discharge from the housing; and a spreading device onto which the discharged straw is directed;

(69) and a weed seed destruction section comprising: a housing arranged to be mounted at the first location for receiving from the first discharge location the feed material containing separated chaff and said weed seeds; a rotor mounted in the housing for rotation about an axis and including rotor surfaces thereon for engaging the feed material and for accelerating the feed material in a direction outwardly from the axis of the rotor; a stator arranged at a location along the direction and including one or more stator surfaces for engaging the weed seeds in the accelerated feed material to cause impacts with the weed seeds; wherein the housing includes a discharge opening for discharge of the feed material after the plurality of impacts;

(70) wherein the straw chopper section and the weed seed destruction section comprise a common unit.

(71) Preferably the common unit includes is a common drive from the combine harvester to the common unit.

(72) That is preferably the weed seed destruction section is driven from the straw chopper section.

(73) In the common unit preferably the weed seed destruction section is arranged such that material from the discharge opening can be fed into the straw chopper section.

(74) In this arrangement there are preferably provided two housings each including a rotor and stator arranged side by side across the width of the second discharge location.

(75) In this arrangement preferably each of the housings is rotatable about the axis of the respective rotor to change an angle of the discharge around the axis such that the discharge opening can be directed to the side of the combine away from the straw chopper, towards the guide fins of the tailboard of the chopper, or into the housing of the straw chopper.

(76) In addition to the above defined features, the seed destruction section can include any of the features previously defined.

(77) The arrangement as described hereinafter may provide one or more of the following features and advantages:

(78) To provide a seed destroyer in which the residue does not pass through rotating or stationary rings of objects so that there is less potential for damage on passage of a solid object.

(79) To provide a seed destroyer in which the impacting members of the destructor can be hard surface coated and easily removable for annual replacement and preparation for the next harvest.

(80) To provide a seed destroyer in which the number of hits a seed impacts can be adjusted or tuned for optimum destruction.

(81) To provide a seed destroyer which can allow passage of debris such as rocks and other hard objects without damage or destruction, and has replaceable parts should the object cause damage.

(82) To provide an integrally mounted seed destroyer in which the trajectory of the discharge can be changed from the side of the combine, to the back of the combine tailboard, or into the chopper so that the residue can be spread with the straw.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) One embodiment of the invention will now be described in conjunction with the accompanying drawings in which:

- (2) FIG. 1 is an isometric view of an apparatus for destruction of weed seeds according to the present invention which is arranged in a first embodiment where the weed seed destruction section is mounted at a position on a combine harvester at the rear of the sieve so as to discharge the chaff and destroyed seeds away from the straw chopper to both sides of the combine harvester.
- (3) FIG. 2 is an isometric view from the front and one side of the combined apparatus including the straw chopper section and the weed seed destruction section of FIG. 1.
- (4) FIG. 2A is an isometric view from the rear and the other side of the combined apparatus including the straw chopper section and the weed seed destruction section of FIG. 1.
- (5) FIG. 3 is an isometric view of the weed seed destruction section of FIG. 1 separate from the combine harvester with the discharge housing arranged for discharge to the sides.
- (6) FIG. 4 is a top plan view of the weed seed destruction section of FIG. 3 separate from the combine harvester with the discharge housing arranged for discharge to the rear.
- (7) FIG. 5 is an isometric view of the weed seed destruction section of FIG. 3 with a part of the housing removed.
- (8) FIG. 6 is an isometric view of the weed seed destruction section according to the present invention which is arranged to feed the discharged material into the chopper rotor of the straw chopper section at the center thereof.
- (9) FIG. 7 is an isometric view of the apparatus of FIG. 6 adjusted to feed the discharged material into the straw chopper section at the sides so as to bypass the rotor and feed directly onto the tailboard.
- (10) FIG. 8 is a side elevational view of the apparatus of FIG. 2 showing the drive system to the combined apparatus including the straw chopper section and the seed destructor section.
- (11) FIG. 9 is a plan view of an alternative arrangement of the weed seed destruction section where the rotors are arranged to rotate about a horizontal axis and thus rotate in a vertical plane to discharge rearwardly.
- (12) In the drawings like characters of reference indicate corresponding parts in the different figures.

DETAILED DESCRIPTION

- (13) The apparatus herein is shown in FIG. 1 mounted on a combine harvester 1 carried on ground wheels 3 and including harvesting components of a conventional nature the rearmost one of which is the sieve 2 which discharges chaff and discarded seeds including weed seeds to the rear edge 4 of the sieve.
- (14) The combine harvester includes a chopper and discharge arrangement 9 shown in FIGS. 1 and 6 is basically as shown in U.S. Pat. No. 6,840,854 issued Jan. 11, 2005 of Redekop, to which reference may be made. The chopper thus comprises a housing 10 defined by a top wall 11, a bottom wall 12 and two end walls 13. The end walls 13 include attachment means 13A for attachment of the housing to the outlet of a combine harvester for discharge of straw and optionally chaff from the combine harvester into an inlet opening 15 of the housing 10. The bottom wall 12 defines a semi-cylindrical portion extending from the inlet 15 to an outlet 16 through which chopped straw and air is discharged at relatively high velocity for spreading across the field or for transportation into a container.
- (15) Within the housing is mounted a hub 17 which is carried on suitable bearings 31 for rotation about a hub axis 18 at a center of the housing so that blade members 19 carried by the hub sweep around within the housing to entrap straw fed through the inlet 15 and to carry the straw and air past stationary blades 20 for chopping and for discharge through the outlet 16. The stationary blades 20 are mounted on the housing at a position approximately midway between the inlet 15 and the outlet 16 so that the blade members 19 sweep between the stationary blades in a cutting action.
- (16) The hub 17 carries a plurality of lugs 21 at angularly and axially spaced positions therealong with each lug mounting a pair of blades 19 for pivotal movement of the blade members 19 about a pin 22 parallel to the axis 18. Each of the lugs 21 carries a pair of the blades 19. Each lug 21 is

aligned with a respective one of the stationary blades **20** so that each stationary blade has associated with it a respective one of the lugs and thus has associated with it the pair of blades carried by that lug.

(17) In this arrangement of the chopper, there is provided three axially spaced sections of the chopper assembly including a first fan section **30** at one end of the hub **17** and the second fan section at the other end of the hub **17**. In-between the two narrow fan sections **30** is defined a center section **30A** which provides the whole of the cutting action.

(18) Within the center section **30A** all of the blades **19** are formed with a cutting edge lying in a radial plane of the axis. The blades are preferably of the conventional flat blade type with a leading and trailing chamfered edge. Thus each of the two cutting blades **19** in the center section can pass closely on either side of a respective one of the stationary blades **20**. Thus the stationary blades can be spaced by a distance which is just sufficient to allow the passage there between of the preferably flat cutting blade. In the preferred arrangement, the spacing between the stationary blades is thus small in that the stationary blades are not sufficiently spaced to allow the passage there between of a fan type blade.

(19) In the fan sections **30**, there is provided a ring **33** which is mounted on the hub **17** at a respective end of the hub. The ring thus surrounds the cylindrical wall of the hub and stands outwardly therefrom just beyond the end of the center section defined by the stationary blades and the blades **19** carried on the hub.

(20) The rings **33** each carry a plurality of fan blades **34** at spaced positions around the ring. The fan blades **34** are arranged thus so that each follow directly behind the next at the same axial location.

(21) Each of the fan blades **34** is bent with a fan blade portion so that each of the fan blades is of the shape shown in FIG. 3 of U.S. Pat. No. 5,482,508 of Redekop, to which reference may be made. However the fan blades **34** do not necessarily have a sharpened leading edge since there is intended to be no cutting action in the fan section. Thus the fan blades are spaced from the end most stationary blade **19** so that in effect no cutting action occurs in this section.

(22) The bent fan blade portion stands outwardly to one side of the flat plate portion of the fan blade **34**. The fan blade portion which is bent at right angles to the main body of the fan blade is maximised in dimension so that it may be rectangular. This large blade area together with the presence of the six blades provides a large fan blade area which generates a significant air flow.

(23) The fan blade portion is inclined forwardly and outwardly so that at a regularly outer position toward the outer end of each fan blade the fan blade portion is angularly advanced relative to its position closer to the axis of the hub. This incline outwardly and forwardly significantly increases the air flow effect driving the air in the greater volume and at higher speed radially from the fan section and outwardly of the exit **16**.

(24) Preferably the fan section comprises only a single row of the six fan blades but in some cases an additional row or rows may be provided although this is not preferred. The fan blades are arranged immediately adjacent the end walls **13** so that they take up minimum space at the end of the chopper assembly. It will be appreciated that the intention is to provide maximum air flow in the fan sections while taking up minimum dimensions so that the maximised chopping effect to provide shortest material is achieved within the center section using the flat blades.

(25) The above arrangement of straw chopper section is one example only of arrangements which can be used herein.

(26) The chopper and spreading assembly **9** is arranged to be mounted at a rear straw discharge **101** of the combine harvester **1** and includes the housing **10**, the rotor **17** mounted in the housing **10** for rotation around a generally horizontal axis and carrying the plurality of chopper blades **19** for chopping the discharge material.

(27) At the exit **16** is provided the material spreading assembly which can be the form of a tailboard **16A** with guide fins **16B** for receiving the chopped material and spreading the material to the rear

and sides of the combine harvester.

(28) An apparatus **35** for destroying seeds comprises a body **36** carried on a frame **37** mounted at a suitable location on the combine harvester by mounting arrangements of a conventional arrangement. The body provides two side by side housings **38**, **39** each located adjacent a respected half of the discharge location the feed material containing separated chaff and discarded seeds separated by the combine harvester from harvested crop. In the embodiment shown in FIG. **1**, the housings are located at the rear edge **4** of the sieve **2**.

(29) Each of the housings, as best shown in FIGS. **3**, **4** and **5** includes an upper impact section **40** and a lower fan section **41**. The upper section **40** includes a housing **42** which is polygonal (in this example octagonal) in plan view with apexes **43A**, **43B**, **43C** etc. The housing **42** includes a top wall **44** connected to the polygonal side wall and defining a circular opening **45** arranged to be mounted at the discharge location of a combine harvester for receiving from the sieve the chaff and discarded seeds including the weed seeds.

(30) A rotor **46** is mounted in the housing for rotation about an upstanding axis **47** at right angles to a bottom base of the housing axis. The rotor includes a cylindrical hub **46A** carrying upper and lower sets of blades **46B** and **46C**. The sets are spaced axially. The individual blades of the set are spaced angularly. The sets are carried above and below respectively a series of angularly spaced lugs **46D** on pins **46E** so as to act as flails.

(31) Each blade includes as best shown in FIG. **5** a base plate **46F** lying in a radial plane and a blade portion **46G** turned out of the radial plane so as to act as a fan blade to drive entrained air and the material centrifugally outwardly from the axis of the rotor.

(32) As best shown in FIG. **5**, the lugs **46D** are located adjacent a top face **461** of the hub **46A** of the rotor **46** so that the base plate **46F** of each blade lies in or closely adjacent to a plane of the top face **461**. The blade portion **46G** stands upward from the base plate **46F** and hence extends in the axial direction of the rotor axis to an upper end edge **46U** at a position beyond the upper face **461** of the hub **46A**.

(33) As best shown in FIG. **5**, the blade portion **46G** of each blade extends diagonally across the base plate **46F** from a radially inner end **46R** of the blade portion **46G** at a trailing edge **46T** of the base plate **46F** to a radially outer end **46Z** of the blade portion at a leading edge **46L** of the base plate **46F**. Thus the blade portion is inclined to a radius of the respective pivot axis of the pin **46E** so that the radially outer end **46Z** of the blade portion **46G** is angularly advanced relative to the radially inner end **46R** of the blade portion **46G**.

(34) Thus the rotor includes components thereon defined by the two sets of blades for engaging the feed material and for accelerating the feed material in a centrifugal direction away from the rotor.

(35) In the housing around the rotor is provided a stator **48** defined by the inside surface of the polygonal housing **40** and arranged at a location centrifugally outside the rotor **46** so that the material and discarded seeds thrown outwardly impact on the stator. The stator includes a series of surface elements **48A** for engaging the discarded seeds in the accelerated material and arranged such that the discarded seeds impact thereon and rebound therefrom back toward the rotor.

(36) Thus the rotor **46** and stator **48** are arranged such that the discarded seeds rebound back and forth between the rotor **46** and the stator **48** to provide a plurality of impacts on the feed material to destroy the seeds.

(37) The housing includes a discharge opening defined by a circular inner edge **50A** of a plate **50** lying in a radial plane of the housing between the impact section **40** and the fan section **41**. Thus the bottom of the impact section is defined by the bottom plate **50** so that air and the entrained material is directed downwardly into the fan section for discharge of the feed material after the plurality of impacts. As the air and entrained material passes downwardly, the discarded seeds discharge from the rotor and do not pass or escape outwardly through the stator **48**. That is the stator wholly or substantially wholly surrounds the rotor section to prevent the seeds from escaping radially. That is all of the seeds are rebounded back inwardly to the rotor and move downwardly

while rebounding back and forth until they pass out of the impact section at the bottom through the hole **50A** in the plate **50** into the fan section **41**.

(38) Thus the rotor **46** rotates around the axis **47** so as to direct the discarded seeds centrifugally outwardly. The stator **48** surrounds the axis **47** so as to rebound the discarded seeds back toward the axis and the discharge opening is arranged such that the discarded seeds discharge axially from within the stator. In this way, the feed material containing the discarded seeds enters the housing axially of the rotor at the top end and discharges axially from the bottom end of the rotor into the fan section, where the material is accelerated radially outwardly into a channel defined by a peripheral wall **41A** which spirals gradually outwardly from a leading edge to a trailing edge **41B** so as to define an outlet location **41C**.

(39) Thus the fan section **41** shown in plan in FIG. **4** at the top includes a series of blades **41F** carried on the rotor **46A** underneath the plate **50** so that the fan components act for driving the discarded seeds from the opposite or bottom end of the rotor **46** radially outwardly to the discharge opening **41C** at the trailing edge **41B**.

(40) As best shown in FIG. **5**, each of the stator surfaces **48A** comprises a generally V-shaped body with two walls **48B** and **48C** converging to an apex **48D** which is located at one of the apexes of the polygonally shaped housing. In FIG. **5** is shown one of the stator surfaces **48A** and it will be noted that the wall **48C** against which the seeds are primarily directed as the rotor **46** turns clockwise is arranged at an angle to a tangent **T** of an imaginary cylindrical surface surrounding the axis. Thus the surface **48C** is inclined forwardly and inwardly so that the seeds moving with the rotor and outwardly of the rotor impact against the surface **48C** and are rebounded inwardly. The stator surface portion **48A** is mounted at the apex **48D** by a hinge pin **48H** which allows the angle of the stator surface **48C** to the tangent **T** to be adjustable to change the level of aggression in the rebound action.

(41) Also the hinged mounting of the stator surface portion **48A** allows the stator surfaces to pivot to allow the passage of foreign objects between the rotor **46** at the outer tip of the blades **46B**, **46C** and stator as defined by the surface portions **48A**. Also the stator surface portions are readily removable for replacement by pulling the support pin **48H** when damaged or worn.

(42) Also the stator surface portions **48A** include one or more fins **48G** lying in a plane at right angles to the walls **48B**, **48C** and thus extending in a radial plane around the rotor. The stator has an octagonal shape and there are four of the stator surface portions **48A** at four of the apexes of the polygon leaving the remainder of the inner surface of the octagon exposed to act as the stator surface. This stator surface surrounds the whole of the rotor and hence prevents outward escape of any material, thus confining the material to move downwardly into the fan section for ejection.

(43) The rotor **46** which carries both the blades of the impact section and fan blades **41F** of the discharge fan section **41** as best shown in FIG. **8**, is driven by a hydraulic drive motor **46H**, the rotational speed of which is adjustable to change the speed of the impact blades and thus the number of impacts a seed encounters during its passage.

(44) Also the velocity of air along the rotor through the impact section from the opening at the top plate **44** to the discharge plate **50** is adjustable to change the number of impacts a seed encounters during its passage.

(45) The rotor and particularly the stator are shaped and arranged so that the impacts and rebounding action act to move the discarded seeds along the rotor from the feed opening at the top plate **44** to the discharge opening at the plate **50** so as to change the position along the rotor at which the impacts of the discarded seeds occurs. Thus the seeds as they rebound back and forth move through the impact section at a rate depending on the shape and position of the stator surfaces and depending on the rotation rate of the rotor and the air speed through the impact section.

(46) In a typical walker style combine there is a large space between chopper **9** and the end of the sieve **2**. In this case the seed destructor **36** is mounted at the end of the sieve **2**. In this position, the discharge openings **41C** of the fan section **41** are located by rotating the housings **38**, **39** so that the

seed destructor discharge is set to the side because the discharges are not close enough to the chopper **9** to allow feeding into the chopper.

(47) The seed destructor is made up of two rotating drums or rotors **46** within the housings **38** and **39** rotating in opposite directions. The housings are rotatably mounted on the frame **37** so that the discharge **41C** can be pointed in the direction required. Although this is shown as a fixed mounting it could be easily designed as a movable mounting so the operator could change it quickly as desired. In one arrangement the adjustment can be obtained conveniently by rotation of the housing around the axis of the rotor.

(48) The impact section **40** contains in the stator **48** replaceable, adjustable impact plates or surface portions **48A**, in which the residue that is dropped into the seed destructor housing is flung against by the rotors **46** with blades **46B** and **46C**. The residue is deflected back by the stator into the rotating blades for another hit.

(49) The fan section **41** at the bottom of the housing acts to accelerate the residue for spreading back onto the field or into the chopper or into the chopper fins as desired.

(50) The rotors can be driven by hydraulic motors which power and mount the rotating hubs **46** in which case the motors are mounted to the frame **37**.

(51) The impact plates **48A** are rotatably adjustable at the apex **48D** and designed to deflect the residue back into the high speed blades. The guide fins **48G** on the impact plates serve to control the angle that the residue is deflected and therefore the number of times the residue rotates in the housing and thus the number of hits a seed encounters in its passage through the destructor. The impact plates **48A** are replaceable and are hard surface coated for a longer life.

(52) At the bottom of the housing assembly below the fan section **41** is provided a bottom plate **60** closing the bottom of the fan section **41** below the plate **50**. In the plate **60** is defined an air inlet schematically indicated at **62** which regulates the flow of exterior air into the fan section through the plate **60**. The opening size of the air inlet **62** can also be varied by an adjustment **62A**. As the adjustment **62A** control the amount of air entering into the fan section, this adjustment increases or reduces the amount of air drawn through the opening **50A** in the plate **50** and thus also serves to change the speed of the residue flowing through the assembly. The air inlet **62** can be regulated so that, as it is closed off, the speed of the residue flow increases, to the point when closed, all air is sucked in from the top of the assembly at the plate **44**, to be discharged with the fan in the discharge zone **41**. When entirely opened the majority of the air is drawn from the bottom plate **60** of the assembly and the speed of the residue flowing through the assembly is reduced allowing for more impacts.

(53) A third method to adjust the number of impacts a seed encounters through the assembly is of course with the speed of the rotor **46**. The drive system to the rotor can be controlled by the combine or by a separate driver operated control and the speed of the assembly can be increased or decreased depending on factors such as seed size, residue toughness, or residue size including factors such as corn cob size and moisture content or sunflower head size.

(54) In a preferred arrangement, the seed destructor section **36** is integrated into the chopper **9** as a common unit with the chopper **9**. In this arrangement the seed destruction section **36** acts two receive all residue from the sieves. The weed seeds are destroyed in the seed destructor and can be ejected into the chopper for spread with the straw residue on the tailboard **16A**.

(55) In this arrangement the combination of all of the residue from both the sieves and the straw exit into the chopper allows the destroyed seeds and chaff residue to mix with the straw residue and be spread in a much wider spread pattern. That is in FIG. **6**, the discharge openings **41C** from the fan section **41** of the seed destruction section **36** are turned on the frame **37** so that they are directed to the center of the inlet **12** of the chopper **9**.

(56) Alternatively the chaff residue and destroyed seeds expelled from the seed destructor at the discharge openings **41C** is expelled at the sides of the chopper at the fan sections **30** so as to bypass the center chopper section of the chopper so as to be directed by the chopper into the fins of the

chopper for mixing on the tailboard **16A** and spreading with the straw residue from the chopper.

(57) As a third option, the discharge openings **41C** can be positioned to the side to spread to the side of the combine as shown in FIG. **1**. Thus the seed destruction section **36** is a part of or closely associated with the chopper **9**. However the position of the outlet in the embodiment of FIG. **14** can be adjusted to the side in the same manner by rotation of the housings on the frame **37**.

(58) Thus the destruction section **36** and the chopper **9** form a common unit which can be supplied as a common assembly for attachment to the combine harvester. The common unit may include a common frame. The common unit can include a common drive arrangement by which a single output drive from the combine harvester is directed to the common unit and then directed by the drive mechanism to the chopper rotor and to the seed destruction section. The common unit can be arranged so that in one or more adjustment positions of the seed of destruction section the output from the fan section is directed into the chopper for common distribution into the field. It is also possible in this arrangement that the seed destruction section be adjusted so that the output therefrom is directed into the field bypassing the chopper.

(59) In an arrangement where the space between the sieve **2** and the straw outlet is greater than can be accommodated by direct feed from the sieve into the inlet of the seed destruction section, a feed duct or other transfer arrangement can be provided.

(60) Thus the combined apparatus comprises the straw chopper **9** as described above together with the apparatus for destroying weed seeds as described above where the discharge opening of the housing is arranged such that the discharge opening can be directed to the side of the combine away from the straw chopper, towards the guide fins of the tailboard of the chopper, or into the housing of the straw chopper.

(61) As an alternate embodiment shown in FIG. **9** the apparatus forming the weed seed destructor section can be designed as a horizontal tube or duct **70** forming an elongate housing into which the material is fed from the sieve **2** by a feed duct **2A**. This can be readily located at this position by a combine manufacturer as a horizontal duct in their combine at a position ahead of the rear discharge for chaff.

(62) The duct **70** contains has a transverse shaft **71** driven at one end **72** and carried on end walls of the duct **70** at bearings **73**. The shaft carries auger fighting **74A**, **74B** divided in the middle so as to move chaff axially along the housing from the inlet at the duct **2A** outwardly to each respective end of the horizontal rotor defined by the shaft **71** and flighting **74A**, **74B**. The arrangement thus provides seed destructors **75**, corresponding to seed destructors **36**, symmetrical to and operating in the same manner as that previously described but arranged in an orientation at 90 degrees to that shown previously and rotating in a vertical plane about a horizontal axis defined by the shaft **71**. Thus the destructor **75** includes a rotor **77** and stator **78**, corresponding to the rotor **46** and stator **48**, as previously described and a fan section **79**, corresponding to the fan section **41** as previous described. The fan section **79** communicates with a discharge zone **76**, corresponding to the outlet location **41C**, which is located at the end of the rotor **77** to expel the chaff and weed seeds after treatment along direction **76A** into a secondary spreading device, or into a straw chopper or into the tail board fins of the straw chopper. The auger flightings **74A**, **74B** and the rotor **77** and the fan section **79** thus form the horizontal rotor defining a generally cylindrical body within the tube or housing **70**.

(63) As shown in FIGS. **2A** and **8** housing of the chopper section **9** and the seed destructor section **35** are formed as a common or integral construction coupled together as single or common unit which can be mounted on the combine harvester at the rear of the combine so as to be associated with the rear straw discharge and the rear chaff discharge.

(64) The chopper **9** has an input drive pulley **9A** on a shaft **9S** connected to the rotor **17** driven by a belt **9C** or other drive component or pulley assembly **9B** from the combine. In addition the pulley **9A** of the chopper drives an output pulley **9D** which communicates drive to the seed of destruction section **35** through a pulley **9E** on a shaft **9T** driven by a belt **9F**. In the arrangement shown the

pulleys 9A and 9D are mounted at the same end of the rotor 17 but this is not essential. The drive 9B to the chopper can be as shown where the output pulley 9G on a shaft 9R of the combine drives a belt 9H connected to a pulley system 9K to drive the belt 9C. Thus as shown in FIG. 2A, the shafts 9R, 9S and 9T are all parallel. Other drive arrangements can be used such as a shaft from an output gearbox.

(65) A shroud or hood 35A is over the seed destructor section to allow for the chaff to be directed underneath the hood into the seed destructor. A roller 35B is required at the leading edge of the hood 35A to eliminate material buildup on the leading edge which could cause possible plugging. The roller rotates in a clockwise direction at 200-500 rpm to roll any long straw over to the chopper section 9 while the chaff and weed seeds flow under the hood the destructor section 35.

(66) While the arrangement shown herein is shown as an externally mounted chopper carried on the combine harvester at the rear straw discharge, some combines include an internal chopper mounted in the housing at a position in advance of the rear discharge. In this arrangement the seed destructor section can be located at the chaff discharge and arranged to direct material into the internal chopper or away from the internal chopper to the ground. In this case the internal chopper does not cooperate directly with a spreading system such as a tail board.

Claims

1. A combine harvester comprising: a separation system for separating from harvested crop at a first discharge location a first material comprising straw and at a second discharge location a second crop residue material comprising chaff and weed seeds; and an apparatus for damaging the weed seeds comprising: a housing having at least one inlet for receiving the second crop residue material from the second discharge location and at least one outlet for discharging the second crop residue material after passage through the housing; two rotors each for rotation about a respective axis where the axes are parallel, each rotor comprising a plurality of radially extending impact members; the housing having a first portion surrounding the two rotors and an axially spaced discharge portion; said at least one outlet of the housing located in the discharge portion and axially spaced from said at least one inlet of the housing; wherein the at least one outlet in the discharge portion is at a location different from the first portion of the housing so that said weed seeds discharged from the rotor through said at least one outlet do not exit radially outwardly through the first portion of the housing; and one or more fan members arranged to urge the crop residue material to move through the first portion of the housing from said at least one inlet to said at least one outlet; wherein the plurality of radially extending impact members are configured to rotate with said two or more rotors and impact against the crop residue material as the crop residue material passes through the first portion of the housing to the discharge portion.
2. The combine harvester according to claim 1 wherein the one or more fan members, the impact members and housing are configured so that less dense material of the second crop residue material defined by the chaff is subjected to less impacts and denser material of the second crop residue material defined by the weed seeds is subjected to relatively more impacts.
3. The combine harvester according to claim 1 wherein said one or more fan members are the form of a paddle of a spreader located at the discharge portion of the housing.
4. The combine harvester according to claim 1 wherein the first portion of the housing is shaped so that it approximates outer dimensions of the rotors.
5. The combine harvester according to claim 1 wherein the first portion of the housing is shaped so that it substantially follows an orbit of a tip of each of the impact members and wherein the impact members are arranged in two parallel rows.
6. The combine harvester according to claim 1 wherein the apparatus is configured so that denser material comprising weeds seeds are retained in the first portion of the housing until the weed seeds are sufficiently impacted so as to damage a substantial amount of weed seed in the second crop

residue material before it exits the outlet and less dense material has received fewer impacts than the seeds within the housing when it exits the outlet.

7. The combine harvester according to claim 1 wherein the housing comprises a plate having a circular opening located at an intersection between the first portion and the discharge portion for passage of the weed seeds to the outlet.

8. The combine harvester according to claim 1 wherein less dense material of the second crop residue material is more influenced by the air flow and denser material of the second crop residue material is more influenced by a centrifugal force imparted by said rotors.

9. The combine harvester according to claim 1 wherein said rotors and the first portion of the housing are arranged such that the weed seeds rebound back and forth between said rotors and the first portion of the housing to provide a plurality of impacts on the weed seeds to destroy at least some of the weed seeds.

10. The combine harvester according to claim 1 wherein each of the rotors rotates around its axis so as to direct the weed seeds centrifugally outwardly, and the first portion of the housing surrounds the axis so as to rebound the weed seeds back toward the axis and discharge axially from within the first portion of the housing to the discharge portion of the housing.

11. The combine harvester according to claim 1 wherein the housing is arranged to be mounted directly under the second discharge location of the combine harvester with the rotor axes generally upright so that the second crop residue material falls directly into the top of the housing on to said rotors along the axial direction of the rotors.

12. The combine harvester according to claim 1 wherein the second crop residue material enters the housing axially of said rotors at one end of the housing and discharges axially from the first housing portion at an opposite end of the housing.

13. The combine harvester according to claim 1 wherein said one or more fan members is arranged in said discharge portion of the housing to direct the second crop residue material radially outwardly.

14. The combine harvester according to claim 1 wherein the first housing portion comprises a stator including one or more stator surfaces for engaging the weed seeds when accelerated by said rotors.

15. The combine harvester according to claim 14 wherein the stator surfaces are arranged at an angle to a tangent of an imaginary cylindrical surface surrounding the rotor axis.

16. The combine harvester according to claim 14 wherein the stator surfaces are arranged to pivot to allow the passage of foreign objects between said rotors and the stator.

17. The combine harvester according to claim 1 wherein the impact members of said rotors include a generally flat surface having a first end edge spaced axially of a second end edge so that the surface when rotated provides a width between the first and second end edges for engaging the weed seeds.
