United States Patent

[11] **3,565,006**

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[21] Appl. No. **769,466**
[22] Filed **Aug. 29, 1968**
[45] Patented **Feb. 23, 1971**
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[54] **APPARATUS FOR CHANGING AND INDICATING THE ROTARY AND AXIAL POSITION OF A PRINTING MEMBER**
7 Claims, 6 Drawing Figs.

[52] **U.S. Cl.** **101/248,** 74/640
[51] **Int. Cl.** **B41f 13/14**
[50] **Field of Search** ..... 101/248; 74/395, 396, 640, 397—399, 675

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2,677,971	5/1954	Greenwood	101/248X
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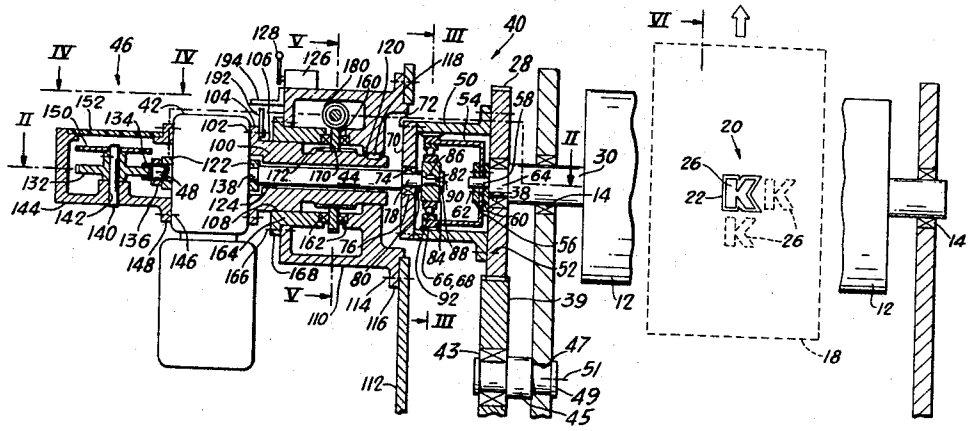
ABSTRACT: Apparatus for dynamically positioning the angular and axial position of a printing roller and means for indicating these positions comprising a printing roller driven by a gear through a motor-driven harmonic gear drive for changing the angular phase relationship of the driving gear and the printing roller; a manually operable worm gear drive for axially shifting the printing roller relative to a reference point; a read-out dial attached to a secondary output of the harmonic gear motor drive for indicating the angular position of the printing roller relative to the roller driving gear; and a linear dial for indicating the axial position of the printing roller.



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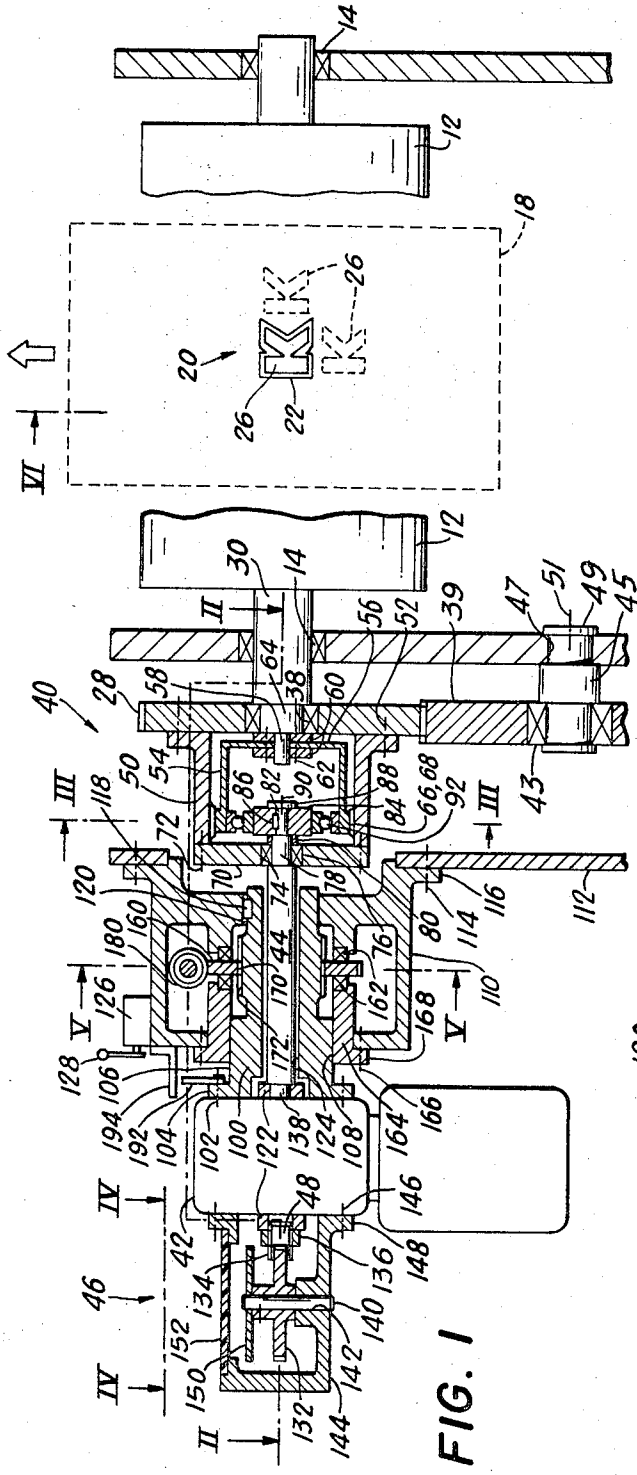

FIG. 1

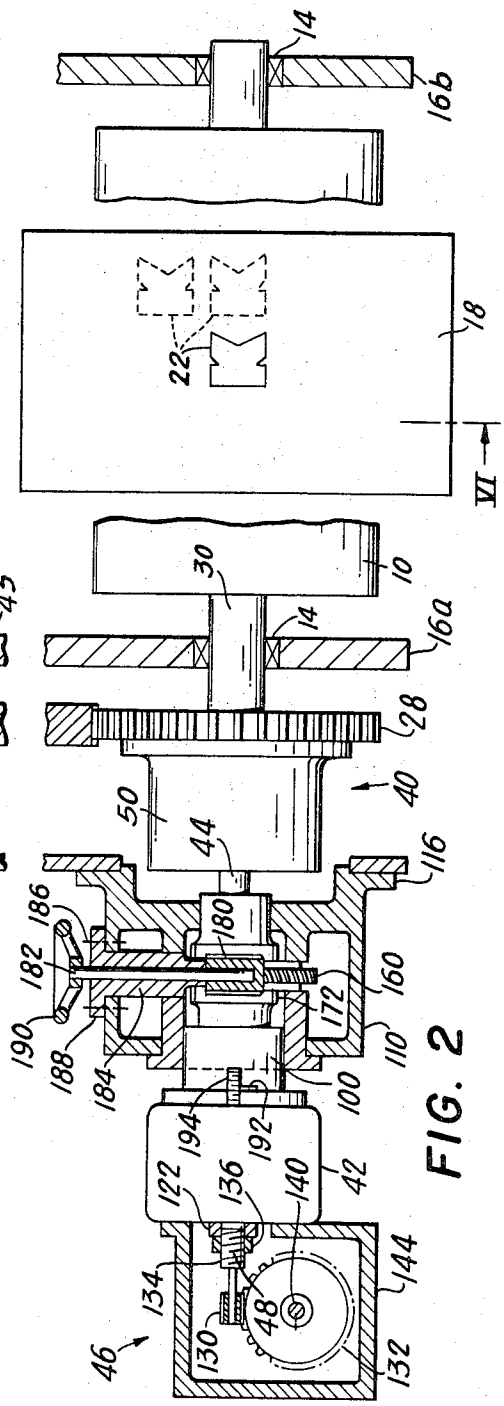

FIG. 2

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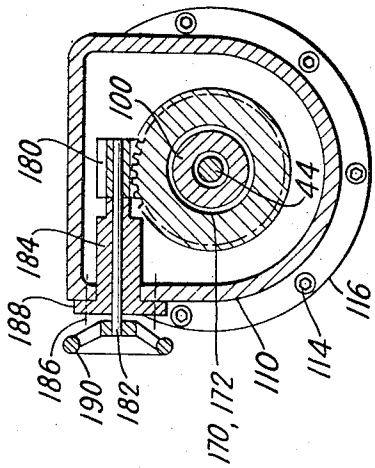

FIG. 5

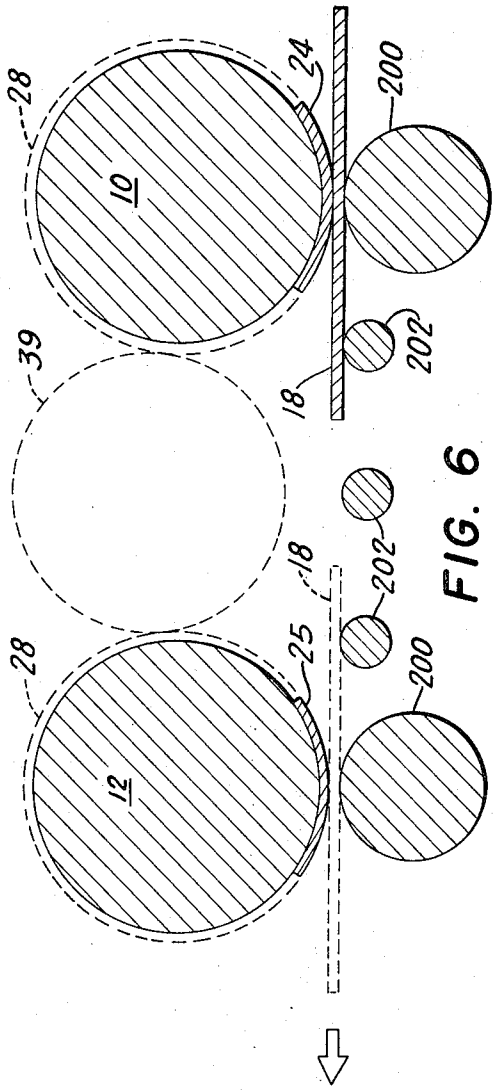

FIG. 6

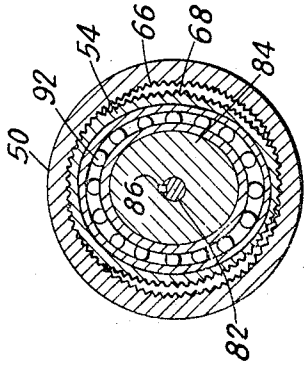

FIG. 3

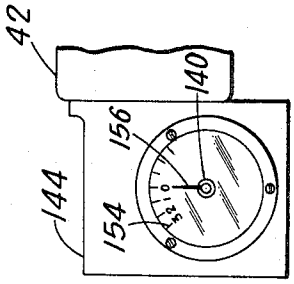

FIG. 4

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APPARATUS FOR CHANGING AND INDICATING THE ROTARY AND AXIAL POSITION OF A PRINTING MEMBER

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to machine elements and mechanisms and more particularly to adjustable gearing.

2. Description of the Prior Art

In the printing of corrugated paperboard blanks, rubber dies are secured to one or more printing rollers which must be kept in register with each other and in register with the blank feeding mechanism to assure registration of the printed indicia on the blank. Since the dies may be improperly positioned around the circumference of and along the axis of the printing rollers, means must be provided for adjusting the angular or circumferential position of the rollers with respect to each other and with respect to the driving gear train. Equally important is means for adjusting the axial position of the printing rollers to provide lateral positioning of the dies across the width of the blank.

Various gearing arrangements have proven capable of performing the required phase change function although generally speaking they are usually complex and expensive. One example is illustrated in H.B. Greenwood U.S. Pat No. 2,677,971, which arrangement is limited in that it is manually operated and relative movement between the printing roller and its driving gear is limited to a few degrees. Preferably, the printing roller is rotatable relative to the driving gear throughout a full 360° and is not limited to a single rotation. Thus, if the mechanism is motor-driven, the roller may be easily rotated to aid in securing the printing dies on the roller. A complex arrangement providing for 360° of rotation is illustrated in H.D. Ward, Jr. U.S. Pat. No. 2,986,952. Other arrangements are shown in U.S. Pat. Nos. 1,868,385; 2,030,027; 2,030,028 and 2,098,112.

It has been suggested that, as outlined in an article appearing in the April 28, 1965 issue of Design News, a Cahners publication located at 3375 S. Bannock St., Englewood, Colorado 80110, strain wave gearing such as that illustrated in C.W. Musser U.S. Pat No. 2,906,143 to be adapted to adjusting the phase relationship between printing rollers and between the rollers and their driving gears. A similar reference may be found in a brochure published by the Harmonic Drive Division of United Shoe Machinery Corporation, Balch St., Beverly, Mass. 01915, Form No. 5033. Nevertheless, no one seems to have satisfactory applied strain wave gearing (commonly referred to as harmonic drives) to the registration of printing rollers in corrugated paperboard blank finishing equipment, probably due to the problems involved. To be satisfactory, such gearing must provide for registration of the printing rollers with a feeding means for the blanks and for registration with each other for longitudinal registration of printing on the blanks. Read-out means must be provided for indicating register or nonregister positions of the rollers and, preferably, readable during rotation of the rollers. End-adjustment means must be provided for axially shifting the printing rollers transversely along with respect to the path of travel of the blanks to register printing transversely along the width of the blanks. Read-out means for indicating transverse registration is necessary.

SUMMARY OF THE INVENTION

The present invention overcomes the complexities of the prior art devices and successfully utilizes harmonic drive principles in combination with means for angular position read-out and end-adjustment with axial read-out means to provide dynamic angular phase adjustment of a full three hundred and sixty degrees while the printing machine is running; position read-out, both as to phase relationship and axial location, are readable while the machine is running.

The foregoing functions are accomplished by providing a harmonic drive of which is its rigid circular spline is coupled to the printing roller driving gear; its flex spline is coupled to the printing roller; and its wave generator is driven by a shaft-mounted gear motor at such time as a change in phase is required between the driving gear and the printing roller. When no change in phase angle is occurring, the printing roller is driven by the driving gear indirectly through the rigid spline and the flexspline, the wave generator being held stationary by a brake incorporated in the gear motor.

Dynamic read-out is provided by a worm and worm wheel coupled to a secondary output of the gear motor, the secondary output rotating at the same speed as the primary output driving the wave generator. By providing the same reduction between the worm and worm wheel as used between the rigid spline and the flexspline, a graduated dial and pointer associated with the worm wheel indicates a the actual change in angular position between the drive gear and printing roller.

To accomplish end adjustment, a pair of worm gears are mounted in a stationary housing with one of the gears including internal screw threads meshing with corresponding external threads on the motor support which moves axially with the input shaft. The input shaft is bearing mounted to the printing roller indirectly through the harmonic drive and printing roller drive gear. The printing roller is axially slidable in bearings housed in the machine frame. Thus, as the threaded worm gear is rotated by the other worm gear, the wave-generator input shaft moves axially thereby moving the printing roller axially. A pointer attached to and moving with the motor support registers axial position of the printing roller along a scale provided on the stationary housing for the worm gears.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and further objects and novel features of the invention will appear more fully from the following detailed description when the same is read in connection with the accompanying drawings. It is to be expressly understood, however, that the drawings are not intended as a definition of the invention but are for the purpose illustration only.

In the drawings wherein the like parts are marked alike:

FIG. **1** is a side elevation in cross section illustrating the invention coupled to a printing roller which is shown in plan view;

FIG. **2** is a plan view in partial cross section taken along the line II–II of FIG. **1** and illustrating the invention coupled to a printing roller located adjacent the printing roller of FIG. **1**;

FIG. **3** is a sectional view of the harmonic drive taken along the line III–III of FIG. **1**;

FIG. **4** is a plan view of the dynamic read-out indicator taken along the line IV–IV of FIG. **1**;

FIG. **5** is a sectional view of the end adjustment taken along the line V–V of FIG. **1**; and

FIG. **6** diagrammatically illustrates two adjacent printing rollers each utilizing the present invention.

DESCRIPTION OF THE PREFERRED CONSTRUCTION

The problem of registration is illustrated by the printing of a solid letter K on top of an outline of letter K in the center of blank **18** as shown at **20** in FIG. **1** using a conventional pair of adjacent printing rollers **10** and **12** which are axially slidably supported in bearings **14** housed in spaced apart machine frames **16***a* and **16***b*. These rollers **10**, **12** of FIGS. **1** and **2** are illustrated in plan view with portions broken away to show the advance of a paperboard blank **18** beneath roller **10** (shown in solid lines) to a position beneath roller **12** (shown in dotted lines) as indicated by the large arrow in FIG. **1**.

The outline **22** is first printed on blank **18** with die **24** (see FIG. **3**) on roller **10**; and the blank **18** is then advanced beneath roller **12** where solid letter K **26** is printed on the blank by die **25**. It should be understood hat the blank ad-

vances continuously at a uniform velocity rather than intermittently.

If the dies on the rollers **10** and **12** are not properly located, the outline letter K **22** may not be printed in the desired location as shown exaggerated by the dotted lines in FIG. **2**. Similarly, the solid letter K **26** may be displaced as shown by the dotted lines in FIG. **1**. The circumferential "out of register condition" can also be caused by an "out of time" relationship with the blank-feeding mechanism (not shown). It will be understood by those skilled in the art that one of the roller driving gears **28** mounted on journals **30** of rollers **10** and **12** will be coupled to the feeding mechanism by a gear train. The feeding mechanism, being a timed machine, will feed blanks **18** sequentially beneath the printing rollers **10** and **12**. Thus, the indicia K will always be imprinted at the same relative location on successive blanks. Since the printing rollers may be uncoupled, to allow access to the dies, from the feeding mechanism gear train and from each other, and be rotated during such uncoupling, then it can be seen than an out of time condition can occur upon coupling of the rollers to the feeding mechanism and to each other.

To compensate (hence, the word compensator is commonly used to denote the phase adjusting mechanism) for the out of register condition, a phase adjusting mechanism and end adjusting mechanism is provided on one end of each of the printing rollers. The compensator is capable of changing the angular (or phase) position of the printing roller with respect to its driving gear. Accordingly, in operation, the compensator is actuated to rotate roller **10** until K **22** is imprinted in the desired circumferential position on blank **18** as shown in FIG. **2**. This establishes registration with the feeding mechanism. Thereafter, the compensator associated with roller **12** is actuated until K **26** is in the circumferential position indicated by numeral **20** in FIG. **1**.

An end-adjustment is provided to laterally shift each printing roller along its axis until K indicia is located at the proper location across the width of the blank. Ordinarily, the amount of end-adjustment required is small being of the order of one-half inch in either direction from a center position between the machine frames **16***a* and **16***b*.

In accordance with this invention, dynamic angular phase adjustment is provided for the full 360° while the machine is operating as well as end-adjustment. Accordingly, driving member **28** for the printing member **10** is rotatable relative to said printing member and there is provided a phase shifting apparatus having an input **50** coupled to the driving member **28** and an output **40** coupled to printing member **10** with a wave generator **84** between input **50** and output **40** for changing the angular phase of output **40** with respect to input **50**. The power means **42** is coupled at **44** to wave generator **84** for selectively rotating the wave generator during rotation of driving member **28** in either a clockwise or counterclockwise direction to change the angular phase in a desired direction. Phase shift indicator **46** coupled by shaft **48** to power means **42** and driven thereby in the direction and at a distance corresponding to the output of said phase shifting apparatus indicates at dial **50** the angular relation of the printing member **10** relative to driving member **28**. Also coupled by way of shaft **100** to said power means **42** is the axial end-adjustment means **160**, **162** for axially shifting the power means **42** during rotation of driving member **28** to shift the printing member **10** axially and an axial indicator **192**, **194** for indicating the axial position of the printing member.

As previously mentioned, a driving gear **28** is rotatably mounted on each of journals **30** of rollers **10** and **12** by conventional radial-thrust bearings **38**. As is conventional practice, the driving gear **28** associated with roller **10** is driven by a gear train (not shown) connected to a blank-feeding mechanism. The driving gear **28** that is associated with roller **12** is driven by the driving gear that is associated with the roller **10** through an idler gear **39**. Idler gear **39** is rotatably mounted, by roller bearing **43**, to an idler stud **45** secured in a hole **47** in machine frame **16***a* by a washer **49** and screw **51** in an ordinary manner.

Each phase shifting mechanism (both are identical) includes three major portions: a harmonic drive **40** coaxially aligned with and secured to driving gear **28**; a gear-motor **42** having a primary output shaft **44** in axial alignment with and coupled to harmonic drive **40** for changing the output of the harmonic drive; and a dial indicator **46** coaxially aligned with and coupled to a secondary output shaft **48** of gear motor **42** for indicating the relative angular position of the driving gear **28** with respect to its associated printing roller. Secondary output **48** is an extension of primary output **44** which extends through a hollow output shaft in gear-motor **42**, to be subsequently explained.

The harmonic drive **40** includes a flanged rigid circular spline **50** mounted to the side of driving gear **28** by screws **52** in the ordinary manner. A flexible circular spline **54** is nested within rigid spline **50**. One end of flexible spline **54** is closed by a radially-extending end portion **56** having a central opening surrounding a reduced shoulder portion **58** of journal **30**. End portion **56** is secured for rotation with journal **30** by washers **60** disposed on either side of the end portion with screws **62** passing through both washers **60** and end portion **56** and into journal **30** in the ordinary manner. This construction also axially secures radial-thrust bearing **38** on reduced shoulder portion **64** of journal **30**.

The open end of flexible spline **54** includes external spline teeth **66** around its outer periphery. These teeth are adapted to mesh with corresponding internal teeth **68** formed around the inner periphery of rigid spline **50**.

Rigid spline **50** includes a radially-extending end portion **70** secured to it by screws **72** in the ordinary manner. Primary output shaft **44** is mounted for rotation within a central opening **74** in end portion **70** by a conventional radial-thrust bearing **76**. Bearing **76** is retained on a reduced shoulder portion **78** of shaft **44** by a spacer **80**.

Shaft **44** includes a further reduced shoulder portion **82** upon which a wave-generator cam **84** is secured for rotation therewith by a conventional shaft key **86**, washer **88**, and screw **90** in the ordinary manner. Wave-generator cam **84** is thus axially urged against spacer **80** to retain bearing **76** on shoulder **78**.

An elliptical roller bearing **92** is secured, as for example by a press fit, around the periphery of cam **84** which is also elliptical as illustrated in FIG. **3**. The major diameter of the bearing **92**, that is, the portion opposite the lobes of cam **84**, urge the external spline teeth **68** into meshing engagement with the internal spline teeth **69**.

Operation of the harmonic drive **40** is fully described in the aforementioned United Shoe Machinery brochure. Briefly, its operation is as follows. Driving gear **28** is secured to the rigid spline **50**, as previously described, and is adapted for rotation around journal **30** by means of bearing **38**. Journal **30** is secured for rotation with flexible spline **54**. The wave-generator, comprising cam **84** and bearing **92**, is held stationary by the primary output shaft **44** of braked gear-motor **42**. The gear-motor rotates the wave-generator to change the angular or phase relationship between gear **28** and roller **12**.

It should be understood that the flexible spline **54** is made of thin flexible metal (plastic materials can be used where transmitted torque is small) so that the wave-generator can deflect the external teeth **68** into engagement with external teeth **66** at the two points opposite the lobes of cam **84**. Thus, rotation of the wave-generator will result in a continuously moving waveform transferred to flexible spline **54**. This causes the flexible spline **54** to rotate with a greatly reduced tangential motion. A full rotation of the wave-generator will produce a rotation of flexible spline **54** through a distance equal to the difference between the circumference of the rigid spline **50** and the circumference of flexible spline **54**. Consequently, the actual reduction ratio can be obtained by dividing the difference between the two circumferences into the circumference of the flexible spline **54**. Since the spline teeth on both the flexible spline **54** and rigid spline **50** have the same circular pitch, the actual number of teeth on each can be used as the circumferential measurement; the reduction ratio of any

unit can be computed by dividing the difference between the number of teeth on the two splines into the number of teeth on the output member (flexible spline **54**). For example, if the rigid spline **50** has 202 teeth and the flexible spline **54** has 200 teeth, the ratio would be

$$\frac{200}{202-200}=\frac{200}{2}=100:1$$

Thus, when the harmonic drive is used in the ordinary manner with the rigid spline **50** fixed and the input going into wave-generator **84**, the output of flexible spline **54** would be one revolution for each hundred revolutions input.

However, as used in the present invention, the wave-generator **84** is held stationary (except when the angular phase is changed) and rigid spline **50** becomes the input with the flexible spline **54** remaining as the output. Thus, the output of flexible spline **54** is at the ration of 202:200 or 101:100. Consequently, the output of flexible spline **54** is 101 revolutions for each 100 revolutions of input to rigid spline **50**.

Since the printing rollers **10** and **12** must rotate at the same circumferential velocity as the lineal velocity of the blank being printed, it is necessary to establish the foregoing ration in reverse between the gear driving the blank feeding mechanism (not shown) and roller driving gears **28**. For example, if the driving gear for the feeding mechanism has 100 teeth, then roller driving gear **28** must have 101 teeth to reduce its velocity by the same amount that the velocity of flexible spline **54** is increased by rigid spline **50**. In this manner, the circumferential velocity of the printing rollers **10** and **12** is made equal to the lineal velocity of the blank **18** being printed.

A harmonic drive with a 100:1 ratio provides a high-resolution phase adjustment. One revolution of the wave-generator produces an adjustment of 3.6° on printing roller **10** or **12**. If the roller is 50 inches in circumference, rotation of wave-generator **84** one revolution by gear-motor **42** produces a circumferential shift of 0.5 inches of the roller relative to the driving gear **28**. The wave-generator may be easily rotated a fraction of a revolution thereby producing a phase shift of a few thousandths of an inch so that very accurate registration is obtained.

Gear-motor **42** is a conventional shaft-mounted type including an integral brake for quickly stopping its output upon release of an energizing switch. Motor **42** is supported by motor support **100** attached to the motor by screws **102** passing through flange **104** and into the motor housing. Support **100** includes a shoulder portion **106** axially slidable in an opening **108** provided in a support housing **110**. Housing **110** is secured to a machine subframe **112** by screws **114** passing through a flange **116** provided on housing **110**. Motor support **100** is secured against rotation in housing **110** by a key **118** slidable in a keyway **120** provided in the housing.

Gear-motor **42** includes a hollow output shaft **122** which projects slightly beyond both sides of the motor gear casing as shown in FIG. **1**. Primary output shaft **44** passes through hollow shaft **122** and is keyed thereto (not shown). Shaft **44** extends through an opening **124** provided in motor support **100** and is connected to the wave-generator as previously described. A conventional drum switch **126** is secured to housing **110** and is provided with an operating lever **128** which causes motor **42** to operate in a clockwise or counterclockwise direction depending on which direction lever **128** is pushed. Switch **126** is wired to motor **42** in an ordinary manner as well understood by those skilled in the art.

The present invention provides a read-out indicator that rotates only during an actual phase adjustment and, even then, it rotates slowly enough to permit visual inspection of the phase adjustment. This feature is advantageous in that the operator, having previously inspected a printed blank and measured the amount of nonregistration, can energize the compensator and simultaneously observe the amount of adjustment occurring. Thus, precise registration is obtainable with a single adjustment rather than by trial and error.

The read-out indicator **46** includes a worm **130** secured to secondary output shaft **48** and driving a worm wheel **132**. Shaft **48** is merely an extension of primary output shaft **44** extending through the hollow output shaft **122** of motor **42**. Worm **130** is secured to shaft **48** in any convenient manner such as setscrews (not shown). Shaft **48** also has screw threads **134** upon which a threaded collar **136** is tightened to draw reduced shoulder portion **138** tightly against hollow shaft **122** to secure the output shaft **44** and motor **42** together.

Worm wheel **132** is secured on a stud **140** which is rotatably mounted in an opening **142** in a worm housing **144**. Housing **144** is secured to the casing of motor **42** by screws **146** passing through a flange **148** provided on housing **144**. A dial **150** is secured for rotation with stud **140** adjacent worm wheel **132**. A transparent face plate **152** is secured to housing **144** above dial **150**.

The reduction ratio of worm **130** and worm wheel **132** is made identical to the reduction ratio of the harmonic drive. Accordingly, if the wave-generator (cam **84**) is rotated one full revolution by shaft **44**, to cause a phase shift of 3.6° of the printing roller, then worm **130** will be rotated one full revolution by shaft **48** and worm-wheel **132** will rotate 3.6°. Thus, dial **150** may have lined graduations **154** that correspond to the inches of circumference of the printing roller. Fractional lines may be placed between the inch line graduations if desired. Transparent face plate **152** includes a 0 or starting line **156** from which phase shifting of the printing roller may begin. The lines **154** and zero line **156** are illustrated in FIG. **4**. Thus, it can be seen that dial **150** rotates only when a phase adjustment is made. The dial will turn relatively slowly because of the geared down speed of the gear-motor output **122**, for example one revolution per minute, so that the amount of phase shift can be readily observed by the operator.

End-adjustment is provided by first providing a conventional worm gear **160** between a pair of thrust bearings **162** mounted in housing **110** by a sleeve **164**. Sleeve **164** is secured to housing **110** by screws **166** passing through a flange **168** provided on the sleeve and into the housing. The central opening of worm gear **160** is provided with screw threads **170** which mate with corresponding threads **172** formed on the periphery of motor support **100**. Thus, as worm gear **160** is rotated, it will cause motor support **100** to move axially in a direction corresponding to the direction that gear **160** is rotated. Motor which is, **100** is, as previously explained, secured to motor **42** which is in turn, secured to shaft **44**. Shaft **44** is rotatably connected to rigid spline **50** via thrust bearing **76** and end plate **70**. Spline **50** is connected to driving gear **28** which is rotatably mounted on journal **30** by thrust bearing **38**. Thus, axial shifting of motor support **100** causes the printing roller to be axially shifted.

Worm gear **160** is rotated by rotation of a similar smaller diameter worm gear **180** which is, of course, positioned for meshing engagement with gear **160**. Gear **180**, as best illustrated in FIG. **5**, is secured for rotation in the conventional manner to a shaft **182**. Shaft **182** is supported in a holder **184** which is itself secured to housing **110** by screws **186** passing through a flange **188** provided on the holder and into the housing. A handwheel **190** is secured for rotation with shaft **182** to enable the operator to easily turn the shaft to effect end-adjustment. If desired, a conventional shaft clamp (not shown) may be provided to prevent rotation of shaft **182** by normal machine vibrations when end-adjustment is not being made.

A pointer **192** is fastened to motor support **100** (See FIG. **1**). A graduated scale **194** is fastened to fixed housing **110** adjacent pointer **192**. As support **100** is shifted axially, the pointer **192** will indicate the end-adjustment distance traveled along scale **194**.

FIG. **6** in addition to illustrating the printing rollers, also schematically illustrates the conventional impression cylinders **200** used to press the blanks **18** against dies **24** ad and **28**. Also shown are conventional support rollers **202** for supporting the blanks as they advance from one printing roller to the next.

In operation, dies **24** and **28** are secured in the known manner to printing rollers **10** and **12**, respectively. Ink is applied to the dies by conventional inking apparatus. Thereafter, one or more blanks are advanced by the feeding mechanism (not shown) between the pairs of printing rollers and impression cylinders. The blank is examined for register by the operator. If axial end-adjustment is required, the operator measures the amount and then turns handwheel **190** until pointer **192** has moved along scale **194** the correct distance. If circumferential adjustment is required, again the distance is measured and then the gear motor is energized to rotate in the proper direction by drum switch lee lever **128** until dial **150** has rotated the correct distance past the zero line **156**.

The foregoing procedure can be used to register the outline of K **22** (roller **10**) with respect to the feeding mechanism, that is, position it the correct distance from the forward and side edge of the blank. Thereafter, the same adjustments can be made to roller **12** to register solid letter K **26** with outline letter K **22** to form the complete indicia K **20**. The machine can be started again and the registration will be accurate. If for some reason it is not, the operator can make final adjustments while the machine is running as set forth above.

I claim:

1. Apparatus for changing and indicating the angular phase and axial position of a printing member comprising;

a driving member for said printing member rotatable relative to said printing member;

phase shifting apparatus having an input coupled to said driving member and rotatably driven thereby and having an output coupled to said printing member and further having a wave-generator between said input and said output for changing the angular phase of said output with respect to said input;

said phase shifting apparatus including:

a. a rigid circular spline secured for rotation with said driving member and having internal spline teeth thereon;

b. a flexible circular spline of smaller diameter than said rigid spline supported within said rigid spline and having external spline teeth thereon;

c. an elliptical wave generator supported within said flexible spline and adapted to deflect said flexible spline to a correspondingly elliptical shape for urging said external teeth into meshing engagement with said internal teeth substantially opposite the foci of said elliptical wave generator;

power means having a primary output coaxially coupled to said printing member through said wave-generator and said flexible spline for selectively rotating said wave-generator in either a clockwise or counterclockwise direction during rotation or nonrotation of said driving member thereby changing the radially angular position of meshing engagement between said internal and external teeth;

said power means including a secondary output axially opposite to said primary output;

phase indicator means coupled to said secondary output and rotated thereby in a direction and at a distance corresponding to the direction and distance of rotation of said primary output for indicating the angular relation of said printing member with respect to said driving member;

said power means including an output shaft coupled to said printing member through said elliptical wave-generator and said flexible spline;

axial end-adjustment means coupled to said power means for axially shifting said output shaft during rotation or nonrotation of said driving member to thereby axially shift said printing member; and

axial indicator means associated with said power means for indicating the axial position of said printing member.

2. The apparatus of claim **1** wherein said driving member is a spur gear to rotatably mounted on one end of said printing member.

3. The apparatus of claim **2** wherein said power means is a gear-motor mounted coaxially with said phase shifting apparatus.

4. The apparatus of claim **3** wherein said phase shift indicator means includes a worm coupled with a secondary output of said gear-motor for driving a worm wheel associated therewith and printing member graduated dial coupled to said worm wheel for indicating the direction and distance of the phase shift of said printing member with respect to said driving member.

5. The apparatus of claim **4** wherein said end-adjustment means includes:

first and second worm gears fixed in rotatable operative engagement in a stationary housing;

a movable support secured to said gear-motor and adapted for sliding engagement within said housing along the axis of said printing member;

said gear-motor including an output shaft coupled to said printing member through said elliptical wave-generator and said flexible spline;

said first worm gear having internal screw threads in operative engagement with corresponding external threads on said movable support; and

a handwheel coupled to said second worm gear for rotating said first worm gear through said second gear whereby said first worm gear axially shifts said movable support to thereby shift said printing member through said output shaft coupled to said printing member.

6. The apparatus of claim **5** wherein said axial indicator means includes a pointer secured to said movable support and a graduated scale secured to said stationary housing adjacent said pointer whereby axial movement of said support moves said pointer along scale for indicating the axial shift of said printing member.

7. Apparatus for changing the angular phase of first and second printing rollers with respect to driving means therefor and with respect to each other and for changing the axial position of said rollers comprising, in combination:

a first spur gear mounted on one end of said first printing roller rotatable relative thereby by said driving means;

a second spur gear mounted on one end of said second printing roller rotatable relative thereby by said first spur gear;

substantially identical phase shifting apparatus coaxially coupled to each of said spur gears, each shifting apparatus having an input rotatably driven by its associated spur gear and an output coupled to its respective printing roller, each shifting apparatus having a coaxial wave-generator radially aligned between said input and said output for changing the angular phase of said output with respect to said input whereby the angular phase of said first printing roller is changed with respect to said driving means upon rotation of its associated wave-generator and the angular phase of said second printing roller is changed with respect to said first printing roller upon rotation of its associated wave-generator;

each of said phase shifting apparatus including: a. a rigid circular spline secured for rotation with said driving member and having internal spline teeth thereon;

b. a flexible circular spline of smaller diameter than said rigid spline supported within said rigid spline and having external spline teeth thereon;

c. an elliptical wave-generator supported within said flexible spline and adapted to deflect said flexible spline to a corresponding elliptical shape for urging said external teeth into meshing engagement with said internal teeth substantially opposite the foci of said elliptical wave-generator;

a gear-motor for each of said phase shifting apparatus having a primary output coaxially coupled to its respective printing member through said wave-generator and said flexible spline for selectively rotating said wave-generator in either a clockwise or counterclockwise direction during rotation or nonrotation of said driving member

thereby changing the radially angular position of meshing engagement between said internal and external teeth;

axial end-adjustment means for each of said printing rollers including:

first and second worm gears fixed in rotatable operative engagement in a stationary housing;

a movable support secured to said gear-motor and adapted for sliding engagement within said housing along the axis of said printing member;

said gear-motor including an output shaft coupled to said printing member through said elliptical wave-generator and said flexible spline;

said first worm gear having internal screw threads in operative engagement with corresponding external threads on said movable support;

each of said second worm gears having a handwheel coupled thereto for rotating said worm gears whereby said first worm gear axially shifts its associated movable support to thereby shift its associated printing roller;

indicator means coaxially coupled to each of said gear-motors including a third worm coupled with a secondary output of said gear-motor for driving a fourth worm wheel in operative rotatable engagement therewith and a graduated dial coupled to said fourth worm wheel for indicating the direction and distance of the phase shift of the associated printing roller; and

axial indicator ma means associated with each of said gear-motors including a pointer secured to said movable support and a graduated scale secured to said stationary housing adjacent said pointer whereby axial movement of said support by said handwheel moves said pointer along said scale for indicating the axial shift of each of said printing rollers.