Jan. 23, 1968 W. S. MILLER 3,364,787

BALL ACCELERATING APPARATUS

Filed May 25, 1965 2 Sheets-Sheet 1

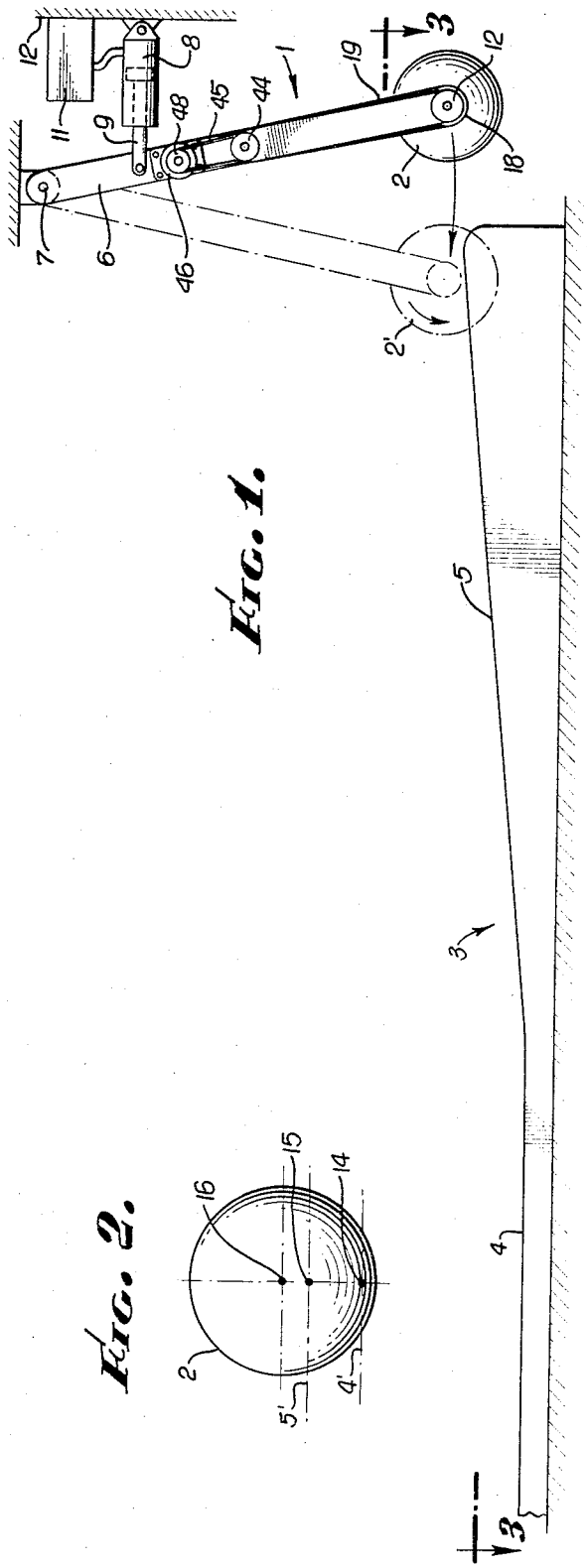


FIG. 1.

FIG. 2.

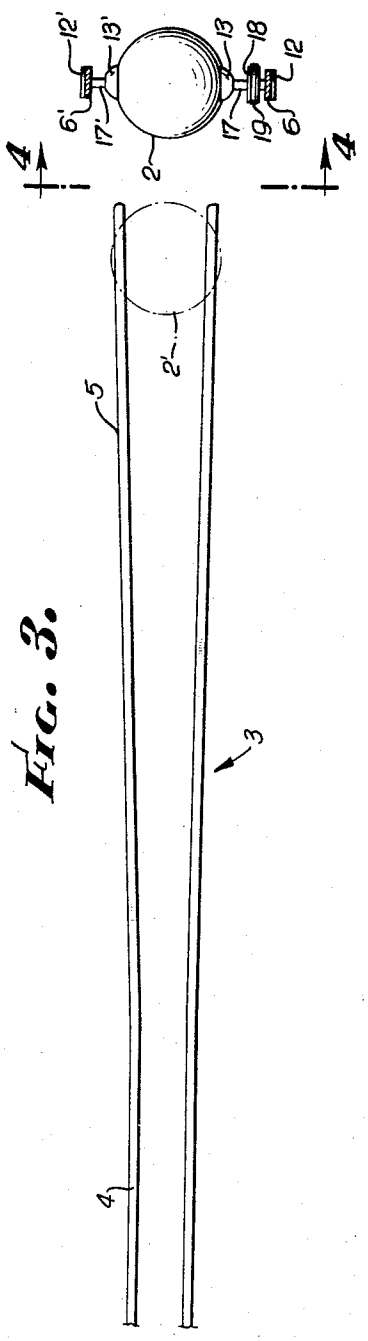


FIG. 3.

INVENTOR.

Wendell S. Miller

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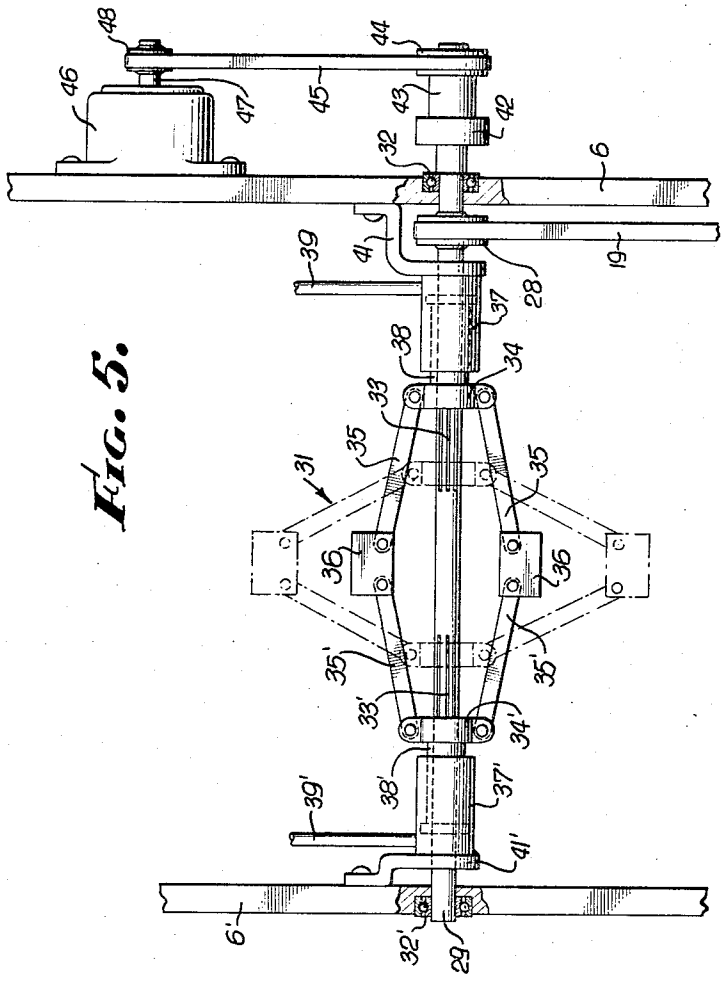


Fig. 5.

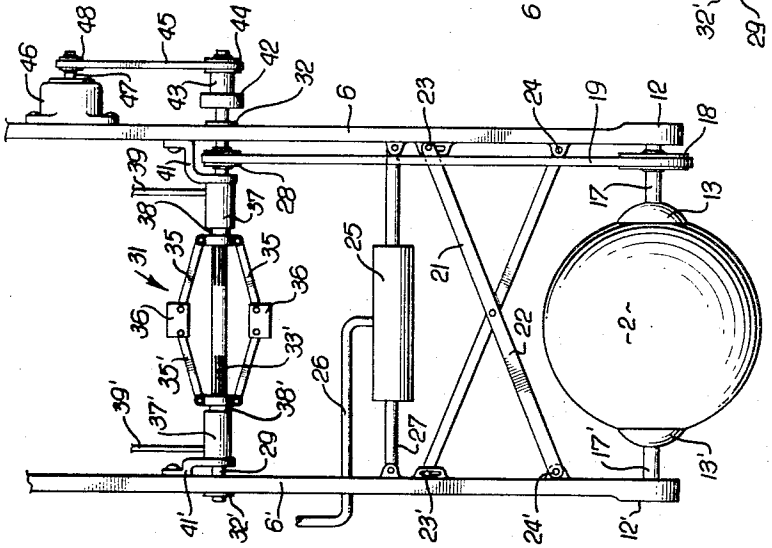


Fig. 4.

INVENTOR.

Wendell S. Miller

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BALL ACCELERATING APPARATUS

Wendell S. Miller, 1425 S. La Brea Ave.,
Los Angeles, Calif. 90019

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ABSTRACT OF THE DISCLOSURE

A device for returning bowling balls from the pin pit to the bowler having a pair of rails of progressively decreasing height and distance apart. A pair of opposed swing arms carried resilient cups lift, spin the ball, and place the ball on the rails. A motor drives a spin shaft through an overriding clutch to impart rotation to a pair of weights link carried by the spin shaft. Fluid actuators cause the links to pull the weights radially inwardly to increase the spin speed due to decrease of the moment of inertia of the weights just prior to engagement of the ball by cups.

This invention relates to ball accelerating apparatus particularly adapted to impart to spherical objects such as bowling balls a high velocity by first angularly accelerating such balls to a high rotational velocity and then converting the kinetic energy of rotation into translational kinetic energy by allowing the ball to roll on a track of continuously decreasing span.

In conventional ball delivery apparatus adapted the return of bowling balls from the pin pit to the approach, several means are employed for imparting the initial velocity to the ball. The most customary means is to raise a ball to a position several feet above the level of the return track either manually or by means of a belt elevator and then to allow the ball to accelerate by rolling down an inclined track to the level of the return track. This method has been in use for decades, but is comparatively slow in operation and tends to delay the play of the game to the economic disadvantage of the bowling proprietor. Time is required both for the elevation of the ball and for its slow, gravity determined acceleration down the inclined track.

The belt elevators employed with devices of this type generally have a constant speed drive on a belt biased to press a ball between itself and a rising track. The speed of lift which can be imparted to a ball by such apparatus is of course approximately half the peripheral speed of the belt. The ball acquires this velocity by means of force applied to it by frictional contact with the belt. The accelerating force, as distinguished from the straight lifting force, is thus imparted only during a period of slippage between the ball and the belt. There is thus necessarily a tendency for the belt to abrade the ball, and conversely the belt, during this slipping frictional engagement. Such a tendency to abrade the ball places a definite upper limit on the velocity with which the belt may travel safely.

In most apparatus the belt elevator serves merely to lift the ball and any excessive speed imparted to the ball by this means would merely cause the ball to leave the track intermittently and would eventually cause impact damage to the track itself. However, in some machines of recent design the balls have been given a preliminary velocity by gravitational means and subsequently accelerated with a belt of the type described above in generally the direction of the return track. Such apparatus still requires a substantial preliminary acceleration be given the ball in order to prevent really excessive abrasion when the ball rolls under the accelerating belt.

In my copending application entitled, Ball Delivery Apparatus, Ser. No. 182,903, filed Mar. 27, 1962, now Patent No. 3,185,475, there is exhibited a belt drive apparatus

utilizing some of the same principles as the machine of this application. There, a pair of belts so disposed as to engage a rolling ball at a progressively decreasing height above the ball supporting track are employed to impart angular momentum to the ball, in a continuous fashion along with a relatively small amount of linear momentum. In this device the tendency to abrade the ball is greatly reduced since while the ball is angularly accelerated, the belt, traveling at constant speed, progressively engage portions of the ball which are traveling at a lower total speed than the top of the ball. This apparatus requires that the total angular momentum be imparted to the ball over a substantial linear extent in order to provide room for the relative movement of the point of contact of the belts with the ball. In common to this system and that presently presented is the teaching of continuously transforming the rotational energy possessed by the ball to translational kinetic energy by means of rolling contact between the ball and tracks of progressively decreasing span.

In applicant's present invention it is assumed that the ball to be handled has been appropriately positioned by conventional ball collection apparatus prior to the actuation of applicant's mechanism. The ball so positioned is then seized by diametrical opposed resilient cup structures adapted to hold, lift and spin the ball. These cup structures are mounted upon axially aligned spin shafts carried by supporting arms. In the preferred embodiment illustrated, the arms are so mounted as to be restrained to parallel displacement with respect to each other and are pivoted to rotate about a common axis parallel to the axis of spin of the ball. The parallel displacement feature is not absolutely essential, but substantial angular displacement is to be avoided because of the difficulty of journaling and gyroscopic effects.

At least one of the spin shafts is mechanically connected to a power shaft from which energy is derived. In the preferred embodiment shown the driven spin shaft and the power shaft are distinct and are connected by a belt power train. It is apparent that the choice of power train is determined merely by engineering convenience. In fact it is not necessary that the power shaft and the driven spin shaft be distinct structures. They could merely be different ends of the same integral rod, but since their functions are separate and distinctive it is preferable to describe them by different names.

Various forms of torque imparting devices may be utilized to accelerate angularly the drive shaft after the engagement of the spin shaft with the ball. The common requirement for such torque motors is that they be capable of delivering intermittently a very high torque at rapidly increasing angular velocity. Hydraulic pneumatic and series wound electric motors are capable of performing this function although they are not as well suited to this as the type of centrifugal mechanical motor which applicant prefers to employ.

Applicant's torque imparting device comprises a balanced set of weights, mounted for centripetal motion with respect to the power shaft by a toggle mechanism attaching weights to two collars, each mounted to the shaft. At least one of which collars must be capable of axial movement on the shaft to vary the distance between the weights and their axis of rotation. This toggle-weight structure is thus capable of being changed from a configuration of comparatively small moment of inertia with respect to the power shaft axis to a condition of comparatively large moment of inertia by the linear displacement of one or both collars axially of the shaft. The collars are spined to the shaft so that this change in moment of inertia may be attributed to the entire power train connected thereto.

When the cups on the spin shafts first seize the ball, the power shaft is in a condition of slow rotation with

the weights fully extended to produce the high moment of inertia condition for the power train. This slow rotational speed may be maintained by a comparatively small power constant speed motor connected to the power shaft through an overriding clutch. This motor thus tends to impart power to the power shaft and thus the ball whenever the shaft tends to rotate at a slower angular velocity than the motor is set to supply. The motor is, however, effectively out of the power train whenever the power shaft tends to rotate at a faster speed. Since grasping an initially stationary ball will tend to absorb power from the power shaft and structure there will be an initial slipping contact between the cup and ball while the motor brings the ball to the initial slow rate of angular rotation. Since the rotational energy of the ball is proportional to the square of the angular velocity the size of the product of the force times the distance through which it is exerted is proportionately smaller as the square than that required to accelerate the ball to an energy content corresponding to that finally desired.

Once the ball has been firmly gripped by the cup and preferably, though not essentially, after it has come to the speed afforded by the motor, a linear actuation of the collars of the centrifugal weight structure is effected. The collars are now drawn apart to substantially reduce the effective moment of inertia of the power train and ball combination. Since this operation makes no change in the total angular momentum of the system, the speed of rotation of weight and ball increase simultaneously and continuously at a very rapid rate. As may be seen in the mathematical treatment which follows a very substantial increase in the total energy content of the system is effected by this displacement. It is thus possible to efficiently convert a very high force with a very small displacement, i.e., that of the collar, into a rapidly accelerating rotary energy mode without slippage.

When the ball has been so angularly accelerated the arms **6**, **6'** holding the ball may be actuated sharply in the direction of the track and simultaneously separated to toss the ball, still spinning, onto the entrance of the track. It is intended that the speed of tossing shall be so co-ordinated with the rotary velocity of the ball that the point of contact of the ball with the tracks will be essentially stationary. The required velocity for this condition he has also calculated below.

The ball is now rotating at a high angular velocity and has a small forward velocity equal to the product of the angular velocity of the ball and the distance between its center and the line through the point of support of the ball on the track. Since this forward velocity may generally be quite small, virtually all of the energy of the ball is in the angular rotation mode at this time. However, since the track is then converged, the rolling frictional engagement between the ball of the tracks converts much of the angular kinetic energy into linear kinetic energy and the ball correspondingly accelerates rapidly of itself without slippage.

After the ball has been released from the apparatus, the mechanical reaction motor is traveling at a high rotational speed with a low moment of inertia, if the linear actuators on the collars are now released so as to permit the swinging weights to return to their extended, high moment of inertia position, the entire drive shaft will tend rapidly to slow down angularly. When the drive shaft has slowed by friction or otherwise to a speed less than that supplied by the electric motor, the overriding clutch re-engages and the motor slowly delivers sufficient power to maintain drive shaft at its initial low angular velocity.

It is, accordingly, an object of this invention to provide a mechanical torque motor adapted to convert linear actuation with high force and low travel into angular actuation of constantly increasing angular velocity.

Another object of this invention is to provide a means of transfer of angular momentum from a rotating mechanical structure to a second rotating mechanical structure coupled thereto by reducing the moment of inertia of the first structure while both structures are in a state of angular rotation.

Another object of this invention is provide a means for rapidly mechanically angularly accelerating a ball with a minimum of slipping frictional contact.

Another object is to provide a means of linearly accelerating a ball by first angularly accelerating a ball in a substantially stationary position and then continuously transforming the kinetic energy of rotation of the ball into kinetic energy of translation by rolling contact.

Another object is to provide means for imparting energy to a ball while efficiently coupling a low powered constant velocity motor to a linear actuator capable of rapidly delivering a comparatively large amount of energy.

Another object is to provide a means of seizing a bowling ball across a diametric axis, angularly accelerating the ball about such axis and then imparting a linear velocity to the ball by tossing it onto receiving tracks.

Other objects of this invention will be apparent from an examination of the more complete description of the apparatus and method which follows:

To now describe the figures:

FIGURE 1 exhibits a side elevation of the ball accelerating system described.

FIGURE 2 exhibits a bowling ball in side elevation with particular attention to the relative positioning of points of support with respect to the center of the ball.

FIGURE 3 exhibits a plan view of the FIGURE 1 device taken along the line 3—3 of FIGURE 1.

FIGURE 4 is a diagrammatic representation in elevation of the ball holding and tossing mechanism of the FIGURE 1 device taken along the lines 4—4 of FIGURE 3.

FIGURE 5 is a diagrammatic detail of the mechanical reaction motor drive shaft and connected elements appearing in FIGURE 4.

In FIGURE 1 is represented at **1** the mechanism adapted to seize, angularly accelerate and toss a bowling ball **2** from the solid line position to the dotted position **2'** for travel on a track section **3**. Portion **4** of this track is of conventional narrow gage adapted to hold and direct a bowling ball on its course back to a bowler from the pit. The portion **5** of the track **3** differs from the portion **4** in that as shown in FIGURE 3 it commences with a particularly wide gage adapted to grasp a bowling ball at points not far from a horizontal diametric axis and then proceed to decrease its span progressively to join uniformly with the narrow span portion **4**. As illustrated, the portion **5** of the track may be relatively elevated with respect to the portion **4**. Such elevation is not essential but is appropriate if the ball **2** is not to change height in passing between these two sections of the tracks.

In FIGURE 2 there may be seen at **4'** and **5'** the comparative heights of the track with respect to the center **16** of the ball and the corresponding points of contacts **14** and **15** of the ball the tracks **4** and **5**, respectively.

In FIGURE 1 the ball accelerating mechanism is carried by a set of arms (of which **6** is seen) pivoted about an axis **7** and capable of being driven between the two positions shown by a cylinder and piston actuators **8** and **9** respectively supplied from a controller **11** and mounted to a stationary object **12**.

In FIGURE 3 it may be seen that the ball **2** is grasped between a pair of cup shaped frictional members **13** and **13'** diametrically opposed to one another across the horizontal axis of the ball which is perpendicular to the direction of the track **5**. The cups **13** and **13'** are rigidly affixed to co-linear spin shafts **17** and **17'** respectively. As shown, **17** only is driven through a pulley **18** and belt **19**, although in practice the frictional engagement with the ball may be improved if necessary by powering both spin shafts. These shafts are in turn mounted in bearings **12**

and 12' respectively. The shafts and cups on either side of the ball are adapted to be moved laterally away from the ball to the dotted line positions shown, prior to grasping the ball, and later during the tossing of the ball.

In FIGURE 4 there are exhibited at 6 and 6' the mounting arms which are constrained for parallel displacement with respect to one another by a conventional scissors parallel movement with rods 21 and 22 central pivoted exhibited. These rods are attached to arms 6 and 6' by pivots 24 and 24' and pivot slots 23 and 23' respectively. It is apparent that other equivalent parallel motion mechanism may be employed, or if adequate gimbaling of the journals of the drive shafts are supplied, the parallel motion mechanism may be dispensed with entirely. Actuation of the parallel motion is obtained through the cylinder 25 and piston 27 through control line 26.

The spin shafts receive their power through pulley 18, belt 19, and pulley 28 attached to drive shaft 29. Also attached to drive shaft 29 is the mechanical reaction torque motor 31 shown in greater detail in FIGURE 5. There 32' indicates a slip bearing between the drive shaft 29 and the arm 6'. Shaft 29 is mounted to arm 6 through bearing 32. As shown, the motor mechanism is symmetrical although this is of itself not necessary. On splined portions 33 and 33' of the drive shaft there ride collars 34 and 34' respectively supporting sets of toggle arms 35 and 35' respectively connected to weights 36. These are preferably made of a heavy material such as lead or depleted uranium with the entire rotary mechanism being carefully balanced statically and dynamically. Linear actuators 37 and 37', preferably hydraulic, are adapted to move pistons 38 and 38' under actuation through control lines 39 and 39' respectively to draw apart the collars to which they are shown attached. Support preventing rotation of these actuators with respect to the arms 6 and 6' is provided by arms 41 and 41' respectively. Attached to drive shaft 29 is an overriding clutch 42 driven by shaft 43 from pulley 44 and belt 45 receiving power from a constant speed motor 46 through shaft 47 and pulley 48. Clutch 42 may be of a conventional silent rachet type so that shaft 43 may drive shaft 29 but not vice versa.

I shall now describe the operation of this mechanism in more detail. A bowling ball 2 will be assumed to have been positioned appropriately by any conventional ball positioning apparatus such as are presently utilized for delivering ball from a pit to a ball elevator. When the ball has been so positioned means may be provided manually or automatically for sequentially actuating the mechanism to the following steps:

First, the apparatus is positioned astride the ball with the arms 6 extended and the shaft 29 rotating at a first, relatively low angular velocity.

Second, the ball is seized by the cups 13 through closure of the arms 6 by actuation of the cylinder piston combination 25 through line 26. Delay may here be provided to enable the motor 46 to return the drive shaft 29 to the previously mentioned first angular velocity through the overriding clutch 42, following the slowing which may take place upon grasping the ball 2 and transferring angular momentum from the mechanical motor to the ball. If necessary arms 6 and 6' may be slightly pivoted about axis 7 by means of actuators 8 and 9 under command of control 11 to carry the ball free of any stationary support.

Third, actuators 37 and 37' are simultaneously activated to draw apart collars 34 and 34' bringing in weights 36 to reduce the moment of inertia of reaction motor 31 thereby rapidly and continuously accelerating the drive shaft and ball.

Fourth, actuator 8 is sharply pulsed to move the ball toward the 2' position of FIGURE 1. During the final portion of this sharp actuation, actuator 25 is pulsed to separate arms 6 disengaging the ball from the cups 13 and 13' and tossing it, still spinning, onto the track portion 5.

Fifth, the fluid supply to actuators 37 and 37' is simultaneously diverted enabling collars 34 and 34' to be drawn together under the tension imparted to arms 35 by the centrifugal force acting on weights 36. Since this motion of the weights 36 tends to sharply increase the moment of inertia of the reaction motor structure 31 the angular velocity of drive shaft 29 will rapidly decrease. At this time there will be a surplus of kinetic energy remaining in the weights 36 which may be drawn off and returned to a hydraulic accumulator by using the actuators 37' as pumps. If the angular velocity of 29 tends to become less than that of shaft 43 driven by motor 46, power will be delivered to the drive shaft through clutch 42 until such time as weights 36 have assumed their maximum extension. At this time the mechanism will have returned to its initial condition with arms 6 and 6' relatively extended, the weights 36 have their extended position and the drive shaft 29 moving at the low angular velocity rate imparted by the motor 46.

Following pulsing of the ball onto the track portion 5, the rolling mechanical transformation of rotary energy to translational energy takes place through frictional contact of the ball with the tracks of constantly decreasing span. For this purpose tracks 5 should, of course, be lined with material having a comparatively high coefficient of friction with respect to the rubber and plastic surface of bowling balls.

The energy and momentum relation involved may be calculated as follows. We shall assume that a standard 16 lb, bowling ball has a moment of inertia I, that the low velocity rate determined by the motor is w, and that the high angular velocity produced is W. For purpose of calculation assume that the moment of inertia of the mechanical reaction motor structure varies between a minimum of I in the contracted position and 9I in the expanded position, corresponding approximately to a 3–1 ratio in weight revolution diameters. If we further take the ratio $W/w=5$, it is apparent that the energy put in during the slipping frictional engagement with the spinning cups, $Iw/2$, is only 4% of the energy of the ball as delivered, $IW/2$. Thus abrasion from this slipping engagement may be considered quite negligible. The energy put in by the displacement of the actuators 37 and 37' corresponds to .8 IW which is somewhat greater than that eventually delivered to the ball. Thus upon the re-expansion of the weight to their high moment of inertia condition the actuators may be utilized as pumps to return a portion of the power consumed to a hydraulic accumulator.

Since in this system the fixed quantities are the low angular velocity, w, determined by the motor 46 and the two extremes of angular momentum possessed by the mechanical reaction motor some variation in speed is to be expected when utilizing bowling balls of different weights. In this regard it must be recalled that conventional ball construction requires a hard and heavy exterior surface regardless of the ball's weight and since the material of which the surface is composed is generally denser than that used for the interior of lighter weight balls the moment of inertia of a ball does not decrease in proportion to a decrease in its weight. Thus for example, an expected range of angular momentum might be from 1 unit with a standard 16 lb. ball to ⅔ of a unit with a 9 lb. ball. Again recalling that it is the total angular momentum of the system which remains constant upon the displacement of the actuators 37, 37', and again consider a ratio of moments of inertia of the reaction motor at 9–1 it may readily be seen that the angular velocity ratio W/w for a light ball will be 5/29. Thus a light ball will tend to be accelerated to a higher angular velocity than a heavy one. This result is desirable since light balls while rolling have a greater proportion of their total energy in the angular momentum mode than do heavy balls with their correspondingly lower proportional moment of inertia. Since light balls are more effected by air and track friction they require this higher proportion

of energy to mass for proper ball handling. This feature is a desirable object in itself.

With reference once more to FIGURE 2 it may be seen that if a ball is rotating about its center **16** with angular velocity W, the point **15** where a ball meets the track **5** at level **5'** will be stationary relative to the track if at that time the ball has a forward overall velocity equal terms *w* times the vertical distance between the level of points **15** and **16**. This is the desired speed of forward motion with which the ball should be tossed onto the track. Small variations from this exact speed resulting from the previously mentioned difference in angular velocity of different weight balls may be tolerated with only very minor loss of efficiency due to the relative slip between the ball and track at the very outset.

With these considerations in mind, it may be seen that I have devised a novel and effective method of smoothly transforming energy from a linear actuator to a rapid rotational mode. This method and apparatus has been here particularly applied to the problem of rapidly accelerating a bowling ball without undue frictional abrasion. While this is deemed to be the most appropriate use for this device which I know, I mean that the scope of coverage afforded by this patent shall be limited by the terms of the claims appended here and their equivalents.

I claim:

1. A mechanical reaction motor comprising support means, a shaft, means for journaling said shaft to said support means for rotation relative thereto, means for rotating said shaft, a pair of ponderous means attached to said shaft and constrained to rotate synchronously with said shaft and mounted for simultaneous movement radially with respect to said shaft while maintaining static and dynamic balance with respect to rotation of said shaft throughout a range of said radial movement, a linear actuator mounted to said support adapted to positively move said ponderous means throughout said radial range during rotation of said shaft, means for isolating said shaft from torsional effect by said means for rotating throughout a predetermined range of angular velocity of said shaft, and means for removing energy from said shaft while it is rotating at an angular velocity within said predetermined range.

2. A mechanical reaction motor as set forth in claim **1** wherein said means for removing energy from said shaft comprises means for coupling said shaft to an inertial workpiece during the movement of said pair of ponderous means radially toward said shaft and decoupling said workpiece from said shaft during the movement of said pair of ponderous means radially away from said shaft.

3. A mechanical reaction motor as set forth in claim **1** wherein said means for rotating said shaft comprise a rotary power source adapted to rotate at a predetermined speed and a power train adapted to a convey power in a rotary motion mode therefrom to said isolating means, said isolating means comprising an overriding clutch operably connecting said shaft and said power train for transfer of energy from said power train to said shaft when said shaft presents to said overriding clutch a resistance to rotation at said predetermined speed.

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MILTON KAUFMAN, *Primary Examiner.*