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(54) A method for molding powder under compression.

(57) A method for molding powder under compression by use of a compression molding machine including a horizontally supported turntable provided with bores vertically extending therethrough, and upper pressure rods and lower pressure rods respectively positioned above and below the respective bores, the upper end portion of each lower pressure rod being fitted in the corresponding bore. The method includes subjecting powder contained in each bore to preliminary compression by dropping the corresponding upper pressure rod into the bore by gravity before the compression molding operation.

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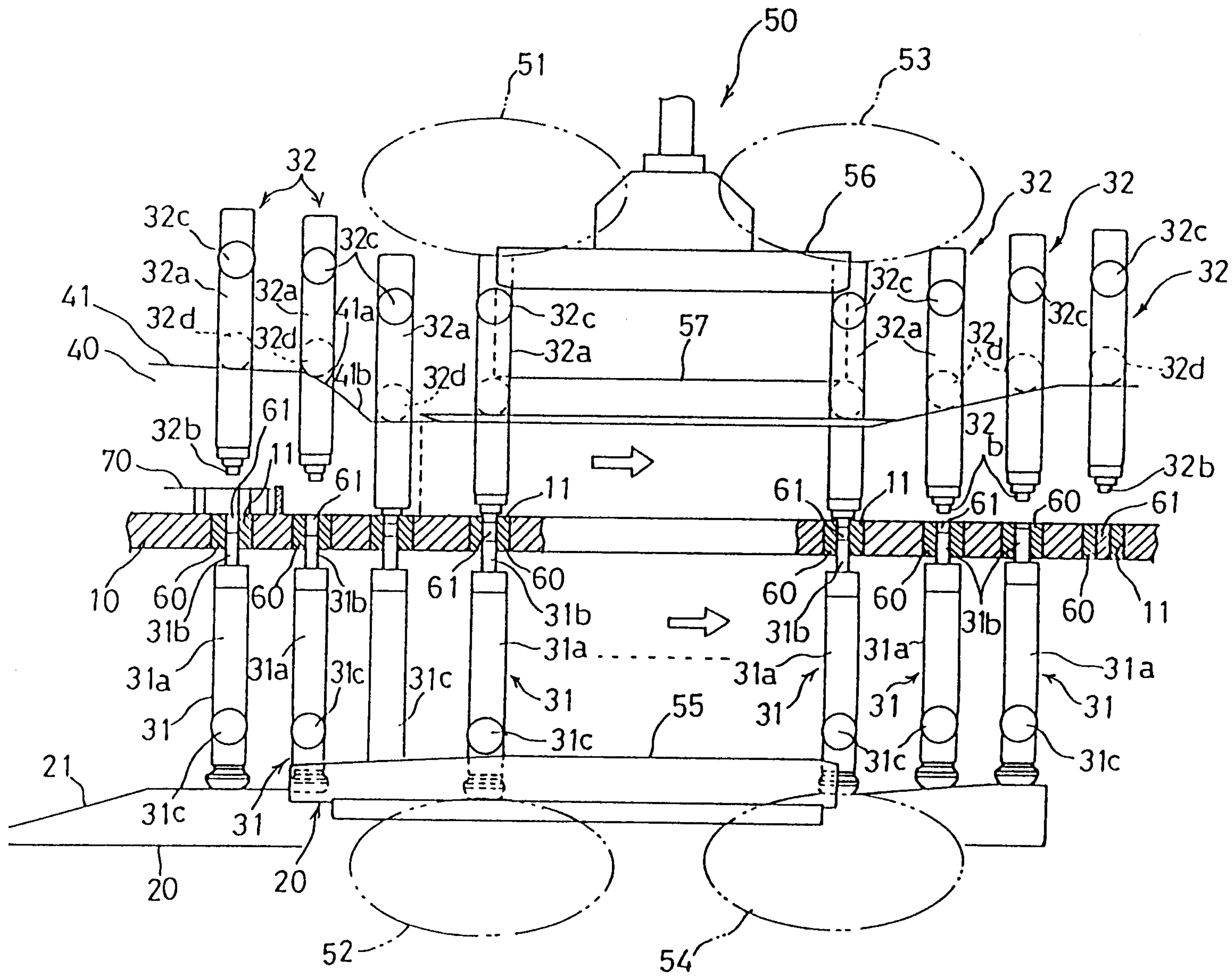
Fig. 1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The present invention relates to a method for molding powder under compression, which is used to mold powder into tablets or the like.

When powders of medicine, food, bubble bath, and the like are to be compressed and molded into tablets, a rotary powder compression molding machine which is called a tablet machine is usually employed. The rotary powder compression molding machine includes a disc-shaped turntable which is horizontally supported and rotatable in a predetermined direction about a vertical axis. The turntable is provided with many bores extending vertically therethrough. The bores are arranged at regular intervals in the direction of rotation of the turntable. A pair of pressure rods are respectively disposed above and below each of the bores in such a manner that they can move toward and away from the bore. These upper and lower pressure rods include compression members which are fitted into the bore as the pressure rods move toward the bore. As the turntable rotates, the upper and lower pressure rods are moved together with the turntable in the direction of its rotation.

With the use of such a compression molding machine, a conventional compression molding process is performed as follows. The compression member of each of the lower pressure rods is always fitted in the corresponding bore, thereby closing the lower opening of the bore. In this state, as the turntable rotates, the lower pressure rods are moved downward while moving in the direction of rotation of the turntable. The downward movement of each pressure rod given a space in the bore to which powder is supplied. As a result, the bores are successively filled with the powder.

Then, the upper and lower pressure rods are pressed first by upper and lower pre-loadiig rollers, and then by upper and lower pressure rollers, respectively, toward the corresponding bore, so that the powder is compressed and molded into a tablet. The thus produced tablet is pushed out of the bore by the lower pressure rod. In this way, with each revolution of the turntable, tablets are successively produced.

In such a rotary powder compression molding machine, air is removed from the powder by the compression effected by the pre-loading rollers for the purpose of preventing a problem of blowing out of the powder from the bore during the compression effected by the pressure rollers and a problem of capping and lamination in the resultant tablets. These problems are effectively avoided when the powder of excellent flowability is molded, wherein the air can be sufficiently removed from the powder by the compression effected by the pre-loading rollers.

However, when the powder contains a large amount of wax-like material such as vitamin E which softens in heat or a large amount of liquid which becomes viscous by the application of heat, the above problems arise for the following reason. In the conventional compression molding machine, heat is generated through friction between the inner wall of the bore and the two pressure rods corresponding thereto. Thus, the temperature in each bore increases with time. When the compression molding operation continues for a long period of time, the temperature in each bore becomes so high as to soften the wax-like material contained in the powder or allows the liquid contained in the powder to become viscous. The softened wax-like material or viscous liquid then sticks to the wall of the bore and the pressure rods, thereby narrowing or closing the gaps therebetween. This prohibits the air in the powder from being sufficiently removed from the bore during the compression by the pre-loading rollers, allowing the powder containing air therein to be molded into tablets. The resultant tablets may possibly have disadvantageous capping or lamination.

Furthermore, the air contained in the powder is likely to rapidly blow out through the narrowed gap between the bore and the pressure rods, and, together with the air blown out, a large amount of powder may possibly blow out of the bore during the final compression effected by the pressure rollers. As a result, the amount of the powder to be molded into a tablet is greatly decreased. Even from a gap which is not narrowed, a large amount of powder is likely to be spilled out. The powder blown out or spilled out may enter parts of the machine, causing abnormal wearing of the parts.

The above problems caused by the increase in temperature of the bore can be avoided to some extent by lowering the operation speed of the compression molding machine, so as to reduce heat generated through friction between the bore and the pressure rods. The problems may also be prevented by lowering the compression speed so that air can be sufficiently removed from the powder. However, lowering the operation speed will greatly reduce the production efficiency.

According to the present invention, there is provided a method for molding powder under compression, by use of a compression molding machine including a horizontally supported turntable provided with bores vertically extending therethrough, each bore being provided with an upper pressure rod and a lower pressure rod respectively positioned above and below the bore, comprises the steps of successively filling each bore with a predetermined amount of powder, with an upper end portion of each lower pressure rod being fitted in the corresponding bore, allowing the upper pressure rods to successively fall by gravity into the respective bores, thereby subjecting the powder contained in each bore to preliminary compression, successively compressing the preliminarily compressed powder in the bores, and further successively compressing the compressed powder in the bores, thereby molding the powder in each bore into a tablet.

In the method for molding powder under compression according to the present invention, powder in each bore of the turntable is subjected to preliminary compression by the corresponding upper pressure roller having a predetermined weight which falls thereon by gravity, before the powder is completely compressed by the pre-loading rollers and the pressure rollers. Through the preliminary compression, air in the powder is completely removed from the bore. Furthermore, since the upper pressure rod falls by gravity onto the powder in the corresponding bore for the preliminary compression, a relatively long period of time can be used for the preliminary compression even when the turntable rotates at a high speed for high-speed compression molding operations. Thus, even when using powder containing a wax-like material, air can be removed from the powder through the preliminary compression irrespective of the lapse of time. As a result, the possibility of causing any capping or lamination in the resultant tablets and the possibility that any appreciable amount of powder will be blown out of the bore with time are eliminated.

Thus, the invention described herein makes possible the objective of providing a method for molding powder under compression, in which air in the powder can be completely removed before the powder is subjected to compression molding, so that tablets without capping or lamination can be produced at high speed operation.

For a better understanding of the invention, and to show how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawing, in which:-

Figure 1 is a schematic diagram showing a powder compression molding machine used for carrying out a method of the present invention.

The method for molding powder under compression according to the present invention is carried out by the use of a rotary powder compression molding machine such as shown in Figure 1.

The powder compression molding machine of Figure 1 comprises a horizontally supported turntable **10** in the shape of a disc which rotates about a vertical axis and is provided with many holes **11** vertically extending therethrough. The holes **11** are arranged in a coaxial circular line at regular intervals in the direction of rotation of the turntable **10**. For the simplicity of explanation, the direction of rotation of the turntable **10** is hereinafter referred to as the "turntable-rotating direction".

In each of the holes **11**, a cylindrical molding block **60** having a bore **61** vertically extending therethrough is fitted. The bore **61** has a predetermined diameter throughout the length thereof.

An upper pressure rod **32** and a lower pressure rod **31** both of which are movable upward and downward are respectively positioned above and below each of the holes **11**, so that the bore **61** of the hole **11** is vertically aligned with the corresponding upper and lower pressure rods **32** and **31**.

Each of the lower pressure rods **31** includes a vertically supported lower cylindrical body **31a** and a lower cylindrical compressing member **31b** coaxially extending upward from the lower cylindrical bady **31a.** The diameter of the lower compressing member **31b** is approximately the same as that of the bore **61**. When the lower pressure rod **31** moves upward, the lower compressing member **31b** thereof is moved upward to fit into the corresponding bore **61**. A guide roller **31c** is mounted on a lower sectino of each lower cylindrical body **31a** in such a manner thet it can rotate with its rotation axis being set in a horizontal direction.

Each of the upper pressure rods **32** includes a vertically supported upper cylindrical body **32a** and an upper cylindrical compressing member **32b** coaxially extending downward from the upper cylindrical body **32a**. The diameter of the upper compressing member **32b** is approximately the same as that of the bore **61**. When the upper pressure rod **32** moves downward, the upper compressing member **32b** is moved downward to fit into the corresponding bore **61**. A guide roller **32c** is mounted on an upper section of each upper cylindrical body **32a** in such a manner that it can rotate with its rotation axis being set in a horizontal direction. Each upper cylindrical body **32a** is provided with another guide roller **32d** mounted on the center thereof and positioned on the side opposite to that provided with the guide roller **32c** in such a manner that it can rotate with its rotation axis being set in a horizonal direction.

The compression molding machine further includes an upper guide **40** and a lower guide **20** for guiding the upper pressure rods **32** and lower pressure rods **31**, respectively. As the turntable **10** rotates, all the upper and lower pressure rods **32** and **31** move together with the turntable **10.** While they are moving in the turntable-rotating direction, the lower end of each lower pressure rod **31** is guided along a guide surface **21** of the lower guide **20**, and the guide roller **32d** of each upper pressure rod **32** is guided along a guide surface **41** of the upper guide **40**.

A hopper (not shown) containing powder to be molded is disposed at a predetermined position above the turntable **10**. A portion of the turntable **10** facing the hopper serves as a "powder feed region" where the powder is supplied from the hopper into each bore **61**. A feed shoe **70** is disposed in contact with the upper surface of the turntable **10** at a position slightly away from the powder feed region toward the turntable-rotating direction. As the turntable **10** rotates, the feed shoe **70** slides along the turntable **10** so as to scrape off any excessive powder in each bore **61**.

A pressure mechanism **50** is appropriately spaced apart from the feed shoe **70** toward the turntable-rotating direction. The pressure mechanism **50** includes upper and lower pre-loading rollers **51** and **52** respectively disposed above and below the turntable **10**, and also includes upper and lower pressure rollers **53** and **54** respectively disposed above and below the turntable **10**. The pressure rollers **53** and **54** are located away from the pre-loading rollers **51** and **52** in the turntable-rotating direction, respectively.

As the turntable **10** rotates together with the upper and lower pressure rods **32** and **31**, the lower ends of the lower pressure rods **31** successively come into contact with the lower pre-loading roller **52** and then with the lower pressure roller **54**, so that each lower pressure rod **31** is pressed upward first by the preloading roller **52** and then by the pressure roller **54**. In the same manner, the upper ends of the upper pressure rods **32** successively come into contact with the upper pre-loading roller **51** and then with the upper pressure roller **53**, so that each upper pressure rod **32** is pressed downward first by the pre-loading roller **51** and then by the pressure roller **53**.

Between the upper pre-loading roller **51** and the upper pressure roller **53**, two pressure guides **56** and **57** are horizontally positioned. The two pressure guides **56** and **57** respectively abut against the guide rollers **32c** and **32d** of the upper pressure rods **32** pressed downward by the pre-loading roller **51**, and guide the respective guide rollers **32c** and **32d** so that the upper pressure rods **32** can be kept pressed downward.

Likewise, between the lower pre-loading roller **52** and the lower pressure roller **54**, two pressure guides **55** are located horizontally so as to abut against the guide rollers **31c** of the lower pressure rods **31** pressed upward by the pre-loading roller **52**, and to guide the guide rollers **31c** so that the lower pressure rods **31** can be kept pressed upward.

A portion of the guide surface **21** of the lower guide **20** corresponding to the powder feed region is horizontal. This horizontal portion extends in the turntable-rotating direction to a position where the lower pre-loading roller **52** is located. The guide surface **21** has a first inclined portion which is located adjacent to the above horizontal portion in the direction opposite to the turntable-rotating direction. The first inclined portion is gradually inclined downward toward the direction opposite to the turntable-rotating direction. Therefore, as each of the lower pressure rods **31** is moved along the first inclined portion of the guide surface **21** by the rotation of the turntable **10**, it is gradually moved upward until it reaches the horizontal portion corresponding to the powder feed region. When the lower pressure rod **31** reaches the powder feeding region, it is in such a position as to allow a predetermined length of the lower compressing member **31b** to fit into the corresponding bore **61**. The lower pressure rod **31** maintains the fixed position in the vertical direction until it reaches the region provided with the pre-loading roller **52**.

The guide surface **21** is not in contact with the lower pressure rods **31** in a region where the pressure mechanism **50** is located (hereinafter referred to as a "pressure mechanism region"). The guide surface **21** further has a second inclined portion which is inclined upward from a position corresponding to the lower pressure roller **54** toward the turntable-rotating direction. As the lower pressure rods **31** move along this second inclined portion, the lower compressing member **31b** of each lower pressure rod **31** is further moved upward within the bore **61**, so that the upper end thereof reaches the same level as that of the upper surface of the turntable **10**. A further portion of the guide surface **21** adjacent to the second inclined portion is gradually inclined downward toward the turntable-rotating direction until it reaches the first inclined portion which is inclined upward in the turntable-rotating direction to the above-mentioned horizontal portion.

On the other hand, the guide surface **41** of the upper guide **40** is horizontal except for inclined planes described below a horizontal plane corresponding to the pressure mechanism region. When each upper pressure rod **32** is guided along the horizontal portion of the guide surface **41**, it maintains a fixed position above the corresponding bore **61** where the upper compressing member **32b** thereof is not fitted in the bore **61**.

The guide surface **41** includes a first inclined plane **41a** which is positioned above the portion of the guide surface **21** located adjacent to the horizontal portion thereof in the turntable-rotating direction. A second inclined plane **41b** is located adjacent to the first inclined plane **41a** in the turntable-rotating direction. The first and second inclined planes **41a** and **41b** are both inclined downward toward the turntable-rotating direction, but the tilt angle of the second inclined plane **41b** is larger than that of the first inclined plane **41a**. The tilt angle of the first inclined plane **41a** is larger than that of the inclined plane of an upper guide of a conventional compression molding machine. Therefore, the total length of the first and second inclined planes **41a** and **41b** is sufficiently shorter than that of the inclined plane of the upper guide of the conventional compression molding machine.

The guide roller **32d** of each upper pressure rod **32** is guided along the first and second inclined planes **41a** and **41b** to be gradually moved downward, thereby allowing the upper pressure rod **32** to move downward. While the guide roller **32d** is being guided along the second inclined plane **41b**, the upper compressing member **32b** of the upper pressure rod **32** fits into the corresponding bore **61** by gravity. The horizontal plane of the guide surface **41** positioned adjacent to the second inclined plane **41b** in the turntable-rotating direction and corresponding to the pressure mechanism region serves to keep the upper pressure rod **32** in such a position as to hold the upper compressing member **32b** within the bore **61**.

The operation of the powder compression molding machine of Figure 1 constructed as described above will now be described.

As the turntable **10** rotates, the upper and lower pressure rods **32** and **31** are moved together with the turntable **10** at the same speed and in the same direction. The lower compression member **31b** of each lower pressure rod **31** is always fitted in the corresponding bore **61**, thereby closing the lower opening of the bore **61**. When one of the bores **61**, for example, reaches the powder feed region, powder is supplied from the hopper into the bore **61**. The bore **61** then moves in the turntable-rotating direction to reach the feed shoe **70**. The feed shoe **70** scrapes off the excessive powder, so that the bore **61** is filled with a predetermined amount of powder.

After the bore **61** passes along the feed shoe **70**, the corresponding upper pressure rod **32** is moved downward along the first inclined plane **41a** and then along the second inclined plane **41b**. While the upper pressure rod **32** is being moved along the second inclined plane **41b**, the upper compressing member **32b** thereof falls into the bore **61** by gravity, thereby moderately compressing the powder therein. This is a preliminary compression process through which any air contained in the powder is discharged out of the bore **61** through a gap between the inner wall of the bore **61** and the peripheral wall of the lower compressing member **31b** and also through a gap between the inner wall of the bore **61** and the peripheral wall of the upper compressing member **32b**. In order to ensure the preliminary compression of the powder, the weight of the entire upper pressure rod **32** is about twice as much as that of an upper pressure rod used in a conventional compression molding machine.

After the preliminary compression, the upper and lower pressure rods **32** and **31** are first pressed by the upper and lower pre-loading rollers **51** and **52**, respectively, so as to allow the upper and lower compressing members **32b** and **31b** to compress the powder in the bore **61**. Then, the bore **61** and the corresponding upper and lower pressure rods **32** and **31** are further moved in the turntable-rotating direction to a position where the upper and lower pressure rollers **53** and **54** are located. At that position, the upper and lower pressure rods **32** and **31** are pressed a second time by the upper and lower pressure rollers **53** and **54**, respectively, so that the upper and lower compressing members **32b** and **31b** further compress the powder in the bore **61** to produce a tablet.

As described above, in the compression molding method according to the present invention, the powder is subjected to the preliminary compression by the upper pressure rod **32** before it is compressed by the upper and lower pre-loading rollers **51** and **52**. Since the preliminary compression is effected by the upper pressure rod **32** falling into the bore **61** by gravity, the load applied to the powder in the preliminary compression is determined by the weight of the upper pressure rod **32**, which is set at such a level that air can be sufficiently removed from the powder. In this example, the weight of the upper pressure rod **32** is set to be about 800 g. Furthermore, since the upper pressure rod **32** is moved along the second inclined plane **41b** of the upper guide **40** to fall into the bore **61** at a high speed, the upper pressure rod **32** can apply pressure to the powder by its own weight for a relatively long period of time, thereby further assuring effective air removal.

In a conventional compression molding machine, temperature rise is likely to occur in the bore **61** with time through friction between the bore containing powder and the upper pressure rod and also between the bore and the lower pressure rod. As described above, when powder containing a wax-like material is used, the wax-like material is softened in the bore having a high temperature.

On the other hand, according to the present invention, the preliminary compression is effected by the fall of the upper pressure rod **32** by gravity. This minimizes the temperature rise by friction in the bore **61** even when the turntable **10** rotates at a high speed, thus preventing softening of the wax-like material contained in the powder. Even if the temperature in the bore **61** becomes high enough to soften the wax-like material contained in the powder, neither capping nor lamination occurs in the resulting tablet. This is because the air in the powder can be sufficiently removed from the bore **61** by the preliminary compression process. Furthermore, because of the sufficient removal of the air, no appreciable amount of the powder will be blown out of the bore **61** during the high-speed compression effected by the pre-loading rollers **51** and **52** or by the pressure rollers **53** and **54**.

In order to evaluate the effect of the preliminary compression according to the present invention, first, wax-like vitamin E (d-α-tocopherol succinate) was used to produce tablets containing the vitamin E at a high ratio (50 mg/240 mg) in a conventional compression molding machine. The rotational speed of the turntable was set to be 40 r.p.m. (1200 tablets per minute). After two hours of compression molding operation, capping and lamination began to arise in many of the produced tablets. Furthermore, a large amount of powder was blown out of the bores during the operation. When the rotational speed of the turntable was decreased to 30 r.p.m., capping and lamination did not arise in the produced tablets before four hours of the compression molding operation, after which they began to arise in many of the produced tablets. The weight of the upper pressure rod was about 400 g.

Then, the same powder was used to produce tablets using the compression molding machine of Figure 1 according to the method of the invention. When the rotational speed of the turntable **10** was set to be 40 r.p.m., neither capping nor lamination arose in the produced tablets regardless of the operation time. Only a negligible amount of powder blew out of the bore **61** during the compression operation. In this case, the weight of the upper pressure rod was about 800 g.

Claims

1. A method for molding powder under compression, by use of a compression molding machine including a horizontally supported turntable provided with bores vertically extending therethrough, each bore being provided with an upper pressure rod and a lower pressure rod respectively positioned above and below the bore, said method comprising the steps of:

   successively filling each bore with a predetermined amount of powder, with an upper end portion of each lower pressure rod being fitted in the corresponding bore;

   allowing the upper pressure rods to successively fall by gravity into the respective bores, thereby subjecting the powder contained in each bore to preliminary compression;

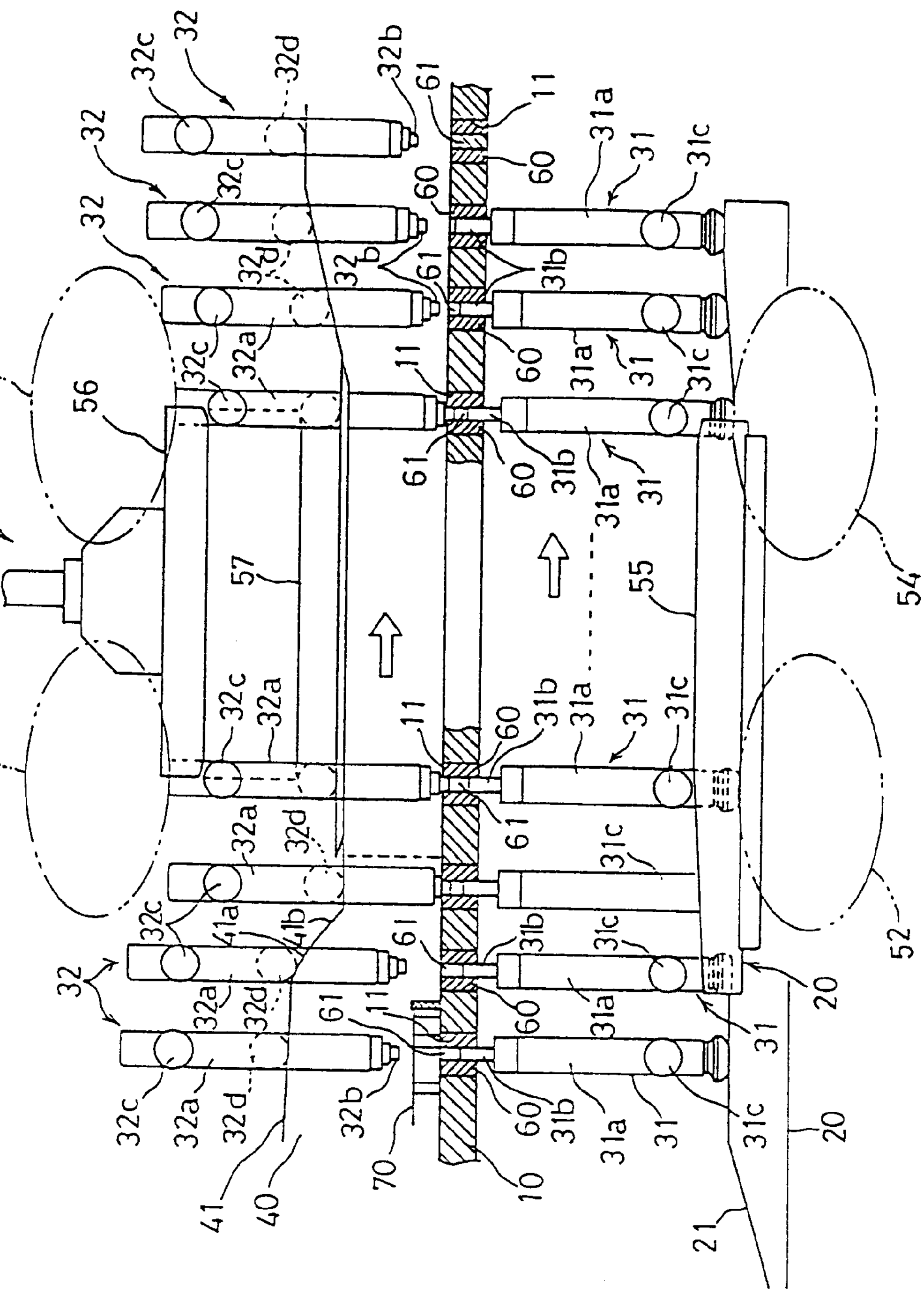
   successively compressing the preliminarily compressed powder in the bores; and

   further successively compressing the compressed powder in the bores, thereby molding the powder in each bore into a tablet.

2. A method for molding powder under compression according to claim 1, wherein the weight of the upper pressure rod is 800 g.

3. A method for molding powder under compression according to claim 1 or 2, wherein the upper pressure rods are guided along a downward inclined surface to fall into the corresponding bores for effecting said preliminary compression.

Fig. 1



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