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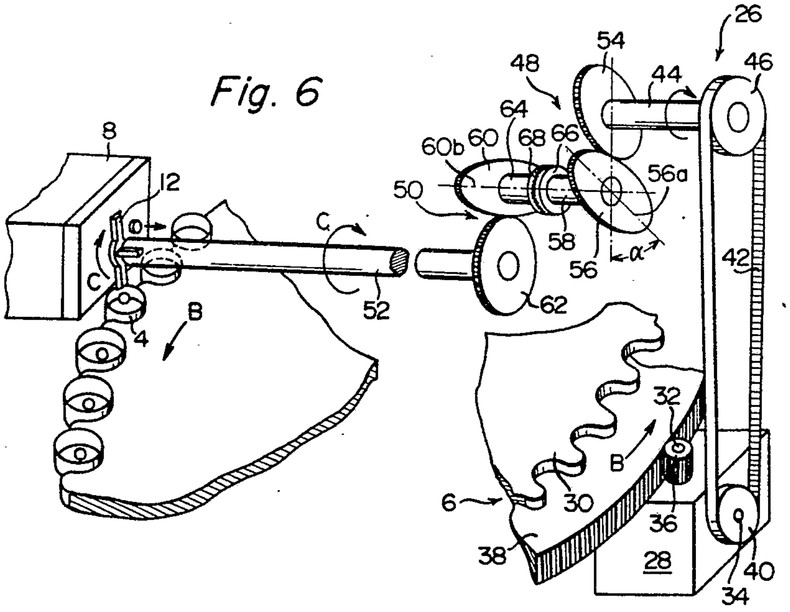
(54) Apparatus for Dispensing Lining Material into Cap Shells

(57) An apparatus for dispensing a lining material into cap shells 4, comprises a cap shell conveying means 6 for conveying the cap shells at a predetermined speed, an extruding means 8 provided along and above a cap shell conveying passage for extruding a predetermined quantity of the lining material through a discharge passage, a cutting blade 12 mounted adjacent to the exit end of said discharge passage rotatably across it for cutting the lining material, a source of driving power, and a transmission means 26 for drivingly connecting said source of driving power to said cutting blade, and is characterized in that said transmission means includes at least two pairs of non-circular gears 54, 56 and 60, 62 disposed angularly relative to each other and that the relative angle between said two pairs of non-circular gears is adjustable by means of coupling members 66, 68.

Fig. 6



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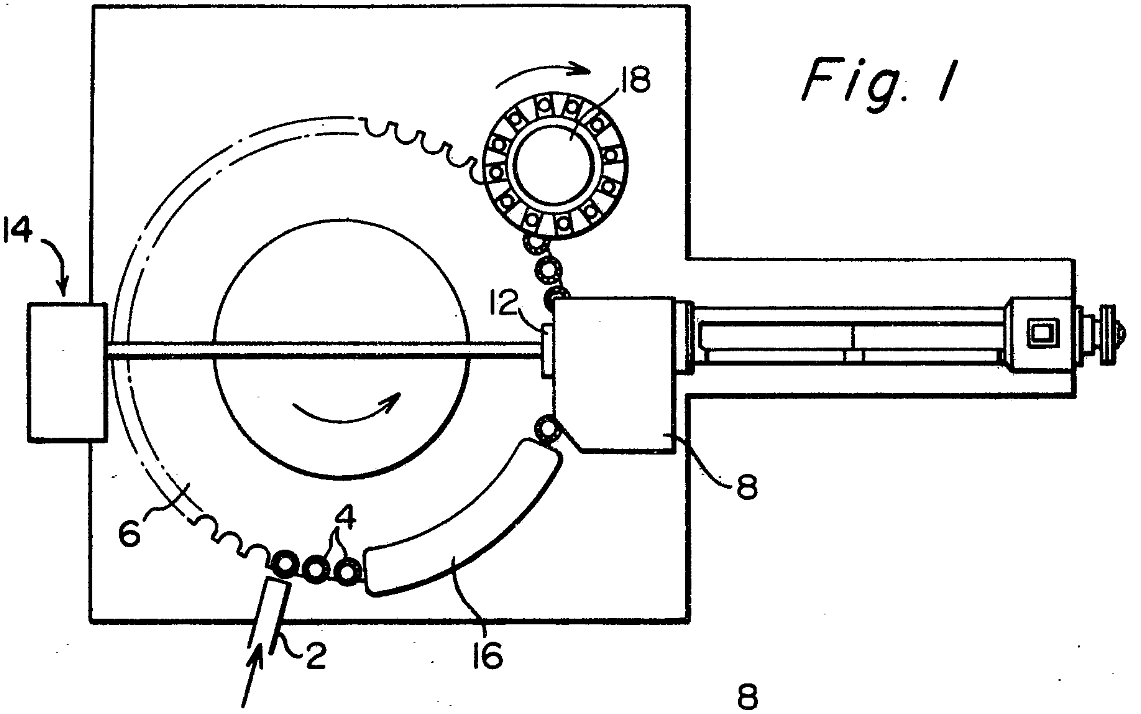


Fig. 1

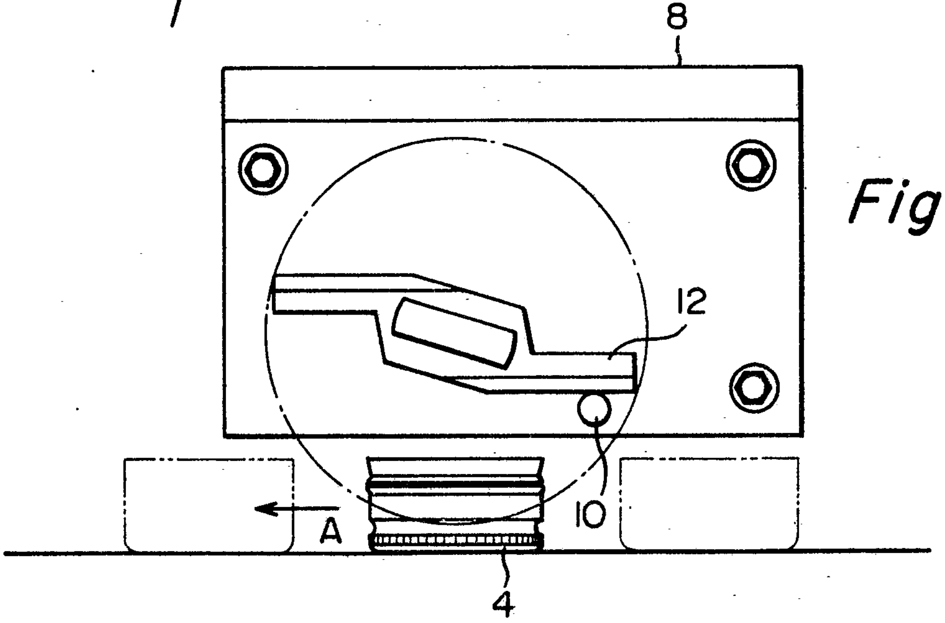


Fig. 2

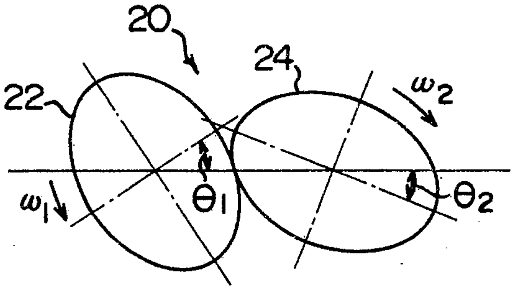


Fig. 3

Fig. 4

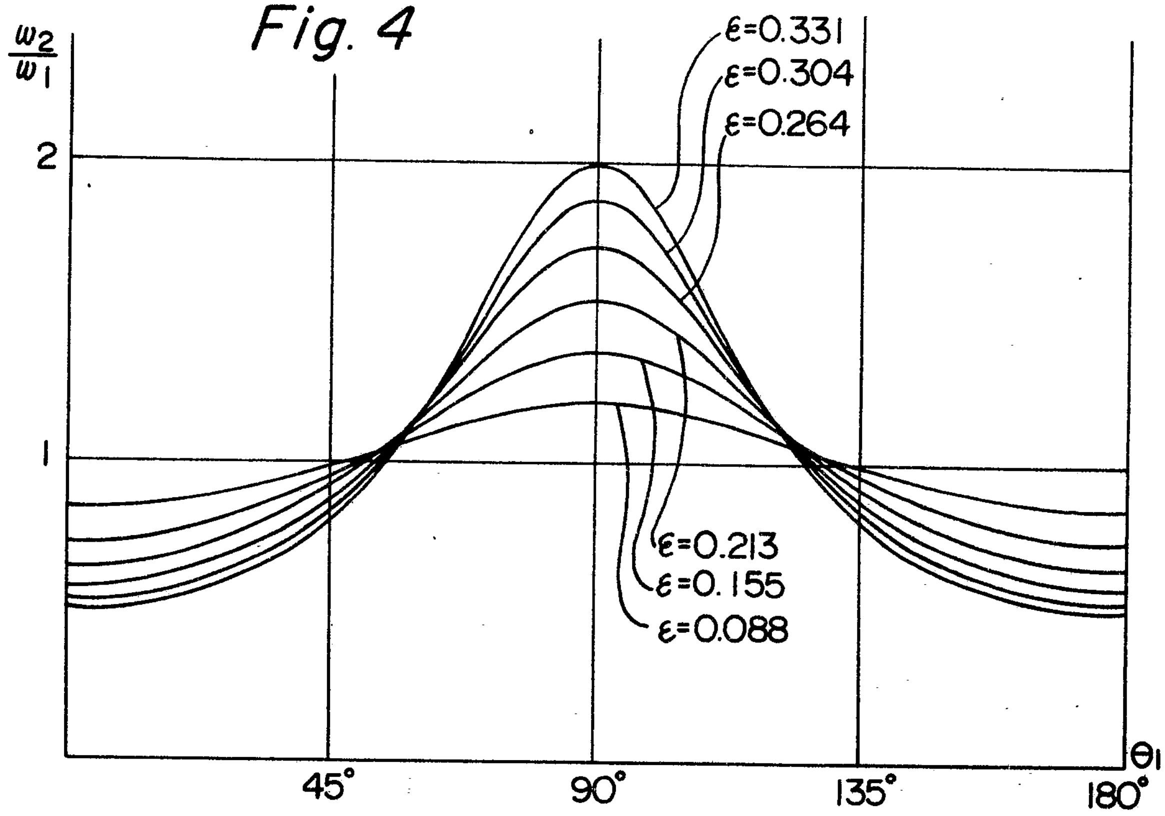

$\frac{\omega_2}{\omega_1}$
2
1
45°
90°
135°
180°
θ_1
ε=0.331
ε=0.304
ε=0.264
ε=0.213
ε=0.155
ε=0.088

Fig. 5

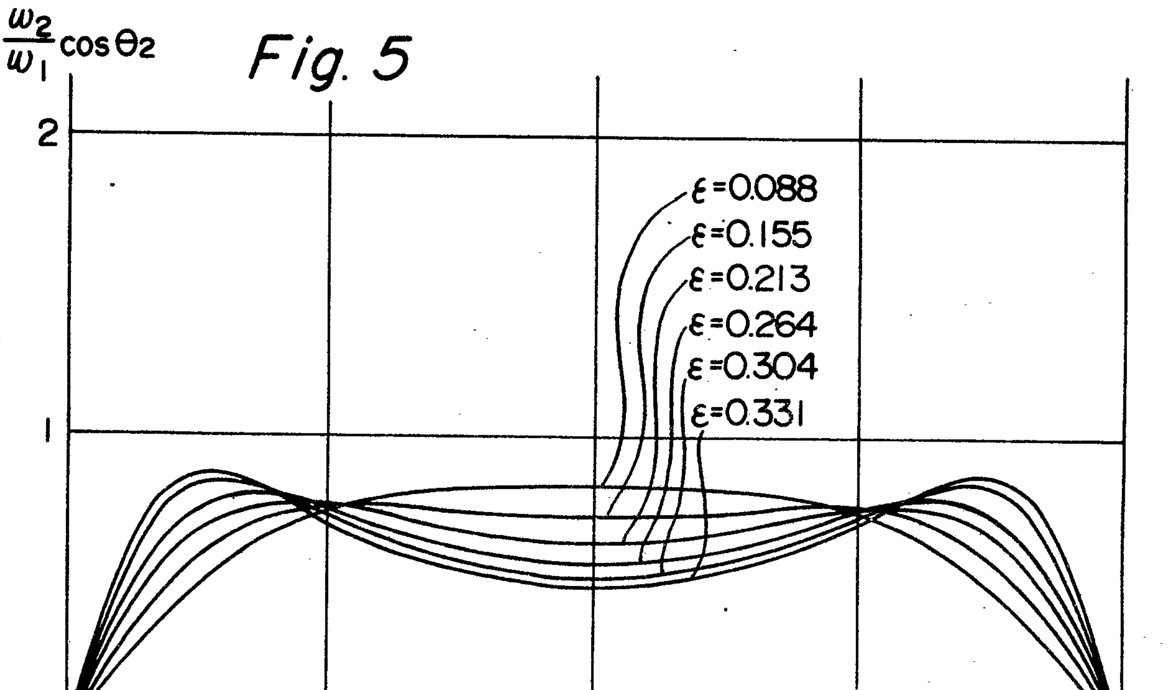

$\frac{\omega_2}{\omega_1}\cos\theta_2$
2
1
-45°
0
45°
90°
θ_1
ε=0.088
ε=0.155
ε=0.213
ε=0.264
ε=0.304
ε=0.331

Fig. 6

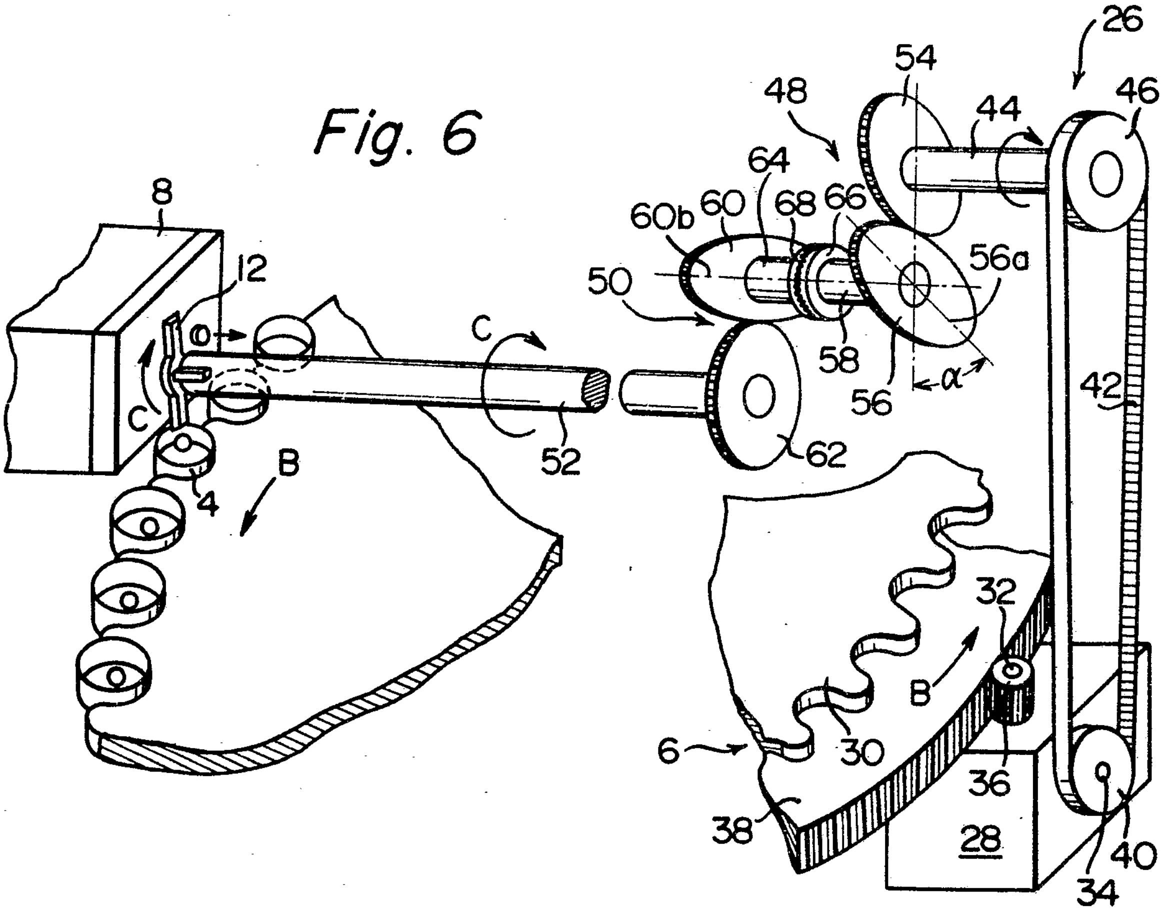

8
12
a
C
C
4
B
52
50
60b
60
64
68
66
48
54
44
26
46
56a
58
56
α
42
62
32
B
30
6
36
38
28
40
34

Fig. 7

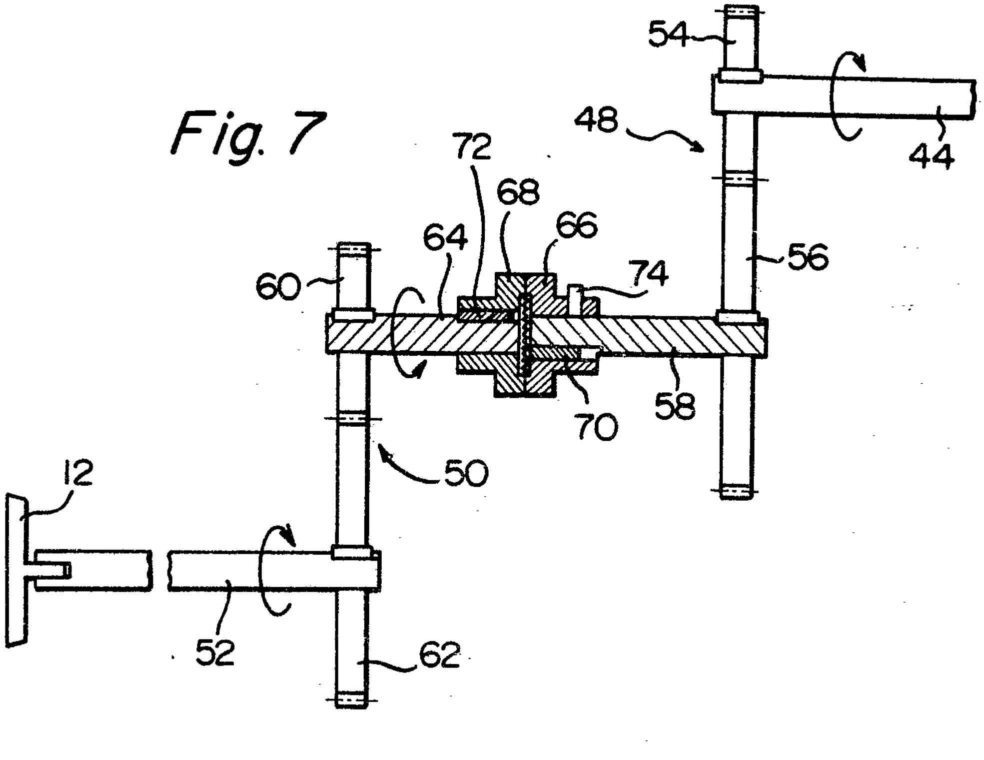

54
48
44
72
68
66
64
74
60
56
58
70
50
12
52
62

Fig. 9

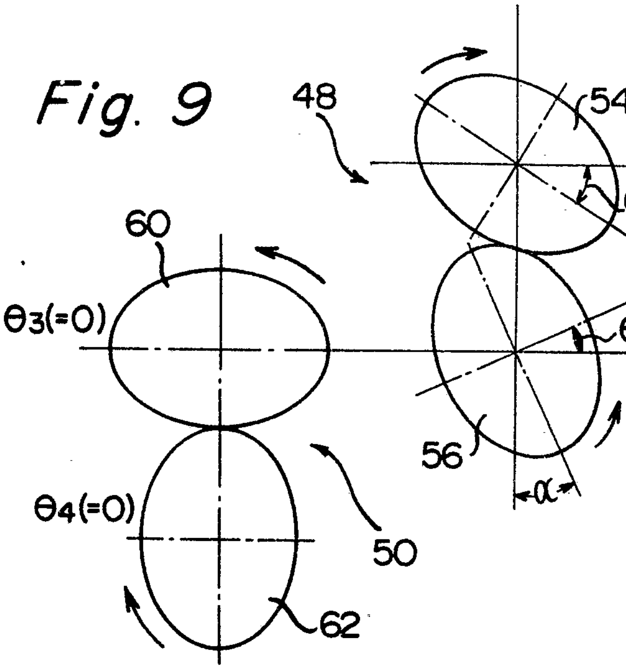


Fig. 8

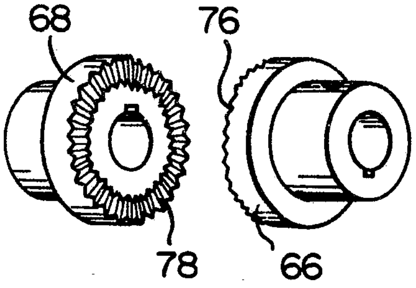


Fig. 11

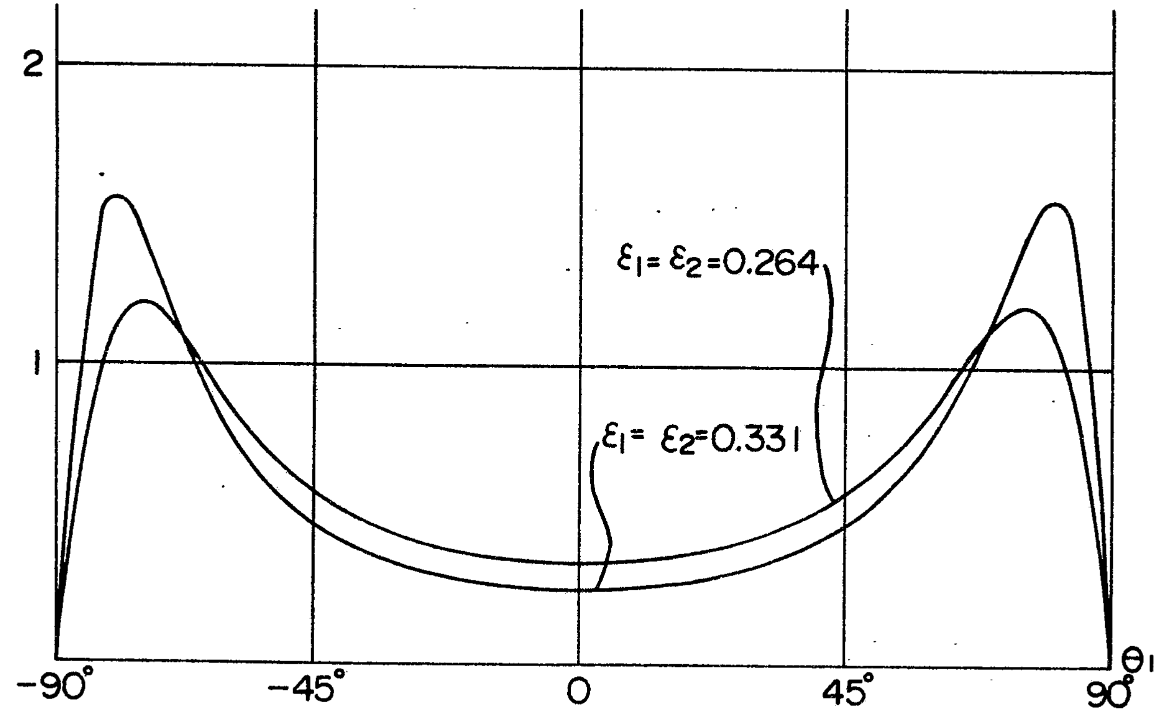
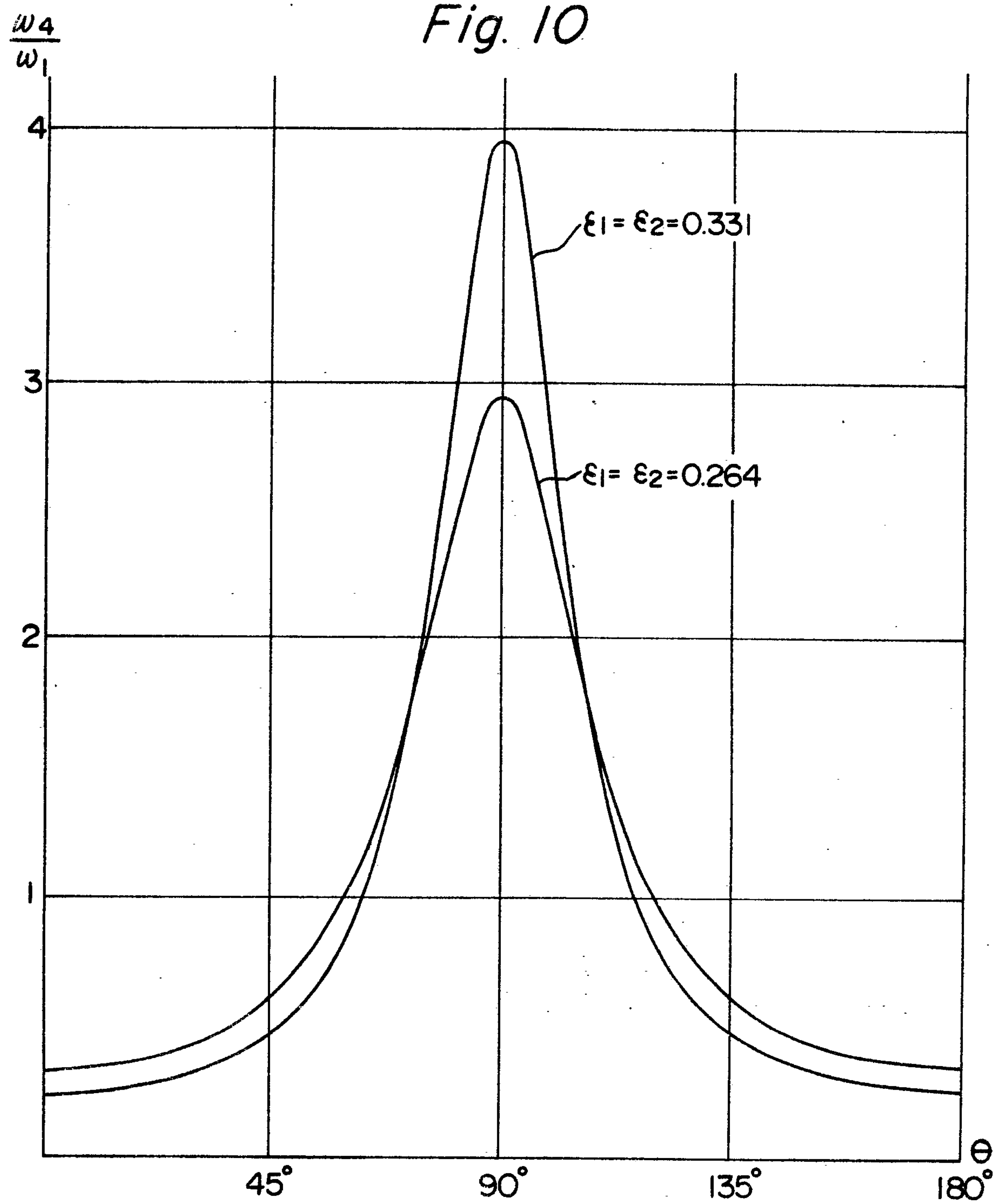


Fig. 10


$\frac{\omega_4}{\omega_1}$
4
3
2
1
$\varepsilon_1 = \varepsilon_2 = 0.331$
$\varepsilon_1 = \varepsilon_2 = 0.264$
θ_1
45°
90°
135°
180°

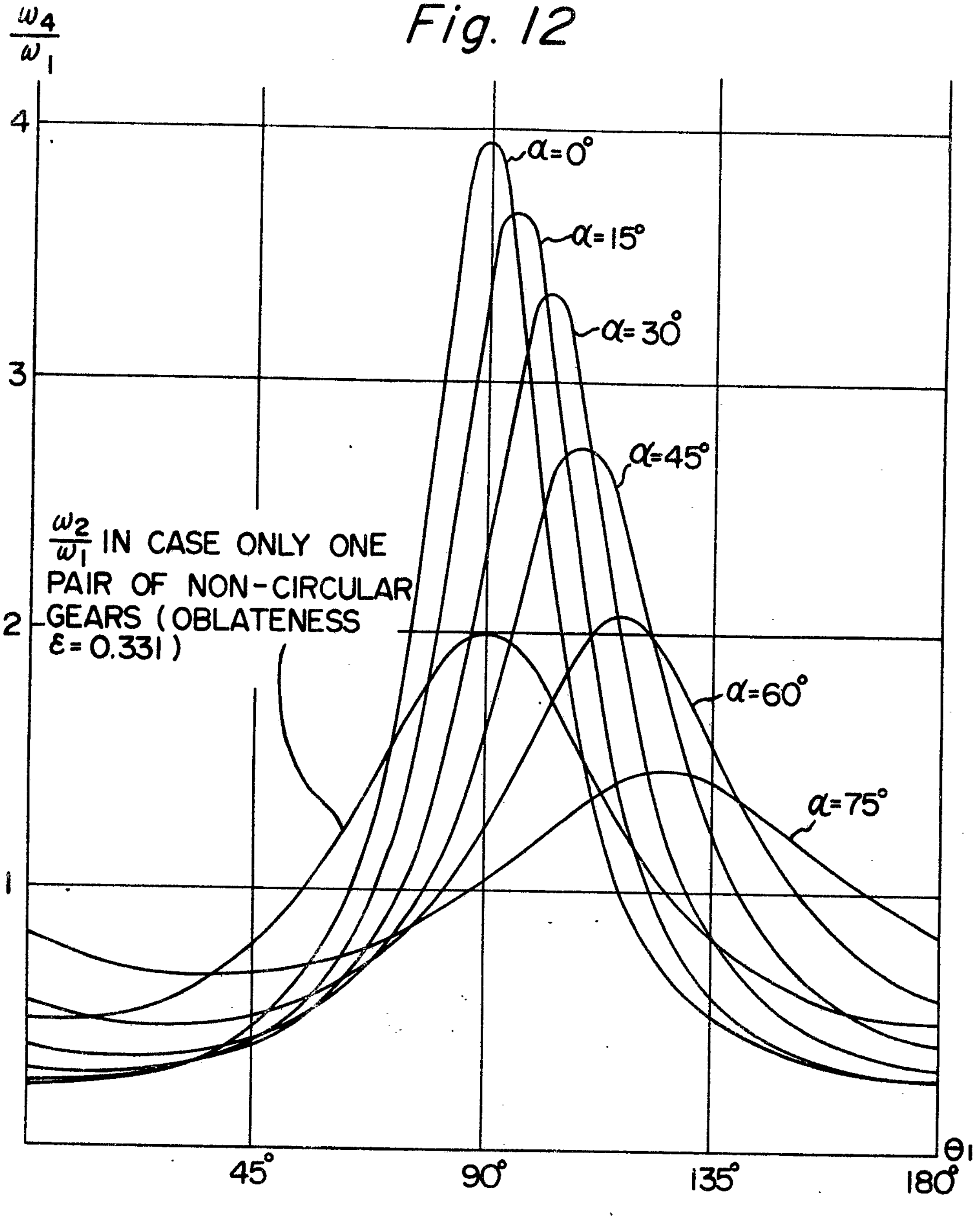


Fig. 12
$\frac{\omega_4}{\omega_1}$
4
3
2
1
α=0°
α=15°
α=30°
α=45°
α=60°
α=75°
$\frac{\omega_2}{\omega_1}$ IN CASE ONLY ONE PAIR OF NON-CIRCULAR GEARS (OBLATENESS ε = 0.331)
45°
90°
135°
180°
θ1

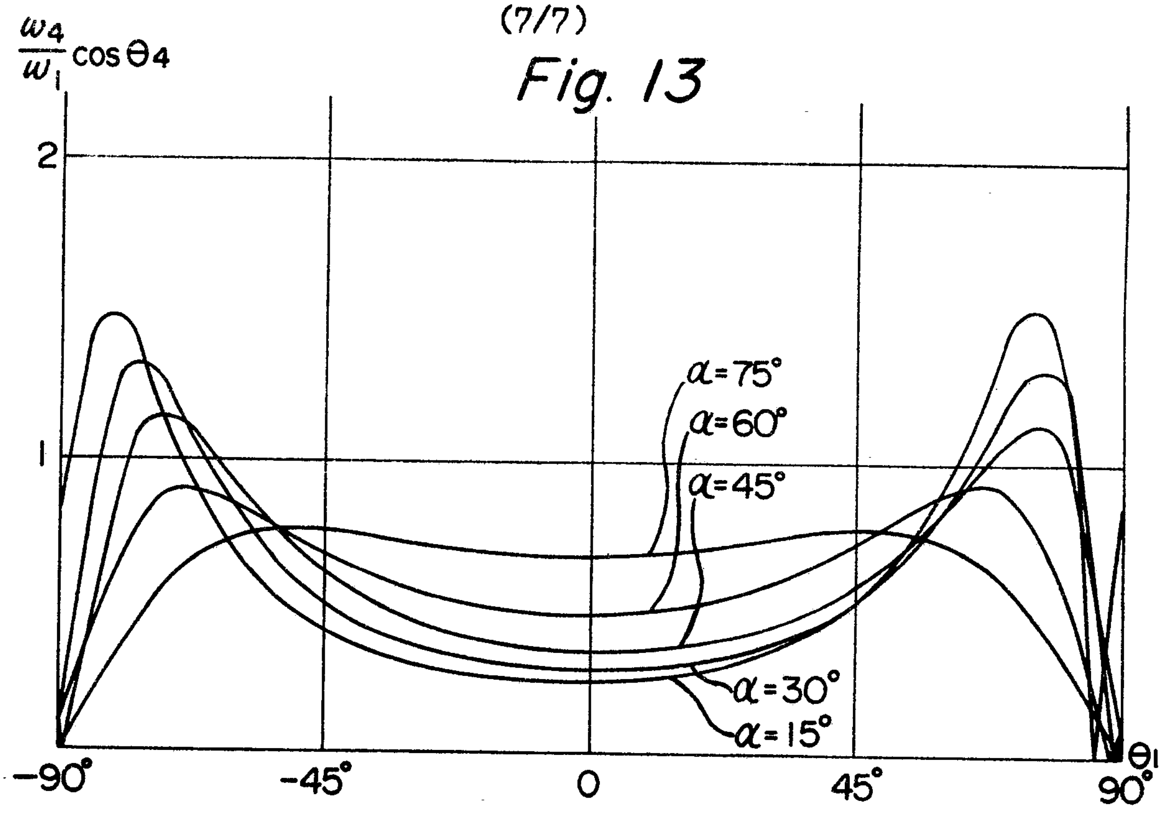


Fig. 13

$\frac{\omega_4}{\omega_1}\cos\theta_4$
2
1
-90°
-45°
0
45°
90°
θ_1
α=75°
α=60°
α=45°
α=30°
α=15°

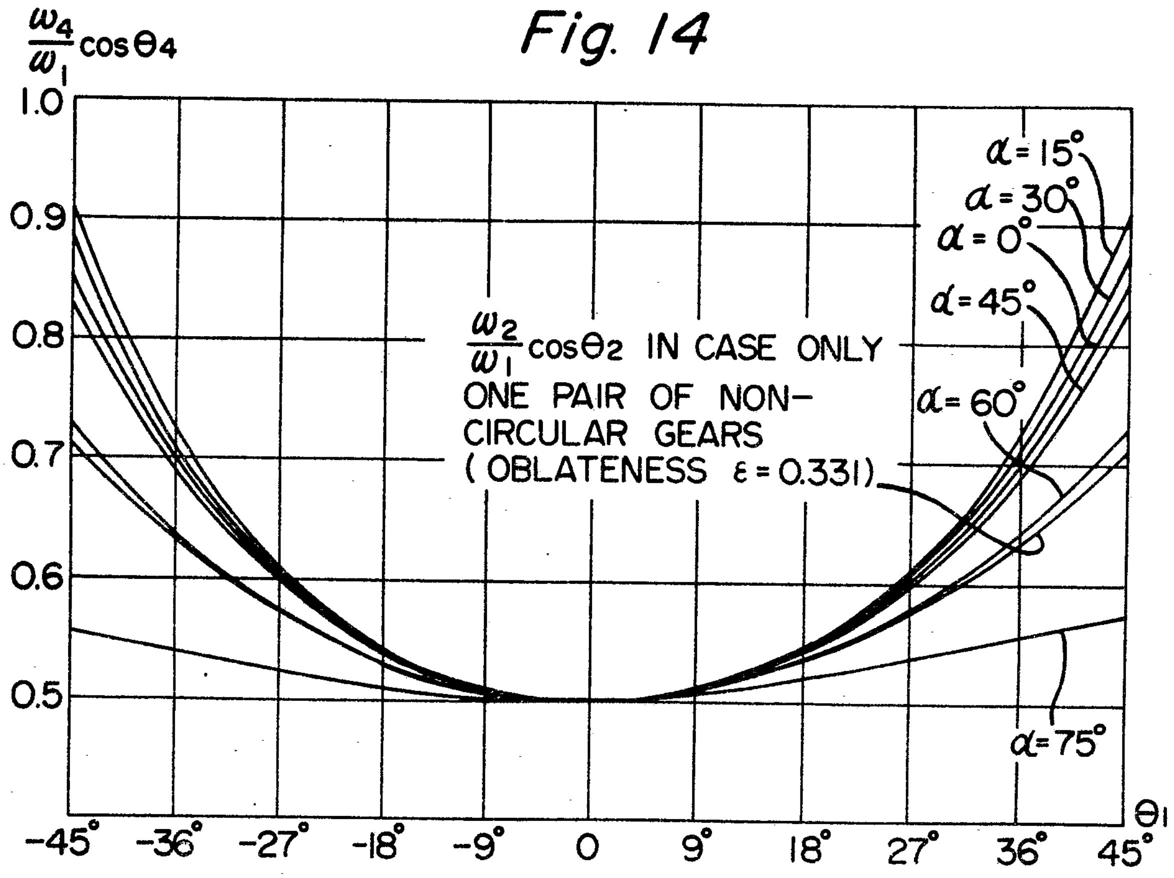


Fig. 14

$\frac{\omega_4}{\omega_1}\cos\theta_4$
1.0
0.9
0.8
0.7
0.6
0.5
-45°
-36°
-27°
-18°
-9°
0
9°
18°
27°
36°
45°
θ_1
α=15°
α=30°
α=0°
α=45°
α=60°
α=75°
$\frac{\omega_2}{\omega_1}\cos\theta_2$ IN CASE ONLY ONE PAIR OF NON-CIRCULAR GEARS (OBLATENESS ε=0.331)

SPECIFICATION

Apparatus for Dispensing Lining Material into Cap Shells

Field of the Invention

This invention relates to an apparatus for dispensing a lining material into cap shells, and more specifically, to an apparatus for dispensing predetermined quantities of a lining material accurately into cap shells, even in caps of the type in which the height of the skirt is relatively large with respect to the cap diameter (that is, deeply recessed caps).

Description of the Prior Art

There has previously been proposed an apparatus for dispensing predetermined amounts of a lining material into cap shells, including a means for conveying cap shells at predetermined speeds, a means provided above and along a shell conveying passage for extruding predetermined quantities of a lining material through a discharge passage, a cutting blade fitted adjacent to the exit end of the discharge passage rotatably across it for cutting the lining material, and a drive means for rotating the cutting blade in response to the conveyance of the cap shells (see, for example, Japanese Patent Publication No. 20759/67).

The prior art apparatus described above is unsatisfactory when it is applied to deeply recessed caps, because the cutting blade is rotated at a uniform speed and therefore its radially outer extremity collides with the skirt portion of the cap shell.

In order to provide an effective solution to the aforementioned drawback, the inventor of this invention has proposed, and disclosed in his U.S. Patent No. 4,060,053, an apparatus of the type generally described above, including a drive means for rotating the cutting blade at a non-uniform speed in response to the speed of cap shell conveyance in such a manner that the speed of blade rotation gradually decreases as the radially outer extremity of the blade approaches the shell conveying passage, and gradually increases as it departs from the passage.

According to this apparatus, collision between the radially outer extremity of the cutting blade and the skirt portion of even a deeply recessed cap shell can be completely avoided as described in detail in the foregoing U.S. Patent No. 4,060,053. Further, a component, in the direction of cap shell conveyance, of the speed of movement of the radially outer extremity of the cutting blade leaving a predetermined position in a cap shell after applying a predetermined quantity of a lining material to that position, can be made substantially equal to the speed of movement of the cap shells to thereby prevent displacement of the lining material from that predetermined position to which it has been applied.

The drive means for rotating the cutting blade at a non-uniform speed as desired comprises a source of driving power, such as an electric motor, rotating at a predetermined constant speed, and a transmission means for converting the output rotation of the driving source to rotation at a non-uniform speed and transmitting it to the cutting blade, as is disclosed in the above-cited U.S. Patent No. 4,060,053. The transmission means preferably includes a pair of non-circular gears. It is also possible to use a pair of eccentric gears, or a special link or cam mechanism, in place of the non-circular gears, but the use of eccentric gears is not very advantageous because they do not lend themselves to rotation at high speed due to their eccentrical mounting with respect to the axis of rotation resulting in localization of gyrating mass, while the use of a special link or cam mechanism is disadvantageous because of its extremely complicated construction and high cost.

In the event a pair of non-circular gears are used to convert uniform-speed rotation to rotation at a non-uniform speed, the magnitude of variations in the non-uniform speed of rotation thereby obtained (i.e., the pattern of the non-uniform speed rotation to which the uniform speed rotation is converted) depends on the degree of oblateness, ε, of the non-circular gears employed [ε=(long diameter-short diameter)/(long diameter+short diameter)]. On the other hand, the apparatus as disclosed in the above-cited U.S. Patent No. 4,060,053 requires the change in the speed of rotation of its cutting blade which depends on the depth of the cap shell into which a linking material is to be dispensed.

The non-circular gears presently available on the market are, however, limited to those having specific degrees of oblateness ε (for example, non-circular gears with a degree of oblateness ε of only 0.088, 0.155, 0.213, 0.264, 0.304 or 0.331 being sold by Kabushiki Kaisha Takeuchi Haguruma Seisakusho, Kanazawa, Ishikawa, Japan), and all non-circular gears having different degrees of oblateness ε require special manufacture to order and are, therefore, more costly. Accordingly, the use of the non-circular gears suited for any desired change in the speed of rotation of the cutting blade results in an extraordinary increase in the overall cost of manufacture of the apparatus.

Moreover, if cap shells having a different depth are to be fed with lining material and thus a different degree of variations is required in the speed of rotation of the cutting blade, it is necessary to change the gears to a different pair of non-circular gears having a different degree of oblateness ε. In order that the apparatus may handle cap shells having a variety of depths, therefore, it is necessary to keep ready for use as many different pairs of non-circular gears having different degrees of oblateness ε which make the apparatus very expensive.

Furthermore, in view of the machine work involved, particularly the cutting of teeth, there is a limitation to the degree of oblateness ε of the non-circular gears which can be manufactured, and at present, it is considered impossible to manufacture any non-circular gears having a degree of oblateness ε over 0.331.

Summary of the Invention

It is a primary object of this invention to provide an apparatus for dispensing a lining material into cap shells which is provided with a transmission means capable of adjusting appropriately the degree of variation in the speed of rotation of the cutting blade, without involving any appreciable increase in cost.

As the result of his energetical research on the variation which can be effected in the speed of rotation by using non-circular gears, the inventor of this invention has found that if at least two pairs of non-circular gears are used and the relative angle between the two pairs of non-circular gears is changed, it is possible to alter the degree of variation in the angular speed of an output shaft with respect to an input shaft which is rotated at a uniform angular speed, so that if a transmission means for drivingly connecting a source of driving power to a cutting blade includes at least two pairs of non-circular gears disposed with an adjustable relative angle therebetween, it is possible to adjust the degree of variation in the speed of rotation of the cutting blade appropriately as desired, without involving any appreciable increase in cost. He has also learned that the use of such a transmission means permits rotation of the cutting blade at a non-uniform speed with a larger degree of variation, as well as with a smaller degree of variation, than that which is obtained by using only one pair of non-circular gears, so that the cutting blade can be rotated at a non-uniform speed varying in any desired pattern without being limited to the degree of variation which may be obtained by using a single pair of non-circular gears having the maximum possible degree of oblateness ε.

Thus, according, to this invention, there is provided an apparatus for dispensing a lining material into cap shells, comprising a cap shell conveying means for conveying the cap shells at a predetermined speed, an extruding means provided along and above a cap shell conveying passage for extruding a predetermined quantity of the lining material through a discharge passage, a cutting blade mounted adjacent the exit end of the discharge passage rotatably across it for cutting the lining material, a source of driving power, and a transmission means for drivingly connecting the source of driving power to the cutting blade, characterized in that the transmission means includes at least two pairs of non-circular gears disposed angularly relative to each other and that the relative angle between those two pairs of non-circular gears is adjustable.

According to a preferred embodiment of the apparatus of this invention, the output shaft of one of the two pairs of non-circular gears is connected to the input shaft of the other pair of non-circular gears in such a manner that the relative angle between the two shafts can be altered as desired, and the relative angle between the two pairs of non-circular gears can be easily adjusted by changing the relative angle between the output and input shafts thereof.

Such a connection between the output and input shafts may be advantageously accomplished by employing coupling members fitted to the mutually opposing ends of the two shafts and provided with a plurality of radially disposed engaging grooves in their mutually engaging end surfaces.

Brief Description of the Drawings

Figure 1 is a simplified top plan view of an entire apparatus embodying this invention;

Figure 2 is a fragmentary enlarged side-elevational view showing the lining material dispensing section of the apparatus shown in Figure 1;

Figure 3 is a view illustrating the operation of a pair of non-circular gears;

Figure 4 is a diagram representing the change in the speed of rotation of a cutting blade in case a single pair of non-circular gears are used;

Figure 5 is a diagram representing the change in the component, in the direction of cap shell conveyance, of the speed of rotation of the radially outer extremity of the cutting blade in case a single pair of non-circular gears are used;

Figure 6 is a partly broken-away, enlarged perspective view showing the details of the transmission means employed in the apparatus of Figure 1;

Figure 7 is an enlarged cross-sectional view of the principal part of the transmission means shown in Figure 6;

Figure 8 is an enlarged perspective view of the coupling members employed in the transmission means of Figure 6;

Figure 9 is a view illustrating the operation of two pairs of non-circular gears;

Figure 10 is a diagram representing changes in the speed of rotation of the cutting blade in case two pairs of non-circular gears are used and the relative angle between those two pairs is 0°;

Figure 11 is a diagram representing changes in the component, in the direction of cap sheel conveyance, of the speed of rotation of the radially outer extremity of the cutting blade in case two pairs of non-circular gears are used and the relative angle between those two pairs is 0°;

Figure 12 is a diagram representing changes in the speed of rotation of the cutting blade in case two pairs of non-circular gears are used and the relative angle between those two pairs is altered;

Figure 13 is a diagram representing changes in the component, in the direction of cap shell conveyance, of the speed of rotation of the radially outer extremity of the cutting blade in case two pairs of non-circular gears are used and the relative angle between those two pairs is altered;

Figure 14 is a diagram representing some of the changes shown in Figure 13 which have been converted for the same minimum value (0.5).

Detailed Description of the Preferred Embodiments

This invention will now be described in further detail with reference to the accompanying drawings showing preferred embodiments thereof.

The apparatus of this invention encompasses an improvement in the transmission means for drivingly connected a source of driving power to a cutting blade, and none of its other constituent elements are, in principle, different from their counterparts disclosed in the above-cited U.S. Patent No. 4,060,053, or Japanese Patent Publications No. 5588/66 and No. 20759/67, and U.S. Patent No. 3,782,329. Therefore, these other constituent elements will hereinafter be described only briefly in this specification, while reference should be made to the foregoing patents for any further structural details thereof.

The apparatus of this invention, as shown in Figures 1 and 2, includes a cap shell conveying means 6 for conveying at a predetermined speed cap shells 4 fed through a cap chute 2, an extruding means 8 provided along and above a cap shell conveying passage for melting a predetermined quantity of a lining material under heat and extruding it through a discharge passage, a cutting blade 12 mounted adjacent to the exit end 10 of the discharge passage rotatably across it for cutting the lining material, and a drive means 14 for rotating the cutting blade 12 in response to the travel of the cap shells 4 on the cap shell conveying means 6. An appropriate heater 16 may be provided between the cap chute 2 and the extruding means 8 for heating cap shells 4.

Each cap shell 4, into which a lining material is dispensed by the apparatus of this invention, is then delivered into a molding station 18, where the lining material in the cap shell 4 is molded into a desired shape.

The drive means of the apparatus disclosed in Figure 4 of the above-cited U.S. Patent No. 4,060,053 comprises a source of driving power which is an appropriate rotary driving source such as an electric motor, and a transmission means which drivingly connects the source of driving power to a cutting blade. The transmission means includes a pair of non-circular gears (shown at 31 and 33 in Figure 4 of the above-cited U.S. Patent No. 4,060,053) by which rotation at a uniform speed is converted to rotation at a non-uniform speed. The variation effected by such a pair of non-circular gears in the angular speed of rotation of the cutting blade, i.e., the pattern of the rotation at a non-uniform speed to which the rotation of the input shaft of the pair of non-circular gears driven at a uniform speed is converted under the action of those gears and which is transmitted to the cutting blade, depends on the degree of oblateness ε of the non-circular gears employed. Attention is directed to Figure 3 of the accompanying drawings for consideration of the angular speed ω_2 of a non-circular gear 24 on the output side of a pair 20 of non-circular gears having their oblateness designated as ε when a non-circular gear 22 on the input side is rotated at a uniform angular speed ω_1 by a source of driving power, such as an electric motor.

As is well known to a person of ordinary skill in the art, the angle of rotation θ_2 of the non-circular gear 24 on the output side is represented in relation to the angle of rotation θ_1 of the non-circular gear 22 on the input side, as follows:

$$\theta_2 = \frac{1}{2} \cos^{-1} \frac{(k+\cos 2\theta_1)}{(1+k \cos 2\theta_1)}$$

wherein

$$k = \frac{2\varepsilon}{1+\varepsilon^2}$$

and the angular speed ω_2 of the non-circular gear 24 on the output side has the following relationship to the uniform angular speed ω_1 of the non-circular gear 22 on the input side:

$$\omega_2 = \omega_1 \cdot \frac{\sqrt{1-k^2}}{1+k \cos 2\theta_1}$$

Accordingly, the ratio ω_2/ω_1 of angular speeds of rotation, i.e., the ratio of the angular speed ω_2 of the non-circular gear 24 on the output side to the uniform angular speed ω_1 of the non-circular gear 22 on the input side is represented as follows:

$$\omega_2/\omega_1 = \frac{\sqrt{1-k^2}}{1+k\cos 2\theta_1}$$

Figure 4 is a diagram representing the foregoing ratio ω_2/ω_1 obtained by each of the six pairs of non-circular gears sold by the above-mentioned Kabushiki Kaisha Takeuchi Haguruma Seisakusho and each having a degree of oblateness ε of 0.088, 0.155, 0.213, 0.264, 0.304 or 0.331, hence the variation in the speed of rotation of the cutting blade which can be achieved by each such pair of non-circular gears. As can be seen from Figure 4, if the non-circular gears 20 have a degree of oblateness ε of, for example, 0.331, the angular speed ω_2 of the non-circular gear 24 on the output side, when the non-circular gear 22 on the input side is rotated at a uniform angular speed ω_1, varies from its minimum value equal to 0.5 ω_1 when the angle of rotation θ_1 of the non-circular gear 22 on the input side is 0°, to its maximum value equal to 2 ω_1 when θ_1 is 90°.

As stated above, the cutting blade is rotated at a non-uniform angular speed ω_2 which is equal to

$$\omega_1 \cdot \frac{\sqrt{1-k^2}}{1+k\cos 2\theta_1}$$

when the non-circular gear 22 on the input side is rotated at a uniform angular speed ω_1. In this case, the component, in the direction of cap shell conveyance (shown by an Arrow A in Figure 2), of the speed of rotation of the radially outer extremity of the cutting blade is represented as

$$\frac{\omega_2}{\omega_1}\cos\theta_2.$$

Figure 5 is a diagram representing the aforementioned component

$$\frac{\omega_2}{\omega_1}\cos\theta_2$$

in the case of each pair of non-circular gears having a degree of oblateness ε of 0.088, 0.155, 0.213, 0.264, 0.304 or 0.331. The axis of abscissa in Figure 5 represents the angle of rotation θ_1 of the non-circular gear on the input side, and according to the apparatus disclosed in the above-cited U.S. Patent No. 4,060,053, the cutting blade takes the position in which its radially outer extremity most closely approaches the inside bottom of a cap shell (as shown by solid lines in Figure 5 and indicated at a10 in the above-cited U.S. Patent No. 4,060,053), when the angle θ_1 is 0.

As can readily be understood from a study of Figure 5 of the above-cited U.S. Patent No. 4,060,053 and the description relating thereto, it is necessary to increase the variation in the speed of angular rotation of the cutting blade, as the length of the skirt portion of the cap shell into which a lining material is to be dispensed is enlarged relative to the cap shell diameter, namely, as the depth of the cap shell becomes greater, in order to prevent collision of the radially outer extremity of the cutting blade with the skirt portion of the cap shell. In other words, the effective dispensation of a lining material into a cap shell having a given depth requires rotation of the cutting blade at a non-uniform speed varying beyond a predetermined range of variation which is defined by the depth of the cap shell. Accordingly, in case the pair of non-circular gears 20 shown in Figure 3 are used as the transmission means to rotate the cutting blade at a non-uniform speed, the non-circular gears 20 are required to have a degree of oblateness ε which is greater than a predetermined value defined by the depth of the cap shell. On the other hand, as the non-circular gears 20 employed have a larger degree of oblateness ε with a resultant increase of the variation in the non-uniform speed of angular rotation of the cutting blade, the component

$$\left(\frac{\omega_2}{\omega_1}\cos\theta_2\right)$$

in the direction of cap shell conveyance of the speed of rotation of the radially outer extremity of the cutting blade shows a greater change in a region where the angle of rotation θ_1 of the non-circular gear 22 on the input side approaches 0° and departs therefrom (for example, from −45° to +45°), or in other words, when the radially outer extremity of the cutting blade approaches its closest position to the inside bottom of the cap shell and then moves away therefrom, as is obvious from Figure 5. However, if there is any difference between the component in the direction of cap shell conveyance of the speed of rotation of the radially outer extremity of the cutting blade and the speed of cap shell conveyance when the radially outer extremity of the cutting blade approaches the inside bottom of a cap shell and applies a certain quantity of lining material thereto, any such difference is likely to cause displacement of the lining material from a predetermined position on the inside bottom of the cap shell to which it has been applied, and eventually even outwardly of the cap shell, as is also taught by the above-cited U.S. Patent No. 4,060,053. Therefore, the component

$$\frac{\omega_2}{\omega_1}\cos\theta_2$$

in the direction of cap shell conveyance of the speed of rotation of the radially outer extremity of the cutting blade in the position where it most closely approaches the inside bottom of the cap shell (when θ_1 is 0 in Figure 5) is generally made substantially equal to the speed of cap shell conveyance. This is, however, still unsatisfactory because the radially outer extremity of the cutting blade does not merely act on the lining material on the inside bottom of the cap shell when it is in the closest position thereto, but also when it moves in the vicinity thereof. In order to ensure prevention of displacement of the lining material from a predetermined position on the inside bottom of the cap shell or outwardly therefrom, therefore, it is desirable to keep at a minimum any possible difference between the component in the direction of cap shell conveyance of the speed of rotation of the radially outer extremity of the cutting blade and the speed of cap shell conveyance, not only when the radially outer extremity of the cutting blade is in its position closest to the inside bottom of the cap shell, but also when it is in its vicinity (for example, while θ_1 is between −45° and +45° in Figure 5). This means that as is readily understood from Figure 5, the component

$$\frac{\omega_2}{\omega_1}\cos\theta_2$$

in the direction of cap shell conveyance of the speed of rotation of the radially outer extremity of the cutting blade should preferably be as uniform as possible in a region in which the angle θ_1 is in the neighborhood of 0 (for example, between −45° and +45°) in Figure 5, and therefore, that if a pair of non-circular gears 20 as shown in Figure 3 are used to rotate the cutting blade at a non-uniform speed, it is desirable to use a pair of non-circular gears 20 having a smaller degree of oblateness ε.

It will be noted from the foregoing that if such a pair of non-circular gears 20 to by used differs the cutting blade at a non-uniform speed, it is important to use a pair of non-circular gears which fulfill the following two requirements most satisfactorily:

(a) To have a degree of oblateness ε which is larger than the value defined by the depth of a cap shell, in order to prevent collision of the radially outer extremity of the cutting blade with the skirt portion of the cap shell; and

(b) To have a minimum possible degree of oblateness ε in order to minimize the variation in the component in the direction of cap shell conveyance of the speed of rotation of the radially outer extremity of the cutting blade during the period when it approaches its closest position to the inside bottom of the cap shell and then moves away therefrom, provided, however, that the requirement (a) above should be satisfied.

Accordingly, the optimum degree of oblateness ε of the non-circular gears 20 to be used differs with the depth of the cap shell into which a lining material is to be dispensed.

As hereinbefore stated, however, only several types of non-circular gears having specific degrees of oblateness ε are presently available on the market; any other non-circular gears require special manufacture with a resultant extra-ordinary increase in cost. It is also necessary to keep a great many non-circular gears having various degrees of oblateness ε in order to handle cap shells having various depths. Further, as it is presently considered impossible to manufacture any non-circular gear having a degree of oblateness ε exceeding 0.331, there is no single pair of non-circular gears satisfying the requirement (a) above for handling a cap shell having a depth which is greater than a certain limited value.

This invention provides a solution to the aforementioned problems by using for converting uniform speed rotation to rotation at a non-uniform speed and transmitting it to the cutting blade a transmission means including at least two pairs of non-circular gears so disposed as to present a freely adjustable relative angle therebetween.

Reference is now made to Figure 6 for describing a preferred embodiment of this invention. A transmission means generally indicated at 26 includes a speed reduction mechanism 28, such as a reduction gear box, having an input shaft connected to an output shaft of an appropriate source of driving power, such as an electric motor (not shown). The speed reduction mechanism 28 has a first output shaft 32 for rotating a turret 30 on the conveying means 6 for conveying cap shells at a predetermined speed, and a second output shaft 34 for rotating the cutting blade 12.

A gear 36 is fixed to the first output shaft 32 of the speed reduction mechanism 28 and meshes with a gear 38 mounted for rotation in unison with the turret 30. Thus, the turret 30 on the conveying means 6 is rotated at predetermined speed in the direction of an arrow B by the source of driving power through the first output shaft 32 of the speed reduction mechanism 28, the gear 36 and the gear 38.

A timing pulley 40 is secured to the second output shaft 34 of the speed reduction mechanism 28. The timing pulley 40 is drivingly connected by a timing belt 42 to a timing pulley 46 which is in turn secured to one end of a shaft 44 rotatably supported by a suitable bearing means (not shown). The shaft 44 is drivingly connected by two pairs of non-circular gears 48 and 50 as will hereinafter be described in detail, to a cutting blade support shaft 52 rotatably supported by a suitable bearing means (not shown) and on one end of which the cutting blade 12 is mounted. Thus, the cutting blade support shaft 52 and the cutting blade 12 mounted thereon are rotated by the source of driving power in the direction of an arrow C through the second output shaft 34 of the speed reduction mechanism 28, the timing pulley 40, the timing belt 42, the timing pulley 46 and the two pairs of non-circular gears 48 and 50.

Detailed description will now be given of the two pairs of non-circular geras 48 and 50 with reference to Figures 7 and 8, as well as Figure 6. A first pair of non-circular gears 48 consists of two mutually engaging non-circular gears (having an equal degree of oblateness ε). i.e., a non-circular gear 54 on the input side and a non-circular gear 56 on the output side. The non-circular gear 54 on the input side is secured to the other end of the shaft 44 to the one end of which the timing pulley 46 is secured, and adapted for rotation with the timing pulley 46 and the shaft 44. The non-circular gear 56 on the output side is mounted on one end of a shaft 58 rotatably supported by a suitable bearing means (not shown). A second pair of non-circular gears 50 likewise consists of two mutually engaging non-circular gears (having an equal degree of oblateness ε), i.e., a non-circular gear 60 on the input side and a non-circular gear 62 on the output side. The non-circular gear 60 on the input side is mounted on one end of a shaft 64 rotatably supported by an appropriate bearing means (not shown) and axially aligned with the shaft 58 on which the non-circular gear 56 on the output side of the first pair of non-circular gears 48 is mounted. The non-circular gear 62 on the output side is mounted on the other end of the cutting blade support shaft 52 to the one end of which the cutting blade 12 is mounted.

In the transmission means 26 of the apparatus according to this invention, it is important to ensure adjustability of the relative angle α between the first and second pairs of non-circular gears 48 and 50, i.e., the angle α defined between the major axis 56*a* of the non-circular gear 56 on the output side of the first pair of non-circular gears 48 and the minor axis 60*b* of the non-circular gear 60 on the input side of the second pair of non-circular gears 50. In order to make adjustable the relative angle α between the first and second pairs of non-circular gears 48 and 50, it is, for example, possible to connect the shaft 58 forming an output shaft for the first pair of non-circular gears 48 and the shaft 64 forming an input shaft for the second pair of non-circular gears 50 in such a manner that the relative angle between the two shafts can be changed as desired. In the embodiment shown in the drawings, the shafts 58 and 64 are connected with each other by a pair of coupling members 66 and 68 best shown in Figure 8 and attached to the mutually opposing ends of the shafts 58 and 64, respectively. The coupling member 66 and 68 are attached to the shafts 58 and 64, respectively, by keys 70 and 72 in such a manner that each of them may rotate in unison with the shaft 58 or 64 without undergoing any rotation relative thereto. At least one of the coupling members 66 and 68 (the coupling member 66 in the embodiment shown) is mounted movably, as desired, along the longitudinal axis of the shaft to which it is attached. In the embodiment shown, the coupling member 66 is mounted movably along the axis of the shaft 58 and releasably fixed in a desired position along the shaft 58 by an appropriate lock means 74. The mutually engaging end surfaces of the coupling members 66 and 68 are each formed with a plurality of radially disposed grooves 76 and 78 which are engaged with each other to connect the coupling members 66 and 68 to thereby drivingly connect the output shaft 58 of the first pair of non-circular gears 48 with the input shaft 64 of the second pair of non-circular gears 50. In order to change the relative angle between the shafts 58 and 60 to adjust the relative angle α between the first and second pairs of non-circular gears 48 and 50, the lock means 74 is first removed to move the coupling member 66 along the shaft 58 to disengage the coupling member 66 from the coupling member 68, and the coupling member 66 is rotated about its own axis by a desired angle to thereby rotate the shaft 58 and hence the first pair of non-circular gears 48, and then, the coupling member 66 is moved back along the shaft 58 toward the coupling member 68, engaged therewith again and locked to the shaft 58 again by the lock means 74.

The adjustability of the relative angle α between the first and second pairs of non-circular gears 48 and 50 may be accomplished in another way without making the relative angle between the two separate shafts 58 and 64 adjustable. For example, it is possible to form the output shaft 58 and the input shaft 64 integrally or as a single shaft and mount at least either the non-circular gear 56 on the output side of the first pair of non-circular gears 48 or the non-circular gear 60 on the input side of the second pair of non-circular gears 50 in such a manner that its angle relative to the integrally formed shafts 58 and 64 may be varied as desired.

Description will now be made of how the first and second pairs of non-circular gears 48 and 50 as hereinabove described will act to convert the rotation at a uniform speed of the shaft 44 defining an input shaft for the first pair of non-circular gears 48 to rotation at a non-uniform speed to transmit the same to the cutting blade 12 through the cutting blade support shaft 52 which is an output shaft for the second pair of non-circular gears 50, and how such a non-uniform speed of rotation will vary with the relative angle α between the first and second pairs of non-circular gears 48 and 50.

Attention is first directed to Figure 9 for discussion of the case in which the first and second pairs of non-circular gears 48 and 50 are disposed with a relative angle α of 0° therebetween. As is apparent from the equations explained before with reference to Figure 3, the angle of rotation θ_2 of the non-circular gear 56 on the output side of the first pair of non-circular gears 48 in relation to the angle of rotation θ_1 of the non-circular gear 54 on its input side is

$$\theta_2=\frac{1}{2}\cos^{-1}\frac{(k_1+\cos 2\theta_1)}{(1+k_1\cos 2\theta_1)} \qquad (1)$$

wherein

$$k_1=\frac{2\varepsilon_1}{1+\varepsilon_1^2}$$

and the angular speed ω_2 of the non-circular gear 56 on the output side has the following relationship to the uniform angular speed ω_1 of the non-circular gear 54 on the input side:

$$\omega_2=\omega_1\frac{\sqrt{1-k_1^2}}{1+k_1\cos 2\theta_1} \qquad (2)$$

Likewise, the angle of rotation θ_4 of the non-circular gear 62 on the output side of the second pair of non-circular gears 50 has the following relationship to the angle of rotation θ_3 of the non-circular gear 60 on its input side:

$$\theta_4=\frac{1}{2}\cos^{-1}\frac{k_2+\cos 2\theta_3)}{(1+k_2\cos 2\theta_3)} \qquad (3)$$

wherein

$$k_2=\frac{2\varepsilon_2}{1+\varepsilon_2^2}$$

and the angular speed ω_4 of the non-circular gear 62 on the output side is represented as

$$\omega_4=\omega_3\frac{\sqrt{1-k_2^2}}{1+k_2\cos 2\theta_3} \qquad (4)$$

in relation to the angular speed ω_3 of the non-circular gear 60 on the input side.

The following relationships exist:

$$\theta_2=\theta_3 \qquad (5)$$

$$\omega_2=\omega_3 \qquad (6)$$

because the non-circular gear 56 on the output side of the first pair of non-circular gears 48 and the non-circular gear 60 on the input side of the second pair of non-circular gears 50 are connected by the shafts 58 and 64, and the relative angle α therebetween is 0°.

If for simplifying the calculations it is assumed that all of the first and second pairs of non-circular gears 48 and 50 have an equal degree of oblateness ε (i.e., the oblateness ε_1 of the first pair of non-circular gears 48=the oblateness ε_2 of the second pair of non-circular gears 50=ε, hence $k_1=k_2=k$), the following equation is derived from the equations (1), (3) and (5) above to represent the angle of rotation θ_4 of the non-circular gear 62 on the output side of the second pair of non-circular gears 50 in relation to the angle of rotation θ_1 of the non-circular gear 54 on the input side of the first pair of non-circular gears 48:

$$\theta_4=\frac{1}{2}\cos^{-1}\frac{(2k+(k^2+1)\cos 2\theta_1)}{(1+k^2+2k\cos 2\theta_1)} \qquad (7)$$

Likewise, the following equation is derived from the equations (2), (4) and (6) above to represent the angular speed ω_4 of the non-circular gear 62 on the output side of the second pair of non-circular gears 50 in relation to the uniform angular speed ω_1 of the non-circular gear 54 on the input side of the first pair of non-circular gears 48:

$$\omega_4=\omega_1\frac{1-k^2}{(1+k\cos 2\theta_1)(1+k\cos 2\theta_3)} \tag{8}$$

Accordingly, the ratio of the angular speed ω_4 of the non-circular gear 62 on the output side of the second pair of non-circular gears 50 to the uniform angular speed ω_1 of the non-circular gear 54 on the input side of the first pair of non-circular gears 48, which represents the variation in the speed of rotation of the cutting blade 12, is represented as follows:

$$\frac{\omega_4}{\omega_1}=\frac{1-k^2}{(1+k\cos 2\theta_1)(1+k\cos 2\theta_3)} \tag{9}$$

Figure 10 is a graph showing the aforementioned ratio,

$$\frac{\omega_4}{\omega_1},$$

of angular speeds of rotation in each of the cases in which all of the first and second pairs of non-circular gears 48 and 50 have an equal degree of oblateness ε of 0.331 ($\varepsilon_1=\varepsilon_2=\varepsilon=0.331$) and 0.264 ($\varepsilon_1=\varepsilon_2=\varepsilon=0.264$). In other words, if the input shaft 44 for the first pair of non-circular gears 48 is rotated at a uniform angular speed ω_1, the cutting blade 12 is rotated at a non-uniform speed varying as shown in Figure 10 in each of the cases represented therein. Figure 11 shows the component,

$$\frac{\omega_4}{\omega_1}\cos\theta_4,$$

in the direction of cap shell conveyance of the speed of rotation of the radially outer extremity of the cutting blade 12 in each of the cases shown in Figure 10.

It will be understood, from a comparison of Figures 10 and 11 with Figures 4 and 5, that the use of two pairs of non-circular gears 48 and 50 disposed with a relative angle α of 0° therebetween can produce a considerable larger variation in the speed of rotation of the cutting blade 12, and particularly a greater change in the speed of rotation of the radially outer extremity of the cutting blade 12 in the direction of cap shell conveyance during the period when it approaches its position closest to the inside bottom of a cap shell 4 ($\theta_1=0$) and then moves away therefrom (for example, when θ_1 is between $-45°$ and $+45°$), than those which can be obtained by the use of only a single pair of non-circular gears having an equal degree of oblateness ε.

Referring to Figure 9 again, consideration will now be given to the effect of change in the relative angle α between the first and second pairs of non-circular gears 48 and 50.

In view of the equations (1) and (3) above, and as $\theta_3=\theta_2-\alpha$, the relationship of the angle of rotation θ_4 of the non-circular gear 62 on the output side of the second pair of non-circular gears 50 to the angle of rotation θ_1 of the non-circular gear 54 on the input side of the first pair of non-circular gears 48 is represented as follows:

$$\theta_4=\frac{1}{2}\cos^{-1}\frac{(k+\cos 2\theta_3)}{(1+k\cos 2\theta_3)} \tag{10}$$

wherein

$$\theta_3=\frac{1}{2}\cos^{-1}\frac{(k+\cos 2\theta_1)}{(1+k\cos 2\theta_1)}-\alpha.$$

Likewise, in view of the equations (2) and (4), and as $\omega_2=\omega_3$, the relationship of the angular speed ω_4 of the non-circular gear 62 on the output side of the second pair of non-circular gears 50 to the uniform angular speed ω_1 of the non-circular gear 54 on the input side of the first pair of non-circular gears 48 is represented as follows:

$$\omega_4=\omega_1\frac{1-k^2}{(1+k\cos 2\theta_1)(1+k\cos 2\theta_3)} \quad (11)$$

wherein

$$\theta_3=\frac{1}{2}\cos^{-1}\frac{(k+\cos 2\theta_1)}{(1+k\cos 2\theta_1)}-\alpha.$$

Accordingly, the ratio of angular speeds of rotation,

$$\frac{\omega_4}{\omega_1},$$

i.e., the ratio of the angular speed ω_4 of the non-circular gear 62 on the output side of the second pair of non-circular gears 50 to the uniform angular speed ω_1 of the non-circular gear 54 on the input side of the first pair of non-circular gears 48 is represented as follows:

$$\frac{\omega_4}{\omega_1}=\frac{1-k^2}{(1+k\cos 2\theta_1)(1+k\cos 2\theta_3)} \quad (12)$$

wherein

$$\theta_3=\frac{1}{2}\cos^{-1}\frac{(k+\cos 2\theta_1)}{(1+k\cos 2\theta_1)}-\alpha.$$

Figure 12 is a graph showing the ratio of angular speeds of rotation,

$$\frac{\omega_4}{\omega_1},$$

obtained in each of the cases in which all of the first and second pairs of non-circular gears 48 and 50 have the equal degree of oblateness ε of 0.331 (i.e., $\varepsilon_2=\varepsilon_1=\varepsilon=0.331$) and the relative angle α between the two pairs of non-circular gears is 15°, 30°, 45°, 60° and 75°. In case the angle α is 90°, it will be noted that the conversion of the speed effected by the first pair of non-circular gears 48 is totally offset by the conversion by the second pair of non-circular gears 50 and the relationship of

$$\frac{\omega_4}{\omega_1}=1$$

is established, resulting in the rotation of the cutting blade 12 at a uniform speed which is equal to the speed of rotation of the input shaft 44 for the first pair of non-circular gears 48. Figure 12 further shows for the purpose of comparison the ratio

$$\frac{\omega_4}{\omega_1}$$

obtained when the angle α is 0°, and the ratio

$$\frac{\omega_2}{\omega_1}$$

obtained when only one pair of non-circular gears having a degree of oblateness ε of 0.331 is used.

Figure 13 is a graph showing the component,

$$\frac{\omega_4}{\omega_1}$$

$\cos\theta_4$, in the direction of cap shell conveyance of the speed of rotation of the radially outer extremity of the cutting blade 12 in each of the cases in which all of the first and second pairs of non-circular gears

48 and 50 have an equal degree of oblateness ε of 0.331 (i.e., $\varepsilon_1=\varepsilon_2=\varepsilon=0.331$) and the relative angle α therebetween is 15°, 30°, 45°, 60° and 75°.

Figure 14 is a graph reproducing a part of Figure 13 on a larger scale by converting the changes in the component of speed so that the minimum value of the component

$$\frac{\omega_4}{\omega_1}\cos\theta_4$$

is brought to 0.5 in all the cases represented in Figure 13, for the purpose of facilitating comparison of the variations obtained in the component in the direction of cap shell conveyance of the speed of rotation of the radially outer extremity of the cutting blade 12 during the period when it approaches its lowermost position (i.e., when $\theta_1=0°$) closest to the inside bottom of a cap shell 4 and then moves away therefrom (for example, when θ_1 is between −45° and +45°, in the case of Figure 14). Figure 14 further includes for the purpose of comparison two additional curves showing respectively the components

$$\frac{\omega_4}{\omega_1}\cos\theta_4$$

and

$$\frac{\omega_2}{\omega_1}\cos\theta_2$$

in the direction of cap shell conveyance of the speed of rotation of the radially outer extremity of the cutting blade 12 when the angle α is 0°, and when only one pair of non-circular gears having a degree of oblateness ε of 0.331 are used.

It will be obvious from Figure 12 that as the aforementioned relative angle α is gradually increased from 0°, the magnetude of the variation in the angular speed ω_4 of the cutting blade 12 in relation to the uniform angular speed ω_1 of the input shaft 44 for the first pair of non-circular gears 48 shows a gradual decrease until it becomes substantially equal to that obtained by using only one pair of non-circular gears having a degree of oblateness ε of 0.331 when the angle α is approximately 60°, and that with a further increase of the angle α beyond 60°, the aforementioned manmagnitude is further reduced and becomes smaller than that obtained by a single pair of non-circular gears having a degree of oblateness ε of 0.331, until eventually when the angle α becomes 90°, the angular speed ω_4 of the cutting blade 12 ceases to vary in relation to the uniform angular speed ω_1 of the input shaft 44 for the first pair of non-circular gears 48 (i.e.,

$$\frac{\omega_4}{\omega_1}=1),$$

resulting in rotation at a uniform speed of the cutting blade 12. According to the apparatus of this invention, therefore, it is possible to adjust the magnitude of variation in the angular speed ω_4 of the cutting blade 12 as desired in the range between a very large variation corresponding to the aforementioned relative angle α of 0° and a zero variation (i.e.,

$$\frac{\omega_4}{\omega_1}=1)$$

corresponding to the angle α of 90°, by changing the angle α appropriately between 0° and 90°.

Attention is directed again to Figures 13 and 14 for observation of the variation in the component in the direction of cap shell conveyance of the speed of rotation of the radially outer extremity of the cutting blade 12, corresponding to the change of the relative angle α between 0° and 90°. As is obvious from Figure 14, when the radially outer extremity of the cutting blade 12 approaches its lowermost position (the angle of rotation θ_1 of the input shaft 44 for the first pair of non-circular gears 48 being 0°) closest to the inside bottom of a cap shell 4 and then moves away therefrom (for example, when the angle θ_1 is between −45° and +45°), the variation of the component,

$$\frac{\omega_4}{\omega_1}\cos\theta_4,$$

in the direction of cap shell conveyance of the speed of rotation of the radially outer extremity of the cutting blade 12 is somewhat greater both when the relative angle α is 15° and 30° than when it is 0°, is substantially the same when the angle α is 45° as when it is 0°, and as the angle α is gradually increased over 45°, the aforementioned variation shows a gradual reduction until when the angle α is 60°, it becomes substantially equal to the variation obtained by using only one pair of non-circular gears having a degree of oblateness ε of 0.331, followed by a further reduction with an increase of the angle α beyond 60°. If the angle α reaches 90°, the relationship of

$$\frac{\omega_4}{\omega_1}=1$$

is established, so that the component

$$\frac{\omega_4}{\omega_1}\cos\theta_4$$

in the direction of cap shell conveyance of the speed of rotation of the radially outer extremity of the cutting blade 12 becomes equal to cos θ_4 and shows a special mode of variation which is entirely different from those obtained when the angle α is in the range of $0° \leqq \alpha < 90°$.

In the light of the foregoing observations made with reference to Figures 12 through 14, it is evident that the apparatus of this invention having a transmission means 26 including at least two pairs of non-circular gears such as indicated at 48 and 50, and in which the relative angle α between those two pairs of non-circular gears is adjustable, advantageously permits an appropriate adjustment of the magnitude of variation in the speed of rotation of the cutting blade 12 by altering the aforementioned relative angle α in accordance with the depth of the cap shells 4 into which a lining material is to be dispensed, and more specifically, the rotation of the cutting blade 12 at a non-uniform speed varying in a greater magnitude (in case of $0° \leqq \sigma <$ approximately 60°) or in a smaller magnitude (in case of approximately $60° < \alpha < 90°$) than when only one pair of non-circular gears are used, as the case may be.

While in the embodiment shown the transmission means 26 includes two pairs of non-circular gears 48 and 50, it will be understood that it is equally possible to use three or four or more pairs of non-circular gears in the transmission means 26 in cases, for example, where it may be desired to rotate the cutting blade 12 at a non-uniform speed varying in a still greater magnitude than can be achieved when the relative angle α between the two pairs of non-circular gears 48 and 50 is 0°.

Claims

1. An apparatus for dispensing a lining material into cap shells, comprising a cap shell conveying means for conveying the cap shells at a predetermined speed, an extruding means provided along and above a cap shell conveying passage for extruding a predetermined quantity of the lining material through a discharge passage, a cutting blade mounted adjacent to the exit end of said discharge passage rotatably across it for cutting the lining material, a source of driving power, and a transmission means for drivingly connecting said source of driving power to said cutting blade, characterized in that said transmission means includes at least two pairs of non-circular gears disposed angularly relative to each other and that the relative angle between said two pairs of non-circular gears is adjustable.

2. An apparatus as set forth in claim 1, wherein one of said two pairs of non-circular gears has an output shaft and the other has an input shaft, said output and input shafts being connected to each other in such a manner as to enable alteration of a relative angle therebetween as desired to thereby adjust the relative angle between said two pairs of non-circular gears.

3. An apparatus as set forth in claim 2, further including coupling members for connecting said output and input shafts, said coupling members being attached respectively to mutually opposing ends of said output and input shafts and having mutually engaging end surfaces each provided with a plurality of radially disposed engaging grooves.

4. An apparatus as set forth in any of claims 1—3, wherein the apparatus is constructed substantially in accordance with the apparatus hereinbefore described with reference to the drawings.

5. Caps comprising a lining which has been dispensed into the shell of the cap by means of an apparatus as set forth in any of claims 1—4.

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