

[54] ROTARY BAG MAKING APPARATUS

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83/299, 298, 311, 312, 324; 53/183

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[57]

ABSTRACT

A rotary bag making apparatus of the type used to fabricate bags from a continuous web of thermoplastic film material is described. The apparatus comprises a smooth feed cylinder driven at a constant velocity and adapted to feed the web material past an operating station and a sealing cylinder having a sealing member adapted to engage the web at spaced intervals during each revolution thereof, the web being heat sealed at such spaced locations between the smooth cylinder and the sealing member. Means in the form of non-circular gearing are provided for rotating the sealing cylinder at a constant RPM with a cyclically varying instantaneous angular velocity. The non-circular gearing means rotates the sealing cylinder through a drive shaft and means are provided for adjusting the angular position of the sealing cylinder relative to that drive shaft whereby the instantaneous angular velocity of the sealing member at the moment of sealing engagement with the web may be adjusted. Bag length is adjusted by changing the RPM of the sealing cylinder relative to the smooth feed cylinder, and means are provided for automatically and simultaneously adjusting the angular position of the sealing cylinder on the drive shaft by a proper amount to maintain the velocity of the sealing member equal to the velocity of the web at the moment of engagement between the two.

21 Claims, 6 Drawing Figures

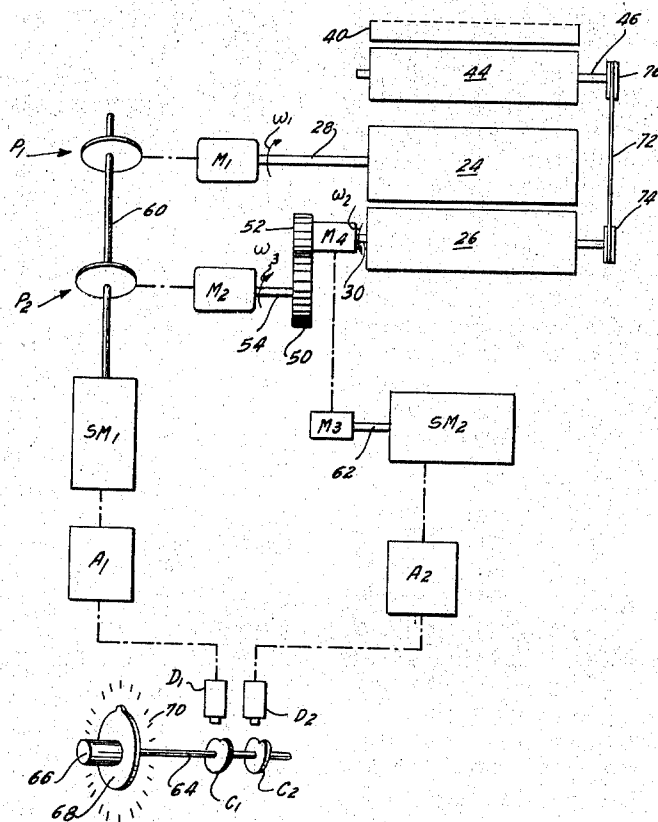


FIG. 3

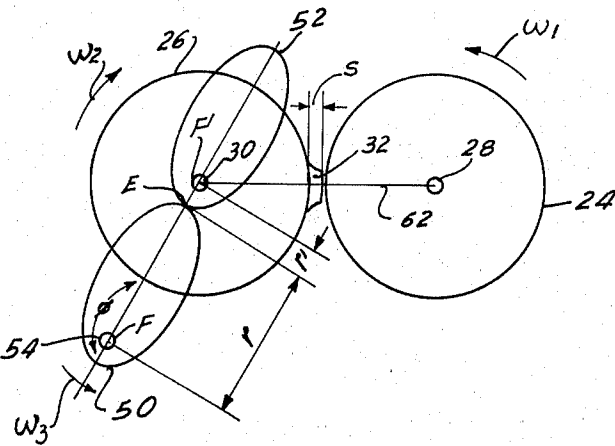
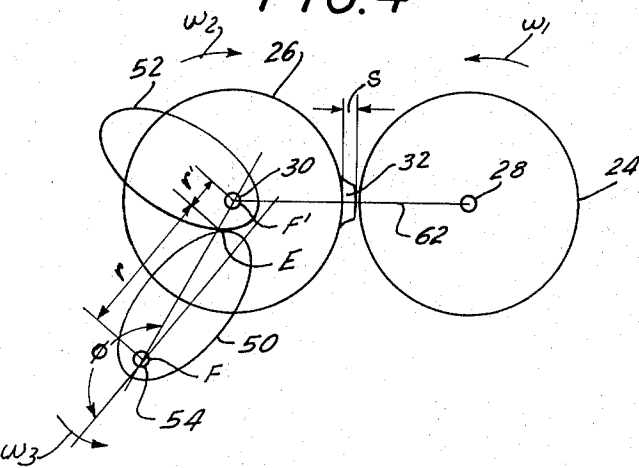


FIG. 4

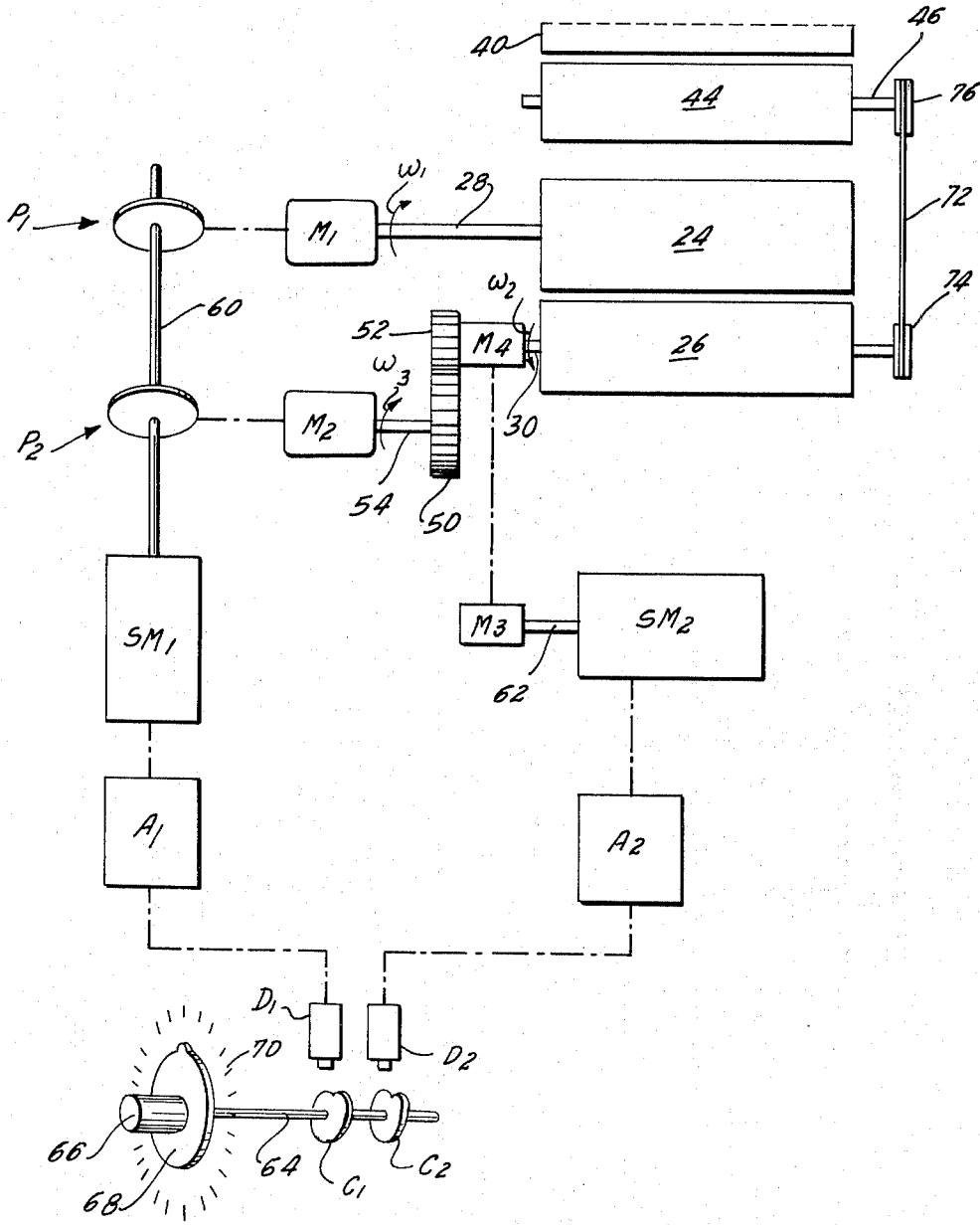


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FIG. 6



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ROTARY BAG MAKING APPARATUS

This invention relates to bag making apparatus and more particularly to a rotary apparatus designed to fabricate bags of thermoplastic film material.

Bags of the type here considered are generally made from a continuous web of double ply thermoplastic film by applying a thermoseal between the two plies and cutting the web at appropriate spaced intervals. The length of the bag is determined by the spacing between such sealing and cutting operations along the web.

In the past, machines designed to perform these operations generally operated on a die cut principle. Thus, the web material was fed to a sealing station positioned along a conveyor line, where a sealing device generally in the form of a pair of heated sealing bars engaged the web to effectively heat seal the two plies together. The web was then moved along the conveyor an appropriate distance, stopped and sealed again at a properly spaced location along the web. The cutting operation was performed by a reciprocating knife edge in the same general fashion, usually simultaneously. The length of bag formed could be varied simply by adjusting the distance the web was transported between successive sealing and cutting operations.

It will be appreciated that the intermittent operation of machines of this type severely limits speed of operation and results in excessive wear on the various reciprocating parts, thereby increasing repair and replacement costs. While output could be increased by utilizing a plurality of sealing and cutting mechanisms properly spaced along the conveyor line, this method significantly increases cost both in the form of equipment and plant space required. Moreover, with such an arrangement bag length could not be adjusted without repositioning the actual sealing and cutting mechanisms. Finally, failure of any one of the devices along the conveyor line would result in down time (during replacement or repair of that device) of the entire machine.

Recently, as a result of the aforementioned drawbacks, apparatus of the rotary type has been developed to perform the bag making operation here under consideration in a rapid and continuous manner. In machines of this type, the web is fed continuously at high speed between a pair of rotary cylinders. One of the cylinders (hereinafter referred to as the sealing cylinder) is provided with a heated sealing bar extending axially along its periphery and adapted to engage the web and press it against the opposing cylinder (hereinafter referred to as the smooth cylinder) in heat sealing relationship, one sealing operation being performed during each complete revolution of the sealing cylinder. The cutting operation is performed synchronously with the sealing operation in a similar fashion by a rotary cutting blade preferably cooperative with a fixed blade, positioned at the other side of the web.

Because the thermoplastic film utilized is easily stretched or torn, it is imperative that the opposing cylinders used for the sealing operation be traveling at precisely the same peripheral speed at the point of sealing engagement. In order to insure that this requirement is met, the opposing rolls are generally precisely mechanically linked to one another by gearing or the like.

While rotary machines of this type are a significant improvement over intermittent bag making apparatus, they have several drawbacks, the most apparent of

which is their inability to adjust the bag length without a change in the size of the cylinders used. Thus, since the web must be fed by the smooth cylinder without slippage or stretching and since the peripheral speed of that cylinder (the linear speed of the web) must be identical to the peripheral speed of the sealing bar on the sealing cylinder, the bag length always equals the circumference of the sealing cylinder regardless of rotary speed. Moreover, since the opposing cylinders are precisely mechanically linked a change in bag length requires a replacement of both cylinders by a different matched pair of cylinders of different dimensions. Thus a different pair of cylinders is required for each bag length and a manufacturer may have to stock ten or fifteen or even more pairs of cylinders to account for the various standard bag lengths. Moreover, the required bag length is often not standard but is determined by the customer in accordance with other considerations. Thus, a manufacturer using equipment of this type will often have to turn down orders because he does not have cylinders properly dimensioned to produce bags of the desired length.

In addition to the expense involved in stocking several pairs of cylinders, there is considerable time and expense involved in changing cylinders for different jobs. Thus, not only must the cylinders themselves be removed and replaced, but also the rotary shafts upon which they are mounted must be moved to the proper spacing to account for the differently dimensioned cylinders. The precise clearance between the sealing bar and the smooth roll surface must then be established and maintained. Moreover, all this must be done while at the same time maintaining the rotary shafts mechanically linked for precise correlation of rotary speed. The above process is not only time consuming but also requires expensive equipment and inevitably leads to inaccuracies.

Finally, while speed of operation is somewhat increased by a continuous rotary mechanism as opposed to intermittent devices, that speed is still limited by the easily stretchable and tearable nature of the film material, particularly at the point of sealing. Thus, high speed rotary sealing may subject the thermoplastic film to excessive stress resulting in seals of low quality and marred appearance.

It is a primary object of the present invention to design a rotary bag making apparatus of the type described having means to adjust the bag length without the requirement of changing any parts.

It is another object of the present invention to design a rotary bag making apparatus adapted to heat seal webs of thermoplastic material between a pair of cylinders rotating at a precisely correlated speed with means to adjust the spacing between successive sealing operations to produce any desired seal spacing within wide limits without affecting the quality or appearance of the seal merely by adjusting the speeds of the rotary driving mechanisms.

It is yet another object of the present invention to provide bag making apparatus of the type described with means to precisely adjust bag length solely by the adjustment of a single knob, which adjustment requires no replacement of parts and may even be carried out during high speed operation.

It is still another object of the present invention to provide bag making apparatus of the type described wherein speed of operation may be significantly in-

creased beyond what has heretofore been considered feasible without any accompanying deterioration in the quality or appearance of the sealing joint.

To these ends, the present invention comprises a bag making apparatus of the rotary type including means to feed a web of two ply thermoplastic film material continuously past a sealing and a cutting station. The sealing means at the sealing station comprises a smooth surfaced cylinder along the periphery of which the web is fed and a matching sealing cylinder provided with an extending sealing projection or bar on the surface thereof. The cylinders are spaced from each other by a clearance only slightly greater than the projecting distance of the sealing bar. Thus, the surface of the sealing cylinder never itself engages the web material. However, each time the sealing bar traverses the clearance between the cylinders, the web is compressed between the heated sealing bar and the smooth cylinder surface, thereby to produce the required sealed joint.

The smooth cylinder over which the web is trained is driven at a constant angular velocity and determines the linear feed velocity of the web. The sealing cylinder is driven through a gear train comprised of non-circular gears. The gear train is here specifically disclosed as a pair of elliptical gears rotatably mounted on shafts positioned at their foci and spaced by a distance equal to their major axes. The driving gear is rotated at a constant angular velocity and accordingly the angular velocity of the driven gear and its associated driven shaft varies during each complete rotation thereof between maximum and minimum values having a 180° phase displacement. The sealing cylinder is operatively connected to the driven shaft for rotation therewith and is rotatably adjustable relative thereto. Accordingly, the sealing bar may be positioned to engage the web at any desired relative position of the meshing elliptical gears (i.e., at any desired instantaneous angular velocity of the sealing cylinder between the minimum and maximum values).

It will be apparent that the length of a bag (i.e., the spacing between successive seals) is equal to the length of web feed in the time it takes for one complete rotation of the sealing cylinder. Since that time interval is the period of rotation of the elliptical gears, the spacing between seals is directly proportional to the angular velocity ratio between the smooth cylinder and the driving elliptical gear. Accordingly, I provide means to vary that angular velocity ratio in accordance with the desired length of bag.

However, since the sealing operation must be accomplished precisely at the moment when the sealing cylinder and smooth cylinder have the same instantaneous angular velocity, the sealing cylinder must be rotatably adjusted relative to the driven shaft to properly position the sealing bar for engagement of the web at the proper angular velocity. The present invention provides such an adjustment mechanism and in accordance with the preferred embodiment here disclosed that mechanism is adapted to automatically rotatably adjust the sealing cylinder in response to a given adjustment of the above noted angular velocity ratio.

Accordingly, the spacing between seals may be conveniently adjusted within limits by a simple speed ratio adjustment while at the same time the sealing bar is rotatably positioned to compensate for the velocity differential between it and the smooth cylinder which

would otherwise occur at the moment of sealing engagement with the web.

To the accomplishment of the above and to such other objects as may hereinafter appear, the present invention relates to high speed rotary bag making apparatus as defined in the appended claims and as described herein with reference to the accompanying drawings in which:

FIG. 1 is a schematic illustration of the bag making apparatus showing the sealing and cutting stations;

FIG. 2 is a schematic illustration of the sealing cylinder and smooth cylinder at the moment of sealing engagement with the elliptical drive gearing superimposed thereon, the sealing operation being accomplished at the minimum angular velocity;

FIG. 3 is a schematic illustration similar to FIG. 2 and showing the sealing engagement of the cylinders at the maximum angular velocity;

FIG. 4 is a schematic illustration similar to FIG. 2 showing the sealing engagement of the cylinders at an arbitrary angular velocity between the minimum and maximum values;

FIG. 5 is a graphical illustration of an ellipse showing the major and minor axes and the ordinate of the focus; and

FIG. 6 is a schematic block diagram illustrating the control mechanisms for varying bag length.

The apparatus of the present invention is designed to operate on a continuously moving web of material at spaced intervals. The invention is here specifically disclosed in connection with the fabrication of bags (commonly known as "poly bags") from a web of thermoplastic features of material. It will be appreciated, however, that the important features of the present invention are applicable to virtually any operation or work performed on a web at spaced intervals in a continuous manner.

Typically, in the fabrication of poly bags a web of two-ply thermoplastic material, such as polyethylene, is provided with narrow sealing joints extending generally transversely across the web and effectively joining the two plies at spaced intervals therealong. The web is then perforated along lines parallel and adjacent to the sealing joints. The web is then separated along the perforations, either automatically, by the manufacturer, or manually, by the ultimate consumer (as in the case of the now popular food storage bags), to form a plurality of bags having sealed bottoms and open tops. The two-ply web may be in the form of a continuous loop or may be pre-sealed along one or more longitudinally extending joints.

The rotary apparatus for performing the above operations is shown schematically in FIG. 1. As there illustrated the web material generally designated 10 is fed to the left in the direction of arrow 12 over an infeed roll 14, past a sealing station generally designated 16 and a cutting station generally designated 18 and thence outwardly in the direction of arrow 20 over an outfeed roll 22. In the case where the bag is to have markings or indicia thereon, the web 10 may be fed to the apparatus directly from the printing station.

The sealing operation is accomplished at sealing station 16 by means of a pair of matched cylinders 24 and 26 rotatably mounted on shafts 28 and 30, respectively. Cylinder 24 (hereinafter referred to as the smooth cylinder) has a smooth outer surface of radius R1 and cylinder 26 (hereinafter referred to as the sealing cylinder)

der) is provided on its outer surface 31 of radius R2 with a sealing projection or bar 32 extending in the axial direction into the plane of the drawing along a generatrix of the cylinder 26 and projecting radially from surface 31 by a distance s. Means (not shown) are provided for heating the sealing bar 32 to a temperature sufficient to effect a good thermoseal.

The web 10 is fed over the smooth cylinder 24 which is in turn rotated through shaft 28 at a constant speed. The web is thus advanced linearly at a constant speed between cylinders 24 and 26. The surface 31 of cylinder 26 is spaced from the surface of cylinder 24 by a distance slightly greater than the projecting width s of the sealing bar 32. Consequently, there is a slight clearance 34 (no direct contact) between the web and the outer surface 31 of sealing cylinder 26. Each time sealing bar 32 comes opposite cylinder 24, the web 10 is compressively engaged between the heated bar 32 and the surface of cylinder 24, thereby to form a heat seal between the two plies extending generally transversely to the direction of web travel.

After the heat seal has been applied at sealing station 16, the web leaves the cylinder 24 and enters the cutting station 18. As illustrated cutting station 18 comprises a pair of spaced rotatable stabilizing rolls 36 and 38 between which a fixed knife blade 40 is mounted. A rotary perforating blade 42 is mounted on a cutting cylinder 44 in opposing relationship with fixed blade 40 and is adapted to cooperate therewith in shearing relationship. As illustrated, the web 10 is fed over stabilizing rolls 36 and 38 and traverses the fixed blade 40. During each complete rotation of cylinder 44 the rotary blade 42 engages the web and cooperates to shear-ingly perforate the web in a direction generally transverse to its direction of travel. The cutting cylinder 44 is driven through a shaft 46 which is mechanically linked, in a manner hereinafter described, to the sealing cylinder such that the web is perforated during each cycle at a location adjacent the sealing joint in the web.

The thus sealed and perforated web is then moved over the outfeed roll 22 and may be conveyed in an appropriate manner to a packing station and/or an automatic separating mechanism in which the individual bags are separated along the perforated lines.

It will be apparent from the foregoing that the spacing between successive sealing joints which in turn determines the length of the bags thus formed is a function of the length of web which traverses the sealing station in the interval between seals. The interval between successive sealing operations is directly proportional to the period of revolution of sealing bar 32. Also, if there is no slippage between the web 10 and the smooth cylinder 24, the length of web feed between seals is directly proportional to the angular velocity of the smooth cylinder 24. Thus the spacing between successive seals is directly proportional to the ratio of the rates of complete rotations of cylinders 24 and 26 or

$$L=K (W1/W2) -$$

(1)

where: L = bag length

(herein used synonymously with seal spacing)

W1 = rate of complete rotations of cylinder 24 (i.e., RPM)

W2 = rate of complete rotations of cylinder 26 (i.e., RPM)

If, as in prior art apparatus, the cylinders 24 and 26 are both driven at constant angular velocity over the rotational cycle, their ratio W1/W2 must be fixed and thus bag length is invariable. This is because it is imperative that the outer surface of sealing bar 32 and the outer surface of cylinder 24 be traveling at precisely the same linear (i.e., tangential) velocity at the moment of sealing engagement with the web 10 to avoid tearing of the web or sliding of the two plies relative to each other. Thus, an increase or decrease in the RPM of one cylinder must of necessity be accompanied by a corresponding increase or decrease in the RPM of the other cylinder. Consequently, these cylinders in prior art systems are generally mechanically linked to insure the required peripheral speed correspondence. Thus, while the speed of operation may be varied, bag length must remain constant. Moreover, output rate is limited by the permissible peripheral speed of the sealing bar at which a good seal may be accomplished.

The present invention overcomes this limitation by providing means for rotating one of the cylinders 24 or 26 at a constant RPM but with an angular velocity which varies between minimum and maximum values during each complete cycle. Expressed mathematically RPM is given by

$$W = \int_0^{2\pi} \frac{w d\phi}{2\pi} \quad (2)$$

where,

w = instantaneous angular velocity

(2)

ϕ = angular displacement

It is possible to adjust the RPM ratio W1/W2 of cylinders 24 and 26 thereby to adjust bag length, while maintaining the instantaneous angular velocity w of the cylinders identical at the point of sealing engagement with the web.

The variable speed drive means as herein specifically disclosed is a non-circular gearing system, although various other eccentric drive systems might be utilized. Moreover, while that gearing system is here shown and described in operative driving relation with the sealing cylinder 26, it might alternatively be utilized to drive the smooth cylinder 24, although this latter arrangement has several drawbacks which will be apparent hereinafter.

As best shown schematically in FIG. 2, the non-circular gearing system employed herein is generally designated 48 and comprises a pair of elliptical gears 50 and 52, gear 50 being the driving gear and gear 52 being the driven gear. In accordance with well known principles of kinematics, the conditions for operative meshing engagement are satisfied when, as shown in FIG. 2, the two elliptical gears are identical and are mounted at one of their foci on shafts, respectively, having a center to center distance equal to their major axes. Accordingly, driving gear 50 is mounted fast on a shaft 54 which is driven at a constant angular velocity in a manner hereinafter described. Driven gear 52 is operatively connected to sealing cylinder 26, as by being mounted fast on the same shaft 30 as that which drives the sealing cylinder 26.

An analysis of the kinematics of the system shown in FIG. 2 requires a brief discussion of the properties of an ellipse. FIG. 5 shows an ellipse having two foci F1 and F2, a major axis $2a$ and a minor axis $2b$, and is defined by the property that the sum of the distances r_1 and r_2 from any point on the circumference to the foci F1 and F2 is equal to the major axis $2a$. The minimum and maximum distances from a focus to the circumference extend along the major axis and are designated c and d respectively.

Referring now to FIG. 2, in order to simplify the analysis it will be assumed that the effective radius of the sealing cylinder (the distance from its center to the outer surface of the sealing bar 32) is equal to the radius of the smooth cylinder 24 or,

$$R2 + s = R1$$

(3)

Thus, since tangential velocity V is given by the equation:

$$V = rw$$

where,

$$r = \text{radius}$$

(3a)

and

$$w = \text{angular velocity}$$

the linear (i.e., tangential) velocities of the outer surface of the sealing bar 32 and the cylinder 24 are equal when the instantaneous angular velocities designated w_1 and w_2 , respectively, of the two cylinders 24 and 26 are equal.

If we now designate the distance from the focal axis F of driving gear 50 to the point of engagement E of the gears as r and the distance between the focal axis F' of the driven gear and the point E as r' then to satisfy the conditions for meshing engagement:

$$w_3 r = w_2 r'$$

(4)

or

$$w_2 = (r/r') w_3$$

(4a)

where,

$$w_2 = \text{angular velocity of shaft 30}$$

$$w_3 = \text{angular velocity of shaft 54}$$

If the gear 50 is driven at a constant angular velocity w_3 , then instantaneous angular velocity of gear 52 and thus of cylinder 26 accordingly varies between a minimum value and a maximum value as follows:

$$(c/d) w_3 \leq w_2 \leq (d/c) w_3$$

(5)

However, it will be appreciated that the RPM of both gears 50 and 52 (the time rate of complete rotations) remains constant. The RPM of cylinder 24, however, may be varied provided the rotative position of sealing bar 32 is adjusted to provide a corresponding angular

velocity of that bar at the point of sealing engagement. Thus, since at the moment of sealing w_2 must be equal w_1 , the RPM of cylinder 24 may be set at a desired value between upper limits such that

$$(c/d) w_3 \leq w_1 \leq (d/c) w_3$$

(6)

Once thus set, the cylinder 26 is rotatably adjusted on the shaft 30 such that sealing engagement of bar 32 occurs at the relative position of gears 50 and 52 where $w_2 = w_1$.

FIG. 2 shows the sealing bar 32 in a position resulting in the minimum angular velocity of the cylinders at the point of engagement. Thus, in the position shown, from equation (4):

$$w_2 = w_1 = (c/d) w_3$$

(7)

FIG. 3 shows the sealing bar 32 at the other extreme position—that is where the sealing engagement occurs at the maximum angular velocity of sealing cylinder 26. Thus again substituting in equation (4):

$$w_2 = w_1 = (d/c) w_3$$

(8)

FIG. 4 shows an intermediate position of sealing bar 32, sealing engagement occurring at a velocity between the minimum and maximum values.

Regardless of the angular position of the sealing bar relative to the gear 52, its period of revolution (or RPM) remains the same. Thus,

$$T_2 = 1/W_2 = 1/W_3$$

(9)

where,

$$W_2 = \text{RPM of shaft 30}$$

$$W_3 = \text{RPM of shaft 54}$$

$$T_2 = \text{period of revolution of sealing bar 32}$$

The distance between successive sealing) gives is given by:

$$L = V_{web} \times T_2$$

(10)

where,

$$V_{web} = \text{linear velocity of the web}$$

Using equations (3a), (9) and (10) and substituting we have:

$$L = (R1 w_1) \times (1/W_3) = (R1 w_1/w_3)$$

(11)

Since w_1 and w_3 are constant, from equation (2):

$$w_1 = 2\pi W_1$$

and

$$w_3 = 2\pi W_3$$

Thus,

$$L = (2\pi R_1 W_1/W_3) = (2\pi R_1 w_1/w_3)$$

(14)

Comparing the above with equation (1), it will be apparent that $K = 2\pi R_1$ = the circumference of cylinder 24.

Theoretically then, the bag length L may be adjusted to any value merely by adjusting the ratio w_1/w_3 . However, as noted above, the ratio w_1/w_3 is limited by the condition that w_1 must equal w_2 at the point of sealing engagement. Thus from equation (6):

$$c/d \leq w_1/w_3 \leq d/c$$

(15) 25

Accordingly, from equation (14) bag length may be varied as follows:

$$2\pi R_1 (c/d) \leq L \leq 2\pi R_1 (d/c)$$

(16)

Thus, by a proper design of the elliptical gears, any desired range of bag lengths may be established.

The adjustment of w_1/w_3 , the angular speed ratio of shafts 28 and 54 within the range defined by equation (15), may be accomplished in a variety of ways. For example, these shafts might have a common drive motor accompanied by adjustable transmission mechanisms capable of establishing a plurality of selected speed ratios for selection of a plurality of predetermined bag lengths. For maximum flexibility, however, it is preferable to have two separate motors driving shafts 28 and 54, respectively, with a continuous speed adjustment mechanism. Such an arrangement is illustrated schematically in FIG. 6. As there shown, shaft 28 is driven by a variable speed motor M1 and shaft 54 is driven by a second variable speed motor M2. Speed adjustment of motors M1 and M2 may be accomplished in a well known manner by potentiometers illustrated schematically and designated P1 and P2, respectively. The speed ratio of motors M1 and M2 might be conveniently adjusted through a common control knob by mounting both potentiometers on a common control shaft 60 in reverse polarity.

It will be recalled, however, that each time the angular speed ratio w_1/w_3 is adjusted, the sealing cylinder 26 must be rotatably adjusted on shaft 30 such that its instantaneous angular velocity w_2 is equal to w_1 at the moment of sealing engagement. This may be accomplished manually each time bag length is varied. However, manual adjustment of this type is time consuming and often not precise. Accordingly, I have devised a mechanism for automatically effecting the required adjustment of cylinder 26 on shaft 30 which must accompany each adjustment of the angular speed ratio. In either case, however, it is necessary to know the relation-

ship between the angular position of sealing bar 32 and the speed ratio w_1/w_3 .

This relationship may be established mathematically by a kinematic analysis using polar coordinates. Referring to FIG. 2, the radius r from a point on one focus to a point on the circumference of an ellipse is given by the equation:

$$r = (\rho/1 + E \cos \phi)$$

10

(17)

where, e is the numerical eccentricity of the ellipse:

$$e = \sqrt{a^2 - b^2}/a$$

(18)

and ρ is the ordinate of the focus (see FIG. 2):

$$\rho = b^2/a$$

(19)

Now it will be apparent that the sum of the radii r and r' is always equal to the major axis $2a$. Thus,

$$r = 2a - r'$$

(20)

substituting:

$$r = 2a - (\rho/1 + E \cos \phi)$$

(21)

and substituting in equation (4a):

$$w_2 = w_3 \times \frac{2a - \frac{\rho}{1 + e \cos \phi}}{\frac{\rho}{1 + e \cos \phi}} \quad (22)$$

The above equation (22) gives us the instantaneous angular velocity of shaft 30 as a function of the angular displacement of elliptical gear 52 (see FIG. 4). Since that velocity, at moment of sealing engagement of bar 22, must be equal to the angular velocity w_1 of cylinder 24, we can calculate the angle ϕ through which the elliptical gears must be rotated in order to satisfy that condition for a given ratio w_1/w_3 . Thus at the moment of sealing engagement:

$$\frac{w_1}{w_3} = \frac{w_2}{w_3} = \frac{2a - \frac{\rho}{1 + e \cos \phi}}{\frac{\rho}{1 + e \cos \phi}} \quad (23)$$

since from equation 14:

$$w_1 w_3 = 2\pi R_1 / L$$

(24)

we have,

$$L = \frac{2\pi R_1 \left(2a - \frac{\rho}{1 + e \cos \phi} \right)}{\frac{\rho}{1 + e \cos \phi}} \quad (25)$$

which gives us the required angular position of the gears at the moment of sealing engagement for a bag length L . The maximum bag length condition occurs when $\phi = 0^\circ$ (FIG. 2) and the minimum bag length condition occurs at $\phi = 180^\circ$ (FIG. 3).

The above mathematical relationship between the bag length L , the speed ratio w_1/w_3 and the angle ϕ may be accurately plotted by known methods and embodied in the automatic control system illustrated in FIG. 6. As there shown the rotation of potentiometer shaft 60 is controlled by a differential transformer D1 through amplifier A1 and servomotor SM1. The angular position of sealing cylinder 26 (sealing bar 32) relative to the gear 52 is controlled by a second differential transformer D2 through amplifier A2, servomotor SM2 and a power selsyn arrangement comprising a control motor M3 driven by servomotor SM2 through a shaft 62 and a controlled motor M4 mechanically linked to cylinder 26 and electrically controlled by motor M3, all in well known manner.

The two differential amplifiers are controlled simultaneously by cams C1 and C2 mounted on a control shaft 64. Cams C1 and C2 are designed in accordance with the relationships established by equations (14) and (25) respectively, establishing bag length L as a function of speed ratio w_1/w_3 and angular position of cylinder 26, respectively. A control knob 66 is provided on one end of shaft 64 together with a pointer 68 and indicator dial 70. The indicator dial may be calibrated directly in terms of bag length. As a result, the operator merely rotates knob 66 to the desired bag length and the speed ratio w_1/w_3 and angle ϕ are automatically adjusted to the proper values.

As schematically illustrated in FIG. 6, the cutting cylinder 44 is drivably linked to the sealing cylinder 26 by means of a belt 72 trained around a pair of pulleys 74 and 76. Pulley 74 is mounted fast on shaft 30 and pulley 76 is mounted fast on shaft 46. The effective radii of the pulleys are established such that the RPM of cutting cylinder 44 is identical to that of sealing cylinder 26 and the cutting position of cylinder 44 is adjusted to correspond with the sealing position of sealing cylinder 26 to provide the desired (usually small) spacing between a sealing joint and a perforation.

The present invention as described herein not only provides increased flexibility and efficiency in automated bag making apparatus but also may provide an increase in output rate with no loss of quality. Thus, it will be appreciated that for a given bag length, the elliptical gears and the smooth cylinder may be designed such that the sealing operation occurs at the minimum angular speed. If the drive mechanisms are now reversed, with the sealing cylinder being driven at a constant angular velocity and the smooth feed cylinder being driven by the elliptical gears, it will be apparent that the average linear speed of the web 10 (i.e., the output) is greater than the instantaneous speed at which sealing occurs. Stated in other terms, output is increased by increasing the feed velocity of the web between sealing operations while maintaining the characteristic of low speed at the instant of seal, thus maximizing seal quality. However, it should be noted that the stretch and tear qualities of the web must be considered in the design of such a system.

It will be appreciated from the foregoing that I have designed and improved apparatus for rapidly and effectively making thermoplastic bags. The apparatus is

characterized by a length adjustment system which is relatively simple and inexpensive in construction and operation and provides enormous flexibility in making bags of any desired length within a wide range. Length adjustment in accordance with my design requires no change of parts and indeed may be accomplished during operation thereby eliminating costly shutdown time.

In addition, the apparatus provides increased accuracy and may be used to significantly increase output while maintaining low speed seal quality.

While only a single preferred embodiment of the present invention has herein been described, it will be apparent that many variations may be made therein, all within the scope of the invention as defined in the following claims.

I claim:

1. A rotary web material working apparatus adapted to operate on web material at spaced intervals therealong comprising an operating station, feed means adapted to feed said web material past said operating station, variable speed web drive means adapted to drive said web feed means at an adjustable speed thereby to adjust the velocity of said web material, operating means comprising an operating member, a variable speed operating member drive means operatively drivingly connected to said operating member for moving same in a cyclical manner at an adjustable frequency, said operating member engaging said web while moving in the direction of web feed once during each operating cycle, adjustable control means operatively connected to said web drive means and to said operating member drive means for simultaneously controlling web speed and operating member frequency and effective to vary the ratio therebetween, and means to vary the instantaneous velocity of said operating member at the moment of engagement with said web material at said operating station, manual adjusting means operatively connected to said control means, to said operating member and to said instantaneous velocity varying means and effective to simultaneously adjust all three in a manner maintaining the velocity of said operating member and said web equal at the moment of engagement between the two, whereby the spacing of said operations on said web material and the speed of operation may be varied without causing slippage between said operating member and said web material or tearing of said web material at said operating station.

2. The apparatus of claim 1, wherein said operating member is adapted to move in a cyclical path engaging said web at a given location on said path during each operating cycle.

3. The apparatus of claim 2, wherein said cyclical path is endless.

4. The apparatus of claim 2, wherein said endless path is generally circular, said operating member being mounted for revolution about a given axis, said frequency varying means comprising means to vary the time rate of complete revolutions of said operating member.

5. The apparatus of claim 3, wherein said operating member drive means comprises a rotary member, means to rotate said rotary member at an angular velocity which varies along the rotary path, and wherein said instantaneous velocity varying means comprise means angularly adjustably mounting said operating

member on said rotary member for movement therewith.

6. The apparatus of claim 2, wherein said instantaneous velocity varying means comprises means to periodically vary the instantaneous velocity of said operating member along said cyclical path during each operating cycle, means to adjust the location along said cyclical path at which said operating member engages said web, thereby to adjust the instantaneous velocity of said operating member at the moment of engagement with said web material.

7. The apparatus of claim 6, wherein said cyclical path is endless.

8. The apparatus of claim 7, wherein said endless path is generally circular, said operating member being mounted for revolution about a given axis, said frequency varying means comprising means to vary the time rate of complete revolutions of said operating member.

9. The apparatus of claim 8, wherein said drive operating member means comprises a rotary member, means to rotate said rotary member, and means mounting said operating member on said rotary member for movement therewith, said location adjusting means comprising means to adjust the angular position of said operating member relative to said rotary member.

10. The apparatus of claim 9, wherein said operating member drive means comprises a rotary drive member adapted to rotate at a constant angular speed, said means to vary the instantaneous velocity of said operating member along said cyclical path comprising non-circular gearing means operatively drivingly connected between said drive member and said rotary member and effective to convert said constant angular velocity of said drive member into a periodically varying angular velocity of said rotary member.

11. The apparatus of claim 10, wherein said non-circular gearing means comprises a pair of elliptical gears.

12. The apparatus of claim 9, wherein said web feed means comprises a second rotary member, a second rotary drive means operatively connected to said second rotary member and effective to rotatably drive same, and wherein said control means comprises means operatively connected to said first and second rotary drive means and effective to simultaneously vary the relative rate of complete rotations of said rotary members.

13. The apparatus of claim 12, wherein said instantaneous velocity varying means comprises means to periodically vary the instantaneous velocity of said operating member along said cyclical path during each operating cycle, means to adjust the location along said cyclical path at which said operating member engages said web, thereby to adjust the velocity of said operating member at the moment of engagement with said web material.

14. The apparatus of claim 13, wherein said drive operating member means comprises a rotary drive member adapted to rotate at a constant angular speed, said

relative velocity varying means comprising, non-circular gearing means operatively drivingly connected between said drive member and said rotary member and effective to convert said constant angular velocity of said drive member into a periodically varying angular velocity of said rotary member.

15. The apparatus of claim 10, further comprising means operatively connected to said angular position adjusting means and to said control means and effective to automatically actuate said angular position adjusting means in response to a variation in the rate of complete revolutions of said operating member relative to said web velocity thereby to adjust the position of said operating member such that it engages said web at a velocity equal to the web velocity.

16. The apparatus of claim 15, wherein said operating member drive means comprises a rotary drive member adapted to rotate at a constant angular speed, said means to vary the instantaneous velocity of said operating member along said cyclical path comprising non-circular gearing means operatively drivingly connected between said drive member and said rotary member and effective to convert said constant angular velocity of said drive member into a periodically varying angular velocity of said rotary member.

17. The apparatus of claim 16, wherein said non-circular gearing means comprises a pair of elliptical gears.

18. The apparatus of claim 10, wherein said manual adjusting means further comprises a rotary control shaft effective to control the speed of said web and said operating member drive means, a manually actuatable control member and first cam means operatively connected between said control shaft and said control member and effective to rotate said control shaft by an amount which is a function of the position of said control member.

19. The apparatus of claim 18, wherein said non-circular gearing means comprises a pair of elliptical gears.

20. The apparatus of claim 18, further comprising means operatively connected to said angular position adjusting means and to said control means and effective to automatically actuate said angular position adjusting means in response to a variation in the rate of complete revolutions of said operating member relative to said web velocity thereby to adjust the position of said operating member such that it engages said web at a velocity equal to the web velocity.

21. The apparatus of claim 20, further comprising a second cam means operatively connected to said control member, and wherein said means for actuating said adjusting means is operatively connected to said second cam means and effective to actuate said adjusting means to adjust the angular position of said operating means by an amount which is a function of the position of said control member.

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