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(54) **Title:** PRECISION SEEDERS

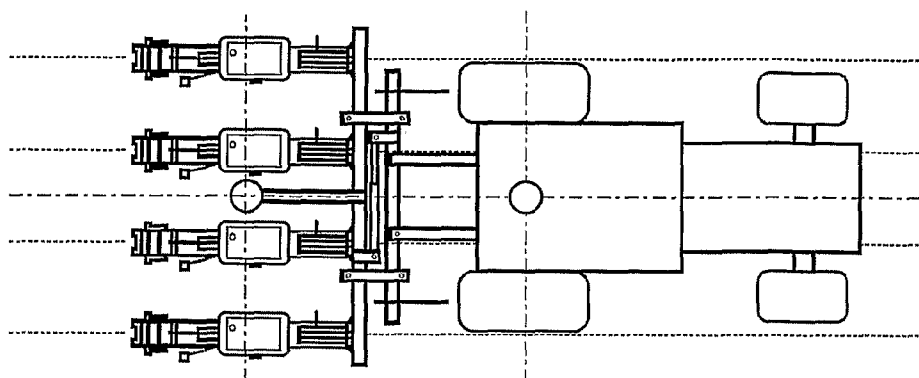


FIG. 1

(57) **Abstract:** The invention provides a seed metering mechanism and a method for controlling the seed metering mechanism. The seed metering mechanism includes a seed metering disc (10) that rotates to drop a plurality of seeds in succession. The rotational speed of the seed metering disc (10) between successive seed drops is varied to control the seed spacing independently of the forward velocity of the seeder (4) whilst maintaining zero ground speed effect when the seeds are dropped. The variation of the speed of the seed metering disc (10) can also be used to minimise the spacing gaps or voids on the ground caused by missing seeds from cells or holes of the metering disc (10).

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PRECISION SEEDERS

FIELD OF THE INVENTION

[0001] This invention has to do with precision seeders designed to give accurate placement of individual seeds.

BACKGROUND

[0002] In recent times there has been an increasing desire in the agricultural production industry for precision seeders that can spatially distribute seeds across a field in an even, regular pattern.

[0003] There are a number of advantages to doing this. In particular, evenly distributed crop plants optimally utilise the available space, nutrients and water, to maximise yields and quality; the even distribution minimises the intra-specific competition effects by giving all crop plants the same space to utilise growth resources. This benefits the whole plant development both above- and below-ground.

[0004] Weed suppression is also better in an evenly distributed crop as a result of better and earlier coverage of the soil surface. Crop plants that are arranged in more even patterns also better facilitate mechanical weeding operations, helping to reduce the crop plant losses (e.g. leaf or root damage) caused by mechanical weeding.

[0005] Moreover, if seeds are accurately placed in known positions when they are initially sown, then the resulting crop plants can be individually located at a later date (based on "seed maps" recorded during sowing), enabling for example the physical and/or chemical treatment of individual plants as the crop develops.

[0006] Conventional seeders utilising seed metering discs to 'single' and subsequently deposit individual seeds are not capable of accurately placing seeds in the desired manner. There is insufficient evenness of seed spacing within rows and also a lack of synchronisation between sequential operating passes. In addition, in seeders utilising multiple seeder units to sow adjacent rows in parallel in one pass (which is the norm), there is also a lack of synchronisation between the separate seeder units.

[0007] Much research effort has been invested to improve the performance of seeders, in particular looking at improved metering systems and the synchronisation of multiple seeders. Some improvements have been seen through replacing conventional mechanical drives with individual electric motor drives for the metering disc of each seeder unit. This facilitates, amongst other things, more accurate synchronisation of the seeder units, as described for example in DE-4234600, which describes an early example of a seeder having multiple seeder units each with their own electric motor drive.

[0008] Griepentrog, 2005, Design of a Seeder to achieve Highly Uniform Sowing Patterns, In: Proceedings of the 5th European Conference on Precision Agriculture, Uppsala, Sweden, 9th – 12th June 2005, pp. 675 – 682, describes a modification of a commercial embodiment of the seeder described in DE-4234600 that uses stepper motors to very accurately control the rotation of each of the seed metering discs. This approach was shown to provide extremely accurate and reliable placement of seeds.

[0009] However, all of these known mechanisms suffer from the disadvantage that the seed spacing cannot easily be changed without a loss of accuracy. This is because the accurate placing of each seed depends not only on timely release of the seed from the metering disc but also on the horizontal (linear) speed of the seed relative to the ground when the seed is released. This is because the seed will not necessarily remain where it is dropped in a furrow. It may roll or bounce along the furrow. This is true even where drop heights are kept low (e.g. below 5cm), especially where the seed has any significant forward or backward momentum relative to the ground when it is dropped.

[0010] To minimise the displacement from the drop point of the point at which the seed comes to rest, the drive for the seeder disc (whether mechanical or electric) is generally arranged to control the speed of the disc to be equal to the forward speed of the seeder unit. In this way, at the point it is dropped, the seed has a horizontal velocity that is equal in magnitude but opposite in direction to the forward velocity of the seeder unit. This results in a relative horizontal speed between the seed and the ground of zero, minimising the displacement of the seed from the drop point in the furrow. This is referred to as the “zero ground speed effect”.

[0011] To maintain the zero ground speed effect it is necessary for the ratio of disc speed to forward speed to be fixed. This in turn means for any particular seeder setup, currently the effect can only be achieved for one given seed spacing setting.

[0012] If a variation in seed spacing is desired (to accommodate different crop densities for example) then it is necessary either to change the seeder disc (i.e. so that the number of seeds placed per revolution of the disc is either increased (to reduce the seed spacing) or decreased (to increase the seed spacing)) or to modify the ratio between forward speed and disc speed, sacrificing the zero ground speed effect. The former has the disadvantage that the seed spacing can only be adjusted in course increments and involves cumbersome switching of seed metering discs. The latter is obviously undesirable as the desired accuracy of seed placement is lost, the seeds being more prone to displacement along the furrow from their drop point.

[0013] A further limit is placed on the maximum seeder disc speed by the desire to ensure that cells in the disc are reliably filled with seeds from a singling mechanism for subsequent sowing as the disc rotates. Often the maximum speed dictated by this requirement is much less than the desired forward speed of the seeder, meaning that a zero ground speed condition is not attainable. For example, some known seeders employing pneumatic seed singling systems use large diameter discs with many cells around their circumference in order that the rotary speed of the disc can be kept low whilst maintaining the desired seed spacing. Such seeders are known to have low accuracy.

SUMMARY OF THE INVENTION

[0014] The present invention is generally concerned with a seed metering arrangement for a seeder in which a seed metering disc is driven independently of the forward motion of the seeder to cater for different seed spacing without the need for changing the metering disc.

[0015] A general proposition of the invention is to modulate the speed of the seed metering disc during continuous operation of the seeder and, in particular, to modulate the speed during a seed drop cycle (i.e. in the period between one seed drop and the next). In this way, the speed of the seed metering disc can be controlled to match the forward velocity of the seeder when a seed is dropped, to achieve the desired zero ground speed effect but the disc speed can be increased or decreased in the period between seed drops to respectively shorten or lengthen the time between successive seed drops.

[0016] Thus, the frequency of seed placement, and hence the seed spacing for any given forward velocity of the seeder, can be set at any desired value whilst

maintaining the zero ground speed effect at each seed drop, simply by selecting an appropriate speed profile for intra-seed drop period.

[0017] The modulation of the metering disc speed between seed drops can also be used to slow the disc at the point in the cycle that it picks up ('singles') a new seed to minimise the occasions where the disc fails to single a seed.

[0018] Furthermore, modulation of the metering disc speed can be used to accelerate the disc in a case where it is detected that a cell is not filled, to more quickly bring the next (filled) cell into the sowing position, in order to minimise or even avoid altogether a uneven seed spacing in the row of sowed seeds.

[0019] In a first aspect the invention provides a seed metering mechanism for a seeder, the seed metering mechanism comprising:

a seed metering disc for sequentially dropping a plurality of seeds;

a variable speed drive for the seed metering disc; and

a controller for controlling the variable speed drive, the controller being programmed to modulate the rotational speed of the seeder disc between successive seed drops.

[0020] The controller preferably controls the variable speed drive for the seed metering disc using a closed-loop approach. The feedback loop can be realised by using e.g. a motor encoder, disc position detector and/or seed detector.

[0021] One input to the controller is preferably the forward velocity of the seeder. The controller can then control the speed of the disc to match the forward velocity of the seeder whenever a seed is dropped in order to achieve the desired zero ground speed effect.

[0022] The modulation of the speed of the seed metering disc may have a speed profile in which the disc is accelerated from the seed drop speed to a higher speed and subsequently decelerated back to the seed drop speed for the next successive seed drop. This would result in a higher seed drop frequency than would be achieved if the metering disc were operated continuously at the seed drop speed (e.g. the speed necessary for the zero ground speed effect) and hence a smaller seed spacing for any given forward velocity.

[0023] Alternatively, the modulation of the speed of the seed metering disc may have a speed profile in which the disc is decelerated from the seed drop speed to a lower speed and subsequently accelerated back to the seed drop speed for the next

successive seed drop. This would result in a lower seed drop frequency than would be achieved if the metering disc were operated continuously at the seed drop speed and hence a greater seed spacing for any given forward velocity.

[0024] It will be appreciated, therefore, that simply through appropriate programming of the controller to modify the speed profile of the seed metering disc during the seed drop cycle, the seed spacing can be varied independently of the forward velocity of the seeder whilst still benefiting from the zero ground speed effect at the point of seed drop.

[0025] It may also be desirable, especially where a pneumatic seed singling system is used, to reduce the rotational speed of the metering disc below the seed drop speed at times in the cycle where a seed is being fixed at the disc holes. In some embodiments, this may be achieved with a speed profile in which the disc is accelerated from a seed drop speed, to a higher speed, decelerated from the higher speed to a singling speed that is less than the seed drop speed, accelerated again back to the higher speed and finally decelerated back to the seed drop speed in time to place the next seed.

[0026] By enabling control of the speed of the metering disc (and hence the timing of seed placement) independently of the forward velocity of the seeder, it also becomes possible to vary the seed spacing between successive seeds during continuous operation of the seeder, so that pitch of the seed placement need not be constant in any one row. This provides for the possibility of placing seeds in more complex patterns, for example to make the best use of the available space in a field and/or to take account of variations in soil condition in the planting area.

[0027] The precise placement of seeds possible using the described approach also means that, when used in conjunction with some means for accurately identifying the geographical position of the seeder (e.g. a GPS system, as described for example in DE-19961442) it is possible to accurately map the position of the sowed seeds for later use in other precision agriculture techniques (e.g. weeding or other physical or chemical treatment) as the crop develops. It also becomes possible to place seeds at predefined geographical positions (either absolute positions or relative to some datum point).

[0028] The seed metering disc may have a conventional form. Although the disc may have only 1 or 2 cells (or holes) for transporting seeds, it preferably includes a

plurality of cells, for example 3 or more cells.

[0029] The variable speed drive is preferably an electric motor, most preferably a motor with feedback control (e.g. closed-loop control) to maintain a fixed speed. Alternatively a stepper motor may be used, avoiding the need for feedback control.

[0030] The controller is preferably a digital controller. It preferably comprises a digital processor and non-volatile memory for storing program instructions for the controller. The controller preferably also includes a user interface in order that a user can direct the controller to do any one or more of: execute a selected one of a plurality of predefined control programs; modify (preferably either during operation or 'off-line') or interrupt one of the control programs; and to upload new control programs.

[0031] In some preferred embodiments, the seed metering mechanism additionally comprises a detector to detect when a seed is missing from a cell of the seed metering disc (e.g. because the singling operation has failed). The controller preferably responds to a missing seed by accelerating the seeder disc to quickly skip past the empty cell and bring the next full cell to the seed drop position to maintain (or at least minimise the disruption to) the planned seed placement pattern.

[0032] In a second aspect the invention provides a seeder unit comprising a seed metering mechanism in accordance with the first aspect above and a seed supply means (e.g. a hopper) for supplying seeds to the seed metering disc. The supply of seeds to the seed metering disc may operate in a conventional, known manner.

[0033] In a third aspect the invention provides a seeder comprising a plurality of seeder units in accordance with the second aspect and a support structure for mounting the seeder units side-by-side for placement of seeds in multiple parallel rows. The seed metering mechanism of each seeder unit is independently controlled.

[0034] A separate controller may be provided for each metering mechanism or, alternatively, a single controller may be used to control all of them. Where multiple controllers are used, one of the controllers is preferably a master controller or a further, separate master controller is provided to coordinate operation of the multiple seeder units.

[0035] In a fourth aspect the invention provides a method for controlling a seed metering mechanism, the seed metering mechanism comprising a seed metering disc that rotates to drop a plurality of seeds in succession, the method comprising varying the rotational speed of the seed metering disc between successive seed drops.

BRIEF DESCRIPTION OF THE DRAWINGS

[0036] An embodiment of the invention is now described by way of example, with reference to the accompanying drawings in which:

Fig 1 is a schematic illustration of a seeder according to an embodiment of the present invention, the seeder being mounted on an autonomous tractor;

Fig 2 is a schematic system of a laboratory based system that can be used to illustrate the operating principles of the seeder of fig. 1;

Figs 3a to 3d illustrate exemplary speed profiles for the seed metering discs of the seeder of fig. 1; and

Fig 4 schematically illustrated a controller used in the seeder of fig. 1.

DETAILED DESCRIPTION

[0037] Fig 1 shows a GPS-guided autonomous ('robot') tractor 2 towing a seeder 4. The seeder 4 has four seeder units 6, each of which includes a seed hopper 8 and a seed metering disc 10 that sows seeds from the hopper 8, one at a time via a sowing coulter 20, into a furrow in the ground below the seeder unit 6. Each metering disc 10 is independently driven by a respective electric motor 12 (see fig. 2) with closed-loop speed control.

[0038] The seeder 4 of this example, is essentially as described in Griepentrog, 2005, Design of a Seeder to achieve Highly Uniform Sowing Patterns, In: Proceedings of the 5th European Conference on Precision Agriculture, Uppsala, Sweden, 9th – 12th June 2005, pp. 675 – 682, the content of which is incorporated herein by reference, save that in place of the stepper motors described in that paper, the proposal in this embodiment is to use electric motors with closed loop control.

[0039] Where this embodiment of the invention differs from what is described in the Griepentrog 2005 paper is in the control of the motors, as described in more detail below.

[0040] The motor 12 drives the metering disc 10 through a step-down gearbox (not shown), in this example with a transmission ratio of 36:1, meaning that the rotation speed decreases 36 times but the torque increases 36 times.

[0041] One example of a suitable motor 12 is a permanent magnet D.C. motor, e.g. the Series GR 42x25 from Dunkermotoren, which is preferably used in combination with a planetary gearbox (e.g. PLG32) and an incremental encoder (e.g. RE30), also from Dunkermotoren.

[0042] Each of the four motors 12 is controlled by a motor controller 14 (e.g. a power stage such as a PHYTRON GLD) to which different running programs are downloaded by a software application executed on a connected main controller 16 (e.g. a PHYTRON IPCOMM). There is a separate motor controller 14 acting as a controller for each of the 4 motors 12. The main controller 16 operates as a master controller to coordinate and synchronise operation of the four motor controllers 14.

[0043] To ensure that the seeder units 6 are correctly synchronised with one another to drop the seeds at the same time (or at desired relative times), the controllers 14 need to recognize the angular position of each seeder disc 10. To do this, an optical disc position detector 18 was used to find an attached mark inside each seeder disc 10. The mark was carefully placed at the same location on each disc 10. The initialization sensors 18 are directly connected to the controllers 14. Predefined controller software can be used, e.g. during a seeder start-up procedure to position all discs in the desired relative positions (e.g. all in the same orientation).

[0044] Seed spacing times can be recorded using seed detection sensors 22 and the disc speed can be measured using an encoder 24 attached to a seeder disc 10. In preferred embodiments of the present invention, similar seed detection sensors 26 can be used to detect missing seeds in disc cells or at disc holes.

[0045] In accordance with aspects of the present invention, and in contrast to the approach described in the Griepentrog 2005 paper, the metering discs 10 are controlled (by controllers 14,16), to vary (modulate) the speed of the disc during operation. Exemplary speed control profiles are shown in figs. 3a to 3d, each profile showing the change in speed between one seed drop and the next one.

[0046] Fig. 3a shows a speed profile in which the seed metering disc 10 accelerates to a (variable) speed (v) higher than the seed drop speed (f) and subsequently decelerates back to the seed drop speed (f) for the next successive seed drop. This results in a higher seed drop frequency than would be achieved if the metering disc were operated continuously at the seed drop speed (f) and hence a smaller seed spacing for any given forward velocity. The seed drop speed (f) is selected to give the desired zero ground speed effect when a seed is dropped. This profile is suitable, for instance, for mechanical precision seeders, where there is no real speed limitation for the singling period.

[0047] Fig. 3b shows an alternative speed profile in which the disc 10 initially spins

with a relatively low variable speed (v) (i.e. lower than the seed drop speed (f)) and subsequently accelerates to the seed drop speed (f) for the seed drop. This results in a lower seed drop frequency than would be achieved if the metering disc were operated continuously at the seed drop speed (f) and hence a greater seed spacing for any given forward velocity. As with the profile of fig. 3a, this profile is suitable, for instance, for mechanical precision seeders.

[0048] Fig. 3c shows another speed profile in which the metering disc 10 rotates at three different speeds during the drop period. It starts with a limited disc speed (s) (lower than the seed drop speed (f)) to ensure good seed singling from the hopper outlet. The higher (variable) speed (v) that the disc is then accelerated to compensates (in terms of the overall cycle time) for the low singling speed period, following which the disc is decelerated to the seed drop speed (f). In this case there are two fixed disc speed periods (s and f), dictated by the requirements for good seed singling and zero ground speed effect respectively, and a variable speed period, the speed during this period being selected to give the desired target seed spacing. This speed profile is suitable, for instance, when using a pneumatic precision seeder that has a speed limitation on the disc for reliable seed singling.

[0049] Fig. 3d shows another speed profile, similar to the profile of fig. 3c, demonstrating operation of the metering disc when the system detects that a seed is missing from a cell in the disc. Specifically, when the missing seed condition is detected at the end of the singling period, the disc is accelerated to a maximum speed (v_f) both for the variable period of the cycle and also for the seed drop period.

[0050] Fig 4. shows, schematically, an example of a digital controller that can be used as the main controller 16 to coordinate the control of the electric motors 12. The controller 16 comprises a digital processor 30, a non-volatile memory 32 for storing program instructions to define, amongst other things, the desired speed profiles for the metering discs 10, which can be used to control the drives of the motors. The main controller 16 also includes a number of interfaces 34 for sending control signals 36 to the motor controllers 14, for receiving forward velocity and geographical position signals 38 from a positioning system (e.g. GPS system, preferably a highly accurate RTK system) and for communication signals 40 to and from a user interface.

[0051] By using an appropriate speed profile it is possible, for example, to:

- vary the seed spacing whilst maintaining the release speed constant;
- vary and/or limit the singling speed of seeds to ensure reliable cell filling and

keep the seed spacing and/or release speed constant;

- vary the disc speed to minimise seed spacing gaps or voids in the ground;
- if used with a position location system (e.g. GPS), release a seed at a definable (absolute) geographical position.

[0052] As noted above, the user interface (not shown) preferably enables a user to direct the controller to do any one or more of: execute a selected one of a plurality of predefined control programs; modify or interrupt one of the control programs; and upload new control programs.

[0053] The skilled person will appreciate that the embodiment described above is one example of a seeder incorporating aspects of the present invention. Many variations are possible within the scope of the invention.

Claims:

1. A seed metering mechanism for a seeder, the seed metering mechanism comprising:
 - a seed metering disc for sequentially dropping a plurality of seeds;
 - a variable speed drive for the seed metering disc; and
 - a controller for controlling the variable speed drive, the controller being programmed to modulate the rotational speed of the seeder disc between successive seed drops.
2. A seed metering mechanism according to claim 1, comprising a seeder forward velocity input to the controller, the controller being operable to control the speed of the disc to match the forward velocity of the seeder when a seed is dropped.
3. A seed metering mechanism according to claim 1 or claim 2, wherein the modulation of the speed of the seed metering disc has a speed profile in which the disc is accelerated from a seed drop speed to a higher speed and subsequently decelerated back to the seed drop speed for the next successive seed drop.
4. A seed metering mechanism according to claim 1 or claim 2, wherein the modulation of the speed of the seed metering disc has a speed profile in which the disc is decelerated from a seed drop speed to a lower speed and subsequently accelerated back to the seed drop speed for the next successive seed drop.
5. A seed metering mechanism according to any one of the preceding claims, wherein controller operates to reduce and/or limit the rotational speed of the metering disc below a seed drop speed at times in the cycle where a seed is being taken into a cell or fixed to a hole in the metering disc.
6. A seed metering mechanism according to any one of the preceding claims, wherein the seed metering disc includes a plurality of seed cells or holes.
7. A seed metering mechanism according to any one of the preceding claims, wherein the variable speed drive is an electric motor.
8. A seed metering mechanism according to claim 7, wherein the variable speed drive has a closed-loop control to maintain a set speed.
9. A seed metering mechanism according to any one of the preceding claims, wherein the controller is a digital controller.

10. A seed metering mechanism according to claim 9, wherein the controller includes a user interface via which a user can direct the controller to do any one or more of: execute a selected one of a plurality of predefined control programs; modify or interrupt one of the control programs; and upload new control programs.

11. A seed metering mechanism according to any one of the preceding claims comprising a detector to detect when a seed is missing from a cell or hole of the seed metering disc.

12. A seed metering mechanism according to claim 11, wherein the controller is operable to respond to the detection of a missing seed by accelerating the seeder disc.

13. A seeder unit comprising a seed metering mechanism according to any one of the preceding claims and a seed supply means for supplying seeds to the seed metering disc.

14. A precision seeder comprising a plurality of seeder units according to claim 13 and a support structure for mounting the seeder units side-by-side for placement of seeds in multiple parallel rows.

15. A precision seeder according to claim 14 in which a separate controller is provided for each metering mechanism.

16. A method for controlling a seed metering mechanism, the seed metering mechanism comprising a seed metering disc that rotates to drop a plurality of seeds in succession, the method comprising varying the rotational speed of the seed metering disc between successive seed drops.

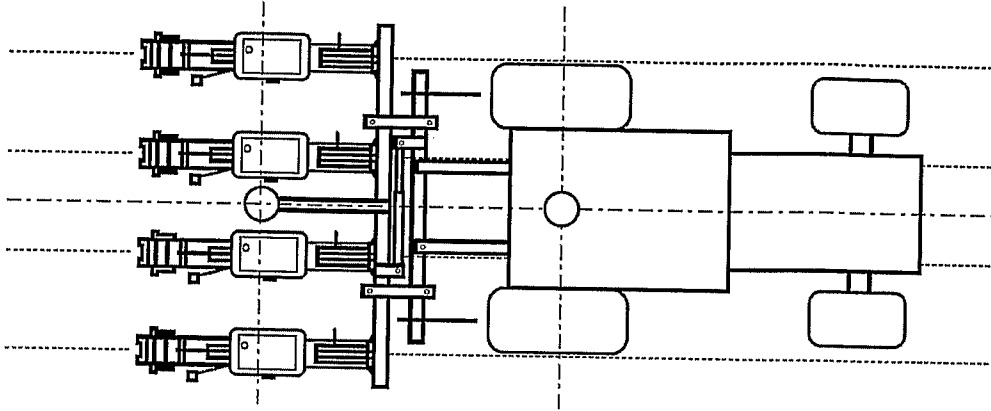


FIG. 1

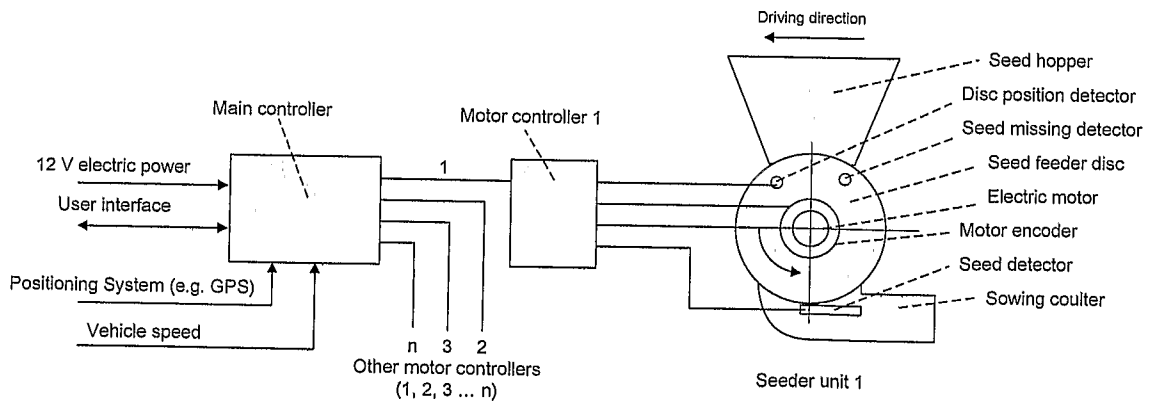


FIG. 2

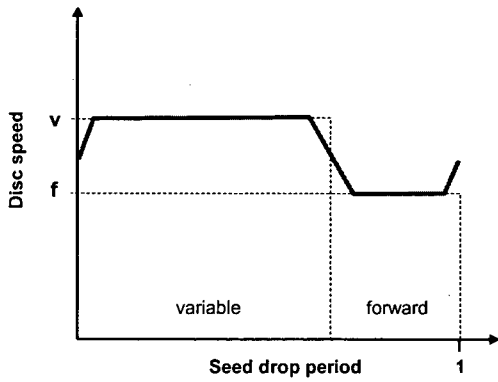


Fig. 3a

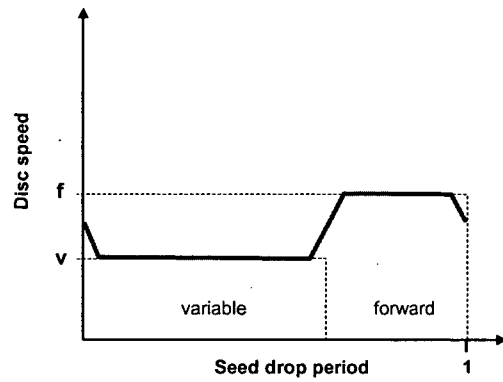


Fig. 3b

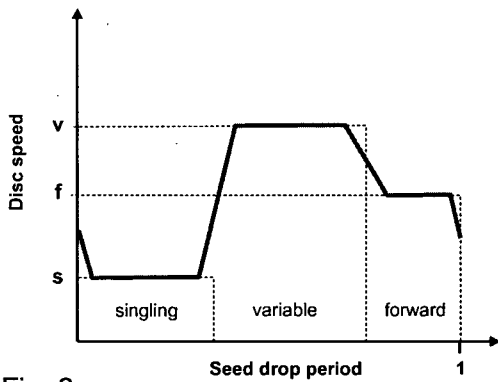


Fig. 3c

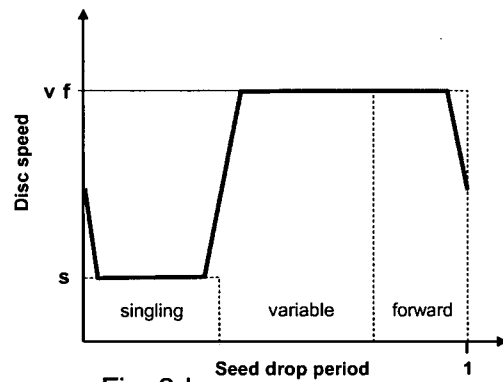


Fig. 3d

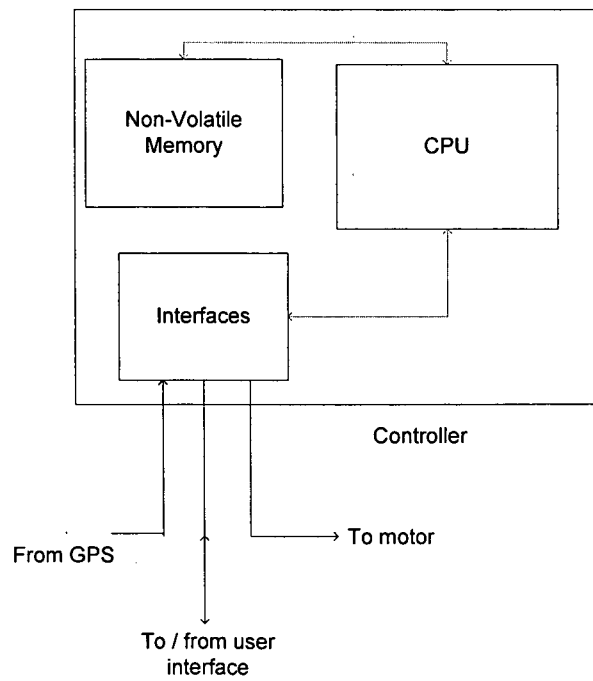


Fig. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2008/001600

A. CLASSIFICATION OF SUBJECT MATTER
INV. A01C7/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A01C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 2 217 043 A (GASPARDO SPA [IT]) 18 October 1989 (1989-10-18) abstract page 3, line 16 - line 21 page 4, line 3 - line 16 claims; figures -----	1-4,6-16
X	US 6 081 224 A (ROSENBROCK RICHARD [US]) 27 June 2000 (2000-06-27) abstract column 5, line 53 - line 67 column 6, line 1 - line 21 column 8, line 19 - line 55 column 12, line 22 - line 60 claims; figures -----	1-4,6-16

Further documents are listed in the continuation of Box C.

See patent family annex.

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Date of the actual completion of the international search

5 August 2008

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12/08/2008

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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