Title: SIZE REDUCTION MILL

Abstract: A size reduction mill (10) comprises a milling area (11), within which is defined a flow path (22) for a product to be milled. A screen (23) and a complementarily-shaped impeller (24) are mounted coaxially in the flow path (22) in spaced relationship relative to one another. One of the screen (23) or the impeller (24) is fixed to the mill housing (13), whilst the other of the screen (23) or the impeller (24) is rotatable relative to the screen (23) by peripheral drive means located externally of the flow path (22).
before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments.

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.
**Size Reduction Mill**

This invention relates to a size reduction mill for use in milling solid products, in granulated or powdered form. The invention is particularly, though not necessarily exclusively, concerned with conical screen mills.

Conical screen mills are widely used as size reduction machines in the milling of solids such as pharmaceuticals and food products. Such mills typically comprise a perforated conical or frusto-conical screen, within which is located an impeller. The impeller blade is generally of complementary shape to the screen and is spaced closely relative thereto. The impeller is mounted on a shaft extending co-axially with the screen, and connected to a drive mechanism located above the milling area. The product is milled by being urged by the impeller into the space between the impeller blade and the screen, and subsequently through perforations in the screen. The size of the granules produced is thus determined by the spacing between the screen and the impeller, and by the size of the perforations in the screen.

In such conventional machines, the need to have the impeller shaft extending co-axially relative to the screen in order that the impeller may rotate within the screen, gives rise to several major problems. Firstly, the drive mechanism causes an obstruction of the inlet tube through which the product enters the mill and thus impedes the flow of material to be milled. Secondly, the extension of the rotor shaft into the milling area means that heat is produced within the
milling area, which is undesirable as the product to be milled will often be heat-sensitive. And thirdly, lubricated parts of the drive mechanism operate within the milling area, which can lead to the product becoming contaminated with lubricants etc.

One previous attempt to solve these problems entailed providing an off-set inlet tube so that the product is introduced into the milling area at an angle relative to the common axis of the screen and the impeller. This overcomes the problem of having an obstructed inlet tube, but leads to poor product flow through the milling area. Furthermore, the problems associated with having machine parts within the milling area are not overcome.

Another potential solution is disclosed in United States Patent No. 5,330,113. This provides a drive mechanism including a gearbox, underneath the milling area. This arrangement also overcomes the problems of obstructing the inlet, but does not avoid heat generation in the milling area. Additionally, the provision of the gearbox below the milling area tends to obstruct the outlet tube through which the product exits the milling area, thus still reducing throughput of product.

The present invention stems from the realisation that a solution to all of the above-stated problems may be achieved by providing a mill in which the rotational motion of the impeller relative to the screen (or indeed the screen relative to the impeller) is driven circumferentially rather than axially.

Therefore, according to the present invention, there is provided a size reduction mill comprising a screen and an impeller, mounted co-
axially in spaced relationship relative to one another and located in a flow path for a product to be milled, wherein one of the screen or the impeller is rotatable relative to the other by peripheral drive means located externally of the flow path.

The term "peripheral drive" as used herein means that the rotation of the impeller or the screen is driven circumferentially rather than axially. As such, there is no rotor shaft extending axially through the milling area, nor is there any drive mechanism located above or below the milling area. The mill may therefore be produced to a much more compact overall size or "shut height" than existing machines.

It is envisaged that the present invention may in certain circumstances be adapted such that the impeller remains stationary and the screen is rotatable relative thereto. However, it is currently preferred that the screen remains stationary and the impeller is rotatable relative thereto and the present invention will be predominantly described with reference to that arrangement. The rotation is effected by the impeller being operably connected to the peripheral drive means, with the screen being fixed.

The flow path in which the screen and impeller are located is preferably generally cylindrical, and is defined at one end thereof by an inlet tube and at the other end thereof by an outlet tube. Each tube is arranged co-axially with respect to the other tube and with respect to the screen and the impeller.

As stated above, the present invention is particularly concerned with conical screen mills, and it is therefore much preferred that the
screen and the impeller should each be of generally conical or frusto-
conical shape. However, it is believed that the principle on which the
present invention operates — namely driving the rotation of the impeller
circumferentially rather than axially from outside the flow path — will be
equally applicable to other shapes and configurations of screen and
impeller.

In a first embodiment of the present invention, the peripheral
drive means comprises an electric motor arranged to drive a first
pulley, which is operably connected by a drive belt to a second pulley
arranged co-axially with the screen and impeller. Preferably, the drive
belt and the second pulley associated therewith extend around the
exterior of the milling area. The second pulley is attached or
otherwise operably connected to transfer the drive to the screen or the
impeller. This may be achieved by means of an intermediate
mechanism such as a drive ring. Alternatively, the drive belt may be
replaced by a drive chain and/or the pulleys may be constructed in the
form of cogs or gears.

In an alternative embodiment of the present invention, the
peripheral drive means comprises an electric motor having a stator
extending circumferentially around the milling area and a rotor
attached or otherwise operably connected to transfer the drive to the
screen or the impeller. As with the first embodiment, this may be
achieved by means of an intermediate mechanism such as a drive
ring.
The stator may be controlled by a driver, adapted to generate a variable wave signal to produce a rotating electromagnetic field (REMF) in the stator. The speed and torque of the rotor - and hence the screen or impeller operably connected thereto - can thus be controlled.

For either of the above embodiments, a drive ring may be connected to one of the screen or the impeller, and be mounted for rotation with respect to the other part.

In a currently preferred arrangement, the impeller comprises an annular collar provided with an out-turned edge, adapted to engage with a complementary ledge formed on the drive ring. The drive ring may be supported on a bearing, with a bearing retainer ring being secured to a portion of the base frame of the mill, which may be in the form of a support ring. Most preferably the bearing is a deep groove single row ball bearing. The other of the impeller or screen, which is not mounted for rotation, may be fixed to the base frame of the mill. Typically, where the screen is fixed, it will be supported on an upper portion of the outlet tube.

One or more seals may be provided, extending circumferentially around the impeller so as to isolate the milling area from the drive means. This ensures that dust from the milled product is kept away from the drive means, as well as preventing contaminants from the drive means, such as lubricants etc. from entering the product flow path.
Preferably, two seals are provided: a first upper seal being located atop the annular collar of the impeller, and in sealing contact therewith and with the drive ring and the inlet tube; and a second lower seal being located atop the support ring, and in sealing contact therewith and with the underside of the drive ring, and the annular collar.

The seals are preferably formed from PTFE, filled with a polyamide, such as Avalon 57™, and carried in a stainless steel casing.

The mill may desirably further comprise adjustment means to enable variation in the distance between the screen and the impeller, thus enabling the granule size to be more accurately controlled. In order to achieve this, the screen is supported on a screen adjuster ring forming an upper portion of the outlet tube. The screen adjuster ring is provided around its external circumference with a thread adapted to co-operate with a complementary thread provided around the inner circumference of a support ring fixed to the base frame of the mill.

The separation between the screen and the impeller can thus be varied by rotating the screen, the screen adjuster ring and the outlet tube, as an assembly, relative to the support ring, the base frame, and the impeller. The screen assembly is thus rotated in one direction to move the screen upwards thus decreasing the separation, and in the other direction to move the screen downwards thus increasing the separation. The distance variation may be carried out both during the running of the mill, and when the mill is stopped.
Preferably, the screen assembly may be removed from the mill by continued rotation in the direction which effects downward movement of the screen. The screen assembly may then be cleaned or otherwise handled and then returned to the mill.

The screen itself may be removably retained on the screen adjuster ring, by a screen clamping ring. Preferably, complementarily-engaging threads, are provided on each of the screen clamping ring and the screen adjuster ring. The screen may thus be removed and replaced whether or not the screen assembly as a whole is removed.

The separation adjustment mechanism removes the need for separate spacers between the screen and the impeller, as are required in order to obtain the correct separation in prior art devices where the screen is fixed to the base frame. In such devices, fitting a thicker or thinner screen to the mill creates an uncontrolled variation in the separation. A further advantage of the separation adjustment means in the preferred embodiment of the present invention, is that it enables the separation to be adjusted when a thicker or thinner screen is fitted, thus maintaining the original separation.

The mill is preferably mounted on a moveable frame having wheels to enable the mill to be mobile.

In order that the present invention may be more clearly understood, preferred embodiments thereof will now be described in detail though only by way of example, with reference to the accompanying drawings, in which:
Figure 1 is a cross-sectional side view of a first embodiment of size reduction mill, according to the present invention;

Figure 2 is an enlarged cross-sectional side view of the milling area of the mill of Figure 1;

Figure 3 is an exploded perspective view of the major components of the mill of Figures 1 and 2;

Figure 4 is an enlarged cross-sectional side view of the milling area of a mill, similar to that shown in Figures 1 to 3, but additionally including a screen-impeller separation adjustment mechanism.

Figure 5 is an enlarged cross-sectional side view of the milling area of a mill, similar to those shown in Figures 1 to 4, but additionally including circumferential sealing means;

Figure 6 is an enlarged cross-sectional side view of a seal for use in the mill of Figure 5; and

Figure 7 is an exploded perspective view of the major components of an alternative embodiment of size reduction mill according to the present invention.

Referring first to Figure 1, there is shown a size reduction mill, generally indicated 10, according to a first embodiment of the present invention. The mill 10 comprises a milling area, generally indicated 11 and a drive section, generally indicated 12 located to one side of the milling area 11. The mill 10 is encased in a housing 13 having a top cover 14, a base frame 15 and mounted at its base on a moveable frame 16 provided with wheels 17. An electric motor 18 is located in the drive section 12 of the housing 13.
The milling area 11 has a cylindrical inlet tube 19 and a cylindrical outlet tube 21, which are arranged co-axially with one another to define a flow path 22 for the product to be milled. As can best be seen from Figure 2, a generally frustro-conical screen 23 and a matching impeller 24 are located to receive product passing along the flow path 22.

The impeller 24 comprises a generally V-shaped blade 25 supported on an annular collar 26. The V-shape of the blade 25 is complementary to the frustro-conical shape of the screen 23, so as to permit rotation of the impeller 24 within the screen 23 and consequent milling of product. The impeller 24 is mounted in spaced relationship from the screen 23 so as to define a gap 27 therebetween. The screen 23 and the impeller 24 are arranged co-axially with one another and with the inlet tube 19 and the outlet tube 21.

The annular collar 26 has around its upper end an out-turned edge 28, which is carried on a ledge 29 formed on a drive ring 31. The drive ring 31 is attached to a driven pulley 32 extending externally around the milling area 11.

Referring again to Figure 1, the driven pulley 32 is connected by a drive belt 33 to a drive pulley 34. The drive pulley 34 is arranged to be driven by the electric motor 18, thus in turn causing rotation of the driven pulley 32, the drive ring 31 and the impeller 24. A motor adjusting plate 35 is arranged to vary the position of the motor 18 so as to ensure the correct tension in the drive belt 33.
The drive ring 31 is mounted for rotation, and supported by a bearing 36. A stationary bearing retainer ring 37 is carried on a support ring 38 fixed to the base frame 15. As can be seen from Figures 2 and 3, the outlet tube 21 is formed with an annular ledge 39 near its upper end, which supports a screen locator ring 41. The screen locator ring 41 holds the support ring 38 away from the upper end of the outlet tube 21 so as to define a space therebetween. The screen 23 is formed with a lip 42 at its upper end which fits into this space. The inlet tube 19 also has an annular ledge 43 extending therearound, which bears against the upper surface of the top cover 14 and prevents the inlet tube 19 impinging on the impeller 24. As can be seen from Figure 3, the top cover 14 has a circular aperture 44 formed therein for receiving the inlet tube 19.

In use, the electric motor 18 causes rotation of the drive pulley 34. The drive belt 33 and the driven pulley 32 transfer the rotation to the drive ring 31, which in turn causes rotation of the impeller 24 relative to the fixed screen 23. The rotation of the impeller 24 is thus driven circumferentially rather than axially.

Referring now to Figure 4, there is shown a mill, generally indicated 50, broadly similar to that described above with reference to Figures 1 to 3, except for the additional provision of an adjustment mechanism by means of which the gap 27 between the screen 23 and the impeller 24 may be varied. Where possible, like reference numerals will be used to denote like components.
The outlet tube 21 is provided with an out-turned rim 51 around its upper end. This rim 51 is clamped to a complementary rim 52 formed on the lower portion of a screen adjuster ring 53, by means of a clamping member 54, to form a protruding ridge 55 extending circumferentially around the outlet tube 21. The upper portion of the screen adjuster ring 53 is formed with an in-turned lip 56 adapted to fit into a recess 57 formed in the support ring 38. The support ring 38 in this embodiment is formed with a downwardly-extending portion 58 which overlies an upper portion of the screen adjuster ring 53.

The downwardly-extending portion 58 is provided with a coarse thread 59 around its inner circumference, which co-operates with a complementary thread 61 provided around the outer circumference of the screen adjuster ring 53. A further thread 62 is provided around the inner circumference of the screen adjuster ring 53, and co-operates with a complementary thread 63 provided around the outer circumference of a screen clamping ring 64. The screen 23 is held in position between the in-turned lip 56 and the screen clamping ring 64.

In use, the gap 27 between the screen 23 and the impeller 24 may be decreased by rotating the screen assembly, generally indicated 65 (comprising the outlet tube 21, the adjuster ring 53, the screen clamping ring 64 and the screen 23) in a clockwise direction. The ridge 55 may be grasped manually in order to effect this rotation. The screen assembly 65 thus rotates relative to the support ring 38 and the base frame 15, by means of the complementary threads 59, 61, so as to screw the screen assembly 65 further into the mill 50 such
that the in-turned lip 56 moves further into the recess 57, and consequently the screen 23 moves closer to the impeller 24.

Conversely, to increase the gap 27, the screen assembly 65 is rotated in an anti-clockwise direction relative to the support ring 38 and the base frame 15, so that the lip 56 is withdrawn from the recess 57, and consequently the screen 23 moves away from the impeller 24. Continued anti-clockwise rotation of the screen assembly 65 enables it to be completely detached from the mill 50 to enable cleaning and replacement of parts etc.

The screen clamping ring 64 may be removed from the screen adjuster ring 53 by rotating it in an anti-clockwise direction. This may be achieved with the use of a special tool (not shown). The screen 23 may thus be removed and replaced, before the screen clamping ring 64 is replaced by rotating it in a clockwise direction. This operation may be carried out either when the screen assembly 65 is engaged with the mill 50, or when it has been withdrawn therefrom.

Referring now to Figure 5, there is shown a mill, generally indicated 70, broadly similar to that described above with reference to Figures 1 to 4, except for the additional provision of upper and lower seals 71, 72, each extending circumferentially around the milling area 11, so as to isolate said milling area 11 from the drive means, (i.e. the driven pulley 32, the drive belt 33 and the drive pulley 34).

The upper seal 71 is located atop the annular collar 26 of the impeller 24, and is in sealing contact therewith, and with the inner circumference of the rotating drive ring 31, and the outer
circumference of the fixed inlet tube 19. Dust from the milled product is thus prevented from entering the drive means 32-34 through the channel 73 formed between the impeller collar 26 and the inlet tube 19. Similarly, contaminants from the drive means 32-34, are prevented from entering the milling area 11 through the same channel 73.

The lower seal 72 extends circumferentially around the impeller collar 26, and is in sealing contact therewith, and with the upper surface of the fixed support ring 38 and the underside of the rotating drive ring 31. Dust from the milled product is thus prevented from entering the drive means 32-34 through the channel 74 formed between the drive ring 31 and the support ring 38. Similarly, contaminants from the drive means 32-34 are prevented from entering the milling area 11 through the same channel 74.

As is shown in Figure 6, the seal 71/72 comprises a stainless steel, outer casing 75, which carries a sealing member 76, formed from PTFE filled with a polyamide such as Avalon 57™. A nitrile, gasket 77 is provided between the casing 75 and the sealing member 76. The seal 71/72 is arranged such that the casing 75 is secured to a fixed part of the mill 70 (i.e. the inlet tube 19 or the support ring 38), with the sealing member 76 bearing against the rotating part, i.e. the drive ring 31).

Referring now to Figure 7, there is shown an exploded view of the components of an alternative embodiment of size reduction mill, generally indicated 80. In this embodiment, an electric motor 18 is
effectively formed around the milling area 11, thus eliminating the need for a separate drive section 12.

This is achieved by the provision of a fixed stator 81 extending circumferentially around the milling area 11, and a rotor 82 rotatable therewithin and operably connected to the impeller 24. The rotor 82 effectively takes the place of the driven pulley 32 and the drive ring 31 from the first embodiment.

A plurality of magnets 83 are fixed around the circumference of the rotor 82 so as to cause rotation thereof upon the production of a rotating electromagnetic field (REMF) in the stator 81. The stator 81 is controlled by a driver (not shown) adapted to generate a variable wave signal so as to produce the REMF. The speed and torque of the rotor 82, and hence the impeller 24, can thus be controlled.

The rotor 82 is mounted for rotation on a bearing 36 via an inner bearing casing 84, which rotates with the rotor 82. The outer circumference of the bearing is fixed to a stationary bearing retainer ring 37, as in the first embodiment.

The inner circumference of the inner bearing casing 84 carries a spiral thread 85. A complementary thread 86 is carried on the outer circumference of a top part 87 of the inlet tube 19.

When assembled, the top part 87 protrudes into the bearing casing 84 such that the complementary threads 85, 86 are brought into closely spaced alignment. The circumference of the top part 87 is slightly less than that of the bearing casing 84 so that no contact between the threads 85, 86 actually occurs. However, in use, the
spinning of the casing 84 creates a vortex-like effect between the spiral threads 85, 86 which prevents dust from the milling area 11 entering the drive means.

In use, the rotor 82, impeller 24 and inner bearing casing 84 rotate on the bearing 36, relative to the remainder of the components, which are fixed via the support ring 38 and the top cover 14 to the mill housing 13. As can be seen, the flow path 22 passes through the central aperture of all the components.
Claims

1. A size reduction mill comprising a screen and an impeller, mounted co-axially in spaced relationship relative to one another and located in a flow path for a product to be milled, wherein one of the screen or the impeller is rotatable relative to the other by peripheral drive means located externally of the flow path.

2. A mill as claimed in claim 1 wherein the impeller is operably connected to the peripheral drive means for rotation relative to the screen.

3. A mill as claimed in claim 1, wherein the screen is operably connected to the peripheral drive means for rotation relative to the impeller.

4. A mill as claimed in any of the preceding claims wherein the screen is generally conical or frustro-conical.

5. A mill as claimed in any of the preceding claims, wherein the screen is generally conical or frustro-conical, and the impeller comprises a generally V-shaped blade supported on an annular collar.

6. A mill as claimed in any of the preceding claims wherein the peripheral drive means comprises an electric motor arranged to drive, by means of a first pulley and a drive belt, a second pulley operably connected to the screen or the impeller.

7. A mill as claimed in claim 6, wherein the second pulley is operably connected to the screen or the impeller by a rotatable drive ring adapted to carry the screen or the impeller.
8. A mill as claimed in any of claims 1 to 5, wherein the peripheral drive means comprises an electric motor having a stator extending circumferentially around the milling area, and a rotor operably connected to the screen or the impeller.

9. A mill as claimed in claim 8, wherein the stator is controlled by a driver adapted to generate a variable wave signal, thereby to control the speed and torque of the rotor.

10. A mill as claimed in claim 8 or claim 9, wherein the rotor is operably connected to the screen or the impeller by a rotatable drive ring adapted to carry the screen or the impeller.

11. A mill as claimed in claim 7 or claim 10, further comprising one or more seals extending circumferentially around the milling area and in sealing contact with the drive ring and a fixed part of the mill.

12. A mill as claimed in claim 11, comprising an upper seal located at or adjacent an upper surface of the drive ring, and a lower seal located at or adjacent a lower surface of the drive ring.

13. A mill as claimed in any of the preceding claims further comprising adjustment means to enable variation of the distance between the screen and the impeller.

14. A mill as claimed in claim 13, wherein the impeller is operably connected to the peripheral drive means for rotation relative to the screen, and the adjustment means comprises complementary screw threads adapted to move the screen axially relative to the impeller.

15. A mill as claimed in any of the preceding claims wherein the flow path is defined at one end thereof by a generally cylindrical inlet tube
and at the other end thereof by a generally cylindrical outlet tube, said tubes being arranged co-axially relative to one another and to the screen and the impeller.

16. A mill as claimed in claim 15, wherein the impeller is operably connected to the peripheral drive means for rotation relative to the screen, and the screen is carried on an upper portion of the outlet tube.

17. A mill as claimed in claim 16, wherein the screen is removably retained on the upper portion of the outlet tube by means of a screen clamping ring, there being complementary screw threads provided on the screen clamping ring and the upper portion of the outlet tube.

18. A mill as claimed in any of the preceding claims, further comprising a mobile support frame.

19. A size reduction mill comprising a screen and an impeller, mounted co-axially in spaced relationship relative to one another and located in a flow path for a product to be milled, wherein the impeller is operably connected to drive means for rotation relative to the screen, and adjustment means comprising complementary screw threads adapted to move the screen axially relative to the impeller.
A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 B02C18/06 B02C18/00

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)

IPC 7 B02C

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

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

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<td>A</td>
<td>US 5 863 004 A (BROILLET MICHEL) 26 January 1999 (1999-01-26) the whole document</td>
<td>1-6, 13-17,19</td>
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<td>A</td>
<td>US 4 759 507 A (LYNCH DANIEL N ET AL) 26 July 1988 (1988-07-26) column 4, line 47-62 column 7, line 32 -column 8, line 29; figures 1,13-17</td>
<td>1,2,4,5, 13-17,19</td>
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Further documents are listed in the continuation of box C. Patent family members are listed in annex.

* Special categories of cited documents:
  *A* document defining the general state of the art which is not considered to be of particular relevance
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  *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
  *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
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Date of the actual completion of the international search: 31 March 2004

Date of mailing of the international search report: 06/04/2004

Name and mailing address of the ISA:
European Patent Office, P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk
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Authorized officer: Strodel, K-H
Box I  Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. □ Claims Nos.:
   because they relate to subject matter not required to be searched by this Authority, namely:

2. □ Claims Nos.:
   because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. □ Claims Nos.:
   because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II  Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. □ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. X As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. □ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. □ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest
□ The additional search fees were accompanied by the applicant’s protest.
□ No protest accompanied the payment of additional search fees.
This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-18
   Size reduction mill comprising peripheral drive means

2. Claim: 19
   Size reduction mill comprising adjustment means
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