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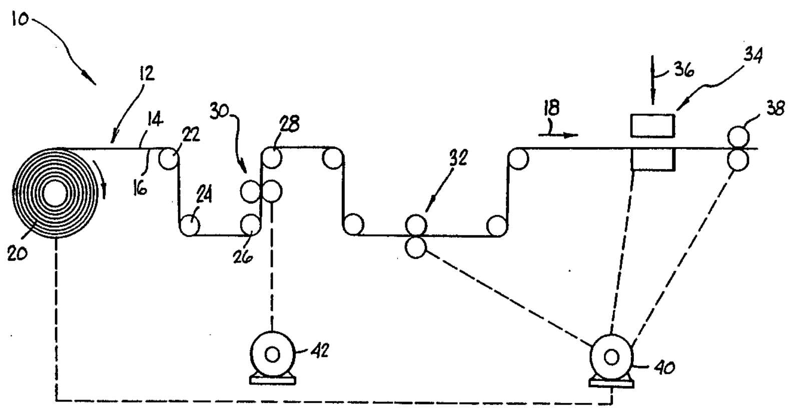

(57) Abstract

A printing apparatus for printing repeat length portions of a continuous moving web with a predetermined print pattern comprising repeat length measuring assembly (90, 98, 96) for measuring the current length of the repeat length portions of the web and generating a repeat length signal indicative thereof; rotary print cylinder (30) having a peripheral printing surface for rotatingly engaging a first surface portion of the web and repeatedly printing the print pattern thereon; print cylinder drive for rotating the rotary print cylinder at a predetermined variable speed dependent on current web speed, the measured current repeat length and the circumference of the peripheral printing surface of the print cylinder is disclosed. A phasing assembly (90, 120, 42) for initially selecting a phasing relationship between web and print cylinder and automatically maintaining the selected phasing relationship is also disclosed.

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ROTARY PRINTING APPARATUS AND METHOD

The present invention relates generally to rotary printing apparatus for printing repeat length portions of a continuous moving web and, more particularly, to a rotary printing apparatus adapted to print webs having small differences in repeat lengths without changing print cylinders.

U.S. Patent No. 4,254,173 for COMPOSITE MATERIAL FOR SECONDARY CONTAINER PACKAGING of A. Dean Peer, Jr. describes a laminated composite material comprising a paper layer and a back-printed plastic film layer which is adhered to the paper layer. The back-printing of the plastic layer (i.e. printing of the surface of the plastic layer which is subsequently adhered to the paper layer) provides high quality graphics which are not subject to smearing due to the fact that the printing indicia is not located on an exterior surface of the resulting composite material. Another advantage of such a composite material is its relatively high strength and high tear resistance as compared to paper material of similar thickness. For economic reasons, the film material used in forming the laminated composite disclosed in U.S. Patent No. 4,254,173 is relatively thin and subject to stretching during the lamination process. U.S. Patent No. 4,496,417 for CONTROL STRETCH LAMINATING DEVICE of Haake et al. and U.S. Patent No. 4,572,752 for CONTROL STRETCH LAMINATING DEVICE of Jensen et al. describe methods for monitoring and controlling the repeat length of the printed film layer prior to laminating it to the paper portion of the laminated composite. The control method includes the sensing of register indicia positioned within each repeat length portion of the web and counting a pulse signal from a rotary encoder occurring between register indicia pulses. Laminating apparatus such as described in U.S. Patent Nos. 4,496,417 and 4,572,752 have been successful in providing composite webs having relatively constant repeat lengths which are defined by the web graphics on the film layer portion of the composite. However, in spite of the control techniques used in such laminating apparatus, minor variations in repeat length sometimes occur within a particular role of composite material thus produced or, more commonly, between different rolls of composite material which are produced at different times and thus subject to different environmental conditions which affect stretch control such as temperature, humidity, etc. Each of the patents cited in this paragraph is hereby specifically incorporated by reference for all that it discloses.

Although the deviations in repeat lengths between composite webs produced with the same film layer graphics are generally quite small, e.g. +/- 1/8 inch on a web having a repeat length of 30 inches, the deviation is sufficient to produce problems when the web is to be subsequently printed with repeat length graphics which must be registered with the originally printed film graphics. The subsequent printing of graphics is typically on the exposed surface of the paper layer and is typically applied with a flexigraphic print cylinder.

Flexigraphic print cylinders generally comprise a rotary steel drum which is adapted to have the outer periphery thereof covered with a relatively thin, e.g. 1/8 inch thick, rubber layer which has raised printing characters on the outer periphery thereof. The circumference of the outer periphery of the rubber attachment defines the "repeat length" of the print cylinder. Typically, a number of rubber print layers of slightly different outer circumference are kept on hand to accommodate differences in web repeat length from one spool of web material to another. If the repeat length of a cylinder varies substantially from the repeat length of the originally printed graphics of the web, the graphics printed in the second printing operation will quickly move out of phase with the originally printed graphics on the web due to the difference in the circumference or repeat length of the print cylinder with respect to the repeat length of the web as defined by the first set of repeating graphics printed thereon. Even a relatively small difference, e.g. 1/16 inch, between the circumference of the print cylinder and the repeat length of the original web graphics will cause a significant phase shift after several printing operations, e.g. a difference of 1/16 inch will produce a relative shift in the position of the second printed set of graphics of 1 inch after 16 repeat printing operations.

Prior to the present invention, the method for maintaining the second set of graphics in registry with the first set of graphics was to change print cylinders so as to match the circumference of the print cylinder exactly with the repeat length of the first set of printed graphics on the web. A problem with this approach is that each new rubberized printing surface which for a printing drum costs on the order of $200, and multiple printing surfaces varying in small increments, e.g. 1/32 inches, must be maintained, ready and available at the printing site. An associated problem is that changing of printing surfaces requires a shut-down of the production line while the new printing surface is installed and rephased to the web. Gravure printing cylinders might also be used for printing the second set of graphics onto previously printed webs subject to repeat length deviations. In a gravure printing operation, the cost of providing extra cylinders to accommodate repeat length variations is even more significant in that, in gravure printers, the outer metal periphery which carries the printing ink to the surface of the web is directly etched. Thus to accommodate a change in web repeat length the entire drum must be replaced at a cost on the order of $4,000 - $5,000 per drum.

The present invention may comprise a printing apparatus for printing repeat length portions of a continuous moving web with a predetermined print pattern. The printing apparatus includes a rotary print cylinder which has a peripheral printing surface which is adapted to engage one surface portion of the web and repeatingly print a print pattern thereon. The printing apparatus includes means for measuring web speed and web repeat length, i.e. the repeat length of previously printed web graphics. The rotary print cylinder is driven by a variable speed drive motor at a predetermined speed which is dependent upon the measured web speed and measured web repeat length and which is also dependent upon the circumference of the peripheral printing surface of the print cylinder. More specifically, the print cylinder is driven at a surface speed which is equal to the measured surface speed of the web multiplied by the circumference (or "repeat length") of the peripheral printing surface of the print cylinder divided by measured repeat length of the web. The invention causes a controlled distortion in the graphics pattern applied by the print cylinder to accommodate slightly different repeat lengths from one web spool to the next. If the repeat length of a web is slightly longer than the circumference of the associated print cylinder, then the surface speed of the print cylinder is precisely controllably decreased relative to the speed of the web to cause a slight elongation of the printed matter in the direction of web movement. Similarly, if the repeat length of the web is slightly shorter than the circumference of the print cylinder, then the speed of the print cylinder is increased by a predetermined amount over the surface speed of the web to cause a relative shortening of the print pattern produced by the print cylinder on the web. Such controlled distortion of the print pattern eliminates the need for replacing print cylinders in response to small changes in repeat lengths between different web spools which are to be printed. Thus speed control is used to effectively increases or decreases the repeat length of the printing cylinder so as to match it to the repeat length of the web without physically altering the print cylinder.

The printing apparatus may also include a phasing assembly which is used to phase the print cylinder to the moving film web, i.e. the phasing apparatus initially orients the print cylinder such that a selected point on the periphery of the cylinder is registered with a selected point within a repeat length of the web and thereafter maintains the selected point on the web in registration with the selected point on the cylinder.

The initial selection of points on the cylinder and web which are to be registered is performed through the use of a strobe light which is actuated in response to the sensing of each register indicia on the film web. The strobe light is positioned at a fixed station along the web and thus illuminates the same region of each repeat length portion of the web. An imaging device such as a video camera is positioned next to the strobe light and images the region of the web illuminated by the strobe light. The strobe light and video camera illuminate and image the side of the web which is being printed by the print cylinder. A push button device is used by an operator to temporarily rapidly accelerate (or decelerate) the print cylinder relative to the web to cause a relative shift in the portion of the newly printed graphics which are illuminated by the strobe. A hairline is provided on a display terminal which displays the illuminated area imaged by the video device. The operator may thus accelerate (or decelerate) the print cylinder until a selected portion of the newly printed graphics on the web is aligned with the cross hairs on the video display.

After the initial phasing relationship is selected the phasing system automatically maintains this phasing relationship even though web repeat length may vary slightly from one end of a web roll to another and even though phasing may temporarily be thrown off substantially by a web splice. The phasing assembly automatically determines the positions of the points on the cylinder and web that are initially selected for registration by counting cylinder encoder pulses after a cylinder absolute position reference pulse and by counting web encoder pulses after a register indicia pulse. These count values are "recorded", i.e. stored in computer memory, and are used during each succeeding cylinder revolution and corresponding repeat length of web travel to determine whether the initially selected phasing relationship between cylinder and web has been maintained. If it is determined that the two selected points are not in registration then the relative speed of the cylinder or web (preferably the cylinder) is temporarily varied by a calculated amount to bring the two points back into registration within the next few repeat lengths of web and cylinder travel. The acceleration/deceleration needed from time to time for phasing adjustment temporarily overrides the speed control used to vary the effective repeat length of the cylinder.

Fig. 1 is a schematic illustration of a web processing apparatus.

Fig. 2 is a plan view of a portion of a web passing through the web processing apparatus of Fig. 1.

Fig. 3 is a schematic illustration of a rotary printing assembly of the web processing apparatus of Fig. 1.

Fig. 4 is a plan view of a portion of a web printed by a printing assembly which does not have the control features of the printing assembly of the present invention.

Fig. 5 is a plan view of a portion of a web printed by the printing assembly of Fig. 3.

Fig. 6 is a schematic signal drawing illustrating various signals used in the control of the printing apparatus of Fig. 3.

Fig. 7 is a flow chart diagram illustrating the basic operations used in association with the web printing apparatus of Fig. 3 for controlling the effective repeat length of the printing cylinder.

Fig. 8 is a flow chart diagram illustrating the basic operations used in association with the web printing apparatus of Fig. 3 for controlling the phasing of the print cylinder to the web.

Fig. 1 illustrates a web processing apparatus 10 for processing a continuous web of material having a first surface 14 and a second surface 16. During processing, the web 12 moves in a downstream direction 18 through the apparatus. The web may be dispensed from a web supply spool 20 and passes over a plurality of idler rolls 22, 24, 26, 28, etc. which define a web path through the processing apparatus 10. After leaving the web spool 20, the web passes through a rotary printing assembly 30, a first draw nip roll assembly 32, a cutter assembly 34, and a second draw nip roll assembly 38. In one exemplary embodiment, the cutter assembly is a reciprocal cutter having an upper die portion moving reciprocally as indicated at 36 to cut carton blanks of a predetermined shape from the continuous web 12. The cutter assembly 34, and the draw nip roll assemblies 32, 38, are attached to a common drive shaft of drive motor 40.

A print roll drive motor 42 is conventionally mechanically linked to the rotary printing assembly 30 and drives the rotary printing assembly at a selectively variable printing speed to accommodate variations in the repeat length of the web, as will be described in detail below.

Fig. 2 is a plan view of the first surface portion 14 of web 12 at a position immediately upstream of the rotary printing assembly 30. The first surface 14 of the web has identical graphics patterns printed on equal-length repeat length portions 54, 56, 58, 60 thereof, which for illustrative purposes are shown separated by dashed lines. In one exemplary embodiment, the web 12 is a composite web comprising a plastic layer portion which provides first surface 14 and a paper layer portion which provides second surface 16. The plastic layer portion has repeating graphics back-printed thereon prior to lamination with the paper layer. Such a laminated web is described in detail in U.S. Patent Nos. 4,254,173; 4,496,417; and 4,572,752 which are hereby specifically incorporated by reference for all that is disclosed therein. These patents describe the process by which the film layer of such a laminate web is back-printed and also describe certain problems associated with stretching of the plastic layer which may cause variations in the repeat length of the composite web which is produced. As a result of the problem of extensibility in the film web portion of a back-printed laminate composite, the repeat length of composite webs produced by the same laminating apparatus may vary somewhat from roll to roll. For example, in a composite roll having a design repeat length of 30 inches, it is not uncommon to encounter a variation in repeat length of +/- 1/8 inch from roll to roll. The printing assembly 30 of the present invention accommodates such variations in repeat length so that graphics patterns printed thereby on the second surface 16 of the web are printed in an appropriate size and are printed in registration with the repeating graphics which are pre-printed on the first surface 14 of the web.

As illustrated in detail in Fig. 3, the rotary printing assembly 30 comprises a print cylinder 70 having a peripheral printing surface 72. As shown in Figs. 4 and 5, the peripheral printing surface 72 comprises an indicia pattern 74 which is adapted to be repeatedly printed on second web surface 16. The print cylinder 70 is driven from the drive shaft of printing assembly motor 42. In one preferred embodiment of the invention, which is presently the best mode contemplated, the print cylinder comprises a flexigraphic print cylinder having raised printing indicia thereon. Flexigraphic print cylinders are conventional and known in the art. In another embodiment of the invention, the print cylinder may comprise a gravure print cylinder having printing indicia provided by etching the peripheral surface of the cylinder. Gravure print cylinders are also conventional and known in the art.

An idler impression cylinder 80, Fig. 3, which may be of a conventional type well-known in the art is provided in operable association with the print cylinder. The impression cylinder 80 is in frictional contact with surface 14 of the web and thus moves at web speed. The print cylinder 70 and impression cylinder 80 define a print nip 82 through which the web passes as it is printed. In a conventional printing nip, the print cylinder and impression cylinder rotate at the same surface speed. It is a feature of the present invention that the print cylinder 70 may rotate at a surface speed different from the surface speed of the impression cylinder 80.

A data processing unit 90 is provided for receiving and processing various data signals and for issuing command signals to drive motor 42 so as to drive print cylinder 70 at an appropriate speed for maintaining proper registration with repeat length portions of web 12. The data processing unit may comprise a conventional microcomputer such as an IBM 386 computer equipped with appropriate software and interfacing with conventional "smart motor" control circuitry. For example, print cylinder drive motor 42 may comprise a commercially available "smart motor" equipped with an imbedded motor control circuit such as Model MC740 available from Galil, Inc. of San Francisco, California. The motor control circuit may be adapted to interface with an IBM compatible 386 computer or other comparable computer.

A print motor encoder 92 which may comprise a conventional electronic encoder is operably mounted on motor 42 and provides an encoder signal representative of the speed and position of the motor shaft which is also indicative of the rotation speed and rotated position of the print cylinder 70.

A web encoder 94 may be mounted on an idler roll 26, immediately upstream of the print nip 82, and provides an electronic signal having a predetermined number of pulses per revolution. The number of pulses in any predetermined period of time is thus representative of the distance of web travel during that period, and the number of pulses per unit of time is indicative of web velocity.

As best indicated in Figs. 2 and 3, a bar code scanner 96 is positioned opposite web first surface 14 at a position in alignment with the path of travel of identical bar codes 97 which comprises a portion of each repeating graphics pattern defining repeat length portions 54, 56, 58, 60, etc. The bar code scanner 96 may have an update interval of approximately 60 updates per second. The bar code scanner, upon detecting the presence of a bar code indicia 97 in its scan path, provides a signal indicative thereof to data processor 90. The data processor 90, in response to receiving the bar code detection signal, actuates a photoeye 98 for a predetermined period of time determined by a preselected distance of web travel either immediately upon receipt of the bar code detection signal or at a predetermined period of time thereafter which may also be dependent upon web travel. The photoeye, upon actuation, senses differences in contrast on the film web and thus may be used to detect a preselected edge portion such as 99 on the web graphics. Since the photoeye may be actuated at any predetermined point in time after the bar code detection signal, the actuation period is selected to begin at a point just prior to the point when a preselected, clearly visible edge portion of the web graphics will pass under the photoeye. Upon sensing the predetermined portion of the web graphics, the photoeye emits a detection pulse indicative thereof which is received and processed by the data processing unit 90. The photoeye is switched off a predetermined number of web travel encoder pulses, or alternatively clock pulses, after actuation and remains off until triggered by the next bar code detection signal. The detection of indicia on a moving web and various equipment used therefore are described in detail in U.S. Patent 4,835,720 of Ditto et al issued May 30, 1989 and U.S. Patent 4,864,631 of Jensen issued September 5, 1989 which are hereby specifically incorporated by reference for all that is disclosed therein.

The data processing apparatus 90 generates an actuation command signal to a strobe light 112 at a predetermined point in time which is dependent upon web travel distance occurring after the indicia detection pulse from the photoeye 98. The strobe light unit 112 is positioned at a predetermined distance of web travel downstream from the photoeye and the printing nip and is adapted to sequentially illuminate a region along the second side surface 16 of the moving web which is in turn imaged by an optical imager 114 such as a high-speed video camera. The video camera 114 is operably connected to a video display monitor 116 having a targeting or cross hair indicia 118 provided thereon which is indicative of the center point 119 of the region on the web which is being imaged. A motor acceleration and/or deceleration control unit 120 is provided, which may be a button-actuated unit. The motor acceleration unit is used to provide a signal to computer 90 which in turn issue a command signal to temporarily rapidly accelerate or decelerate motor 42 to cause a relative phase shifting of the web with respect to print cylinder 70 to control the longitudinal position at which printing is initiated in each repeat length portion of the web.

Fig. 4 is a plan view of the second surface 16 of the web in which dashed lines 122, 124, 126, 128 illustrate the divisions between repeat length portions 54, 56, 58, 60 of the web. The repeat length portions of the web are defined by the graphics patterns which have been preprinted on the first surface 14 of the web in a prior printing process (not shown) such as that described in U.S. Patent 4,572,752. Each repeat length portion of the web comprises a region 130 in which printing performed by cylinder 70 should be positioned for proper registry with the graphics patterns on the opposite side of the web. Each of these regions 130 comprises a leading edge 132 at which the printing should commence and a trailing edge 134 at which the printing should terminate. In a conventional printing process, the circumference of the peripheral printing surface 72 of the print cylinder L_p should be equal to the repeat length L_w of the web. In such a situation, once the graphics pattern 74 on the cylinder is properly phased to the web, then each area 140 on which printing actually took place would correspond to the region 130. However, in a situation as illustrated in Fig. 4 in which the circumference L_p of the print cylinder is slightly less than the repeat length L_w of the web and in which no accommodating cylinder speed adjustment is made, phasing and registration problems occur. Fig. 4 shows the registration and phasing errors which occur in such a situation. Unprinted repeat length 54 indicates an area 130 where the graphics pattern associated with surface 74 of the print cylinder is designed to be printed. In repeat length portion 56 in which printing initially takes place, the leading edge of the printed pattern 142 is properly phased with the leading edge 132 of the design or "target" printing area 130. However, due to the fact that the length of the printing region 74 on the print cylinder is shorter than the length of the target area 130, the trailing edge 144 of the printed portion is positioned forward of the trailing edge 134 of the target area. In the next repeat length portion of the web 58, the printed portion 140 has phase-shifted relatively forward with respect to the target area such that the leading edge 142 of the printed portion is positioned downstream of the leading edge 132 of the target area, and the trailing edge 144 of the printed area is positioned farther downstream from the trailing edge 134 of the target area than in the previous repeat length portion 56. The phasing error continues to accumulate as illustrated in repeat length portion 60 and will further increase with each succeeding repeat length.

In rotary repeat length printing processes used prior to the present invention, the manner of accommodating a small variation in repeat length was to change print cylinders. A print cylinder having a circumference equal to the circumference of the current repeat length of the web was used in replacement of the undersized or oversized print cylinder previously mounted in the apparatus. Such a solution was expensive because it required the use of multiple print cylinders of slightly different sizes and also because it required shut-down of the printer and mounting of a new print cylinder each time that a spool of material having a repeat length variation from the previous spool was encountered.

Fig. 5 illustrates operation of the same printing apparatus as that illustrated in Fig. 4 but with the print length and phasing control of the present invention in operation, i.e. the print cylinder circumference L_p in Fig. 5 is identical to that in Fig. 4, but the repeating graphics portions 140 printed on the repeat length portions 56, 58, 60 are made to be identical in length and placed in registry with the target areas 130.

The manner in which this result is achieved will now be described. Fig. 6 is a signal value/time graph of various signals used to implement the cylinder speed control function of the printing assembly 30. Signal 220 is a bar code pulse signal generated by bar code reader 96 and having bar code sensing pulses 222. Signal 230 is a register indicia signal generated by photoeye 98 and having register indicia pulses 232 corresponding to the detection of a register indicia. Signal 240 is a web encoder signal having encoder pulses 242 which are representative of a predetermined distance of web travel. Signal 250 is a clock pulse signal having pulses 252 representative of a predetermined unit of time. Signal 260 is a print cylinder encoder signal having pulses 262 representative of a predetermined distance of print cylinder surface travel and having pulses 263 occurring once per cylinder revolution for providing an absolute reference.

As indicated in Fig. 2, each bar code 97 has been provided on the web at a fixed location with respect to graphic indicia 99 printed on the web. Photoeye unit 98 is positioned at a lateral location relative to the web such that it will sense the passage of a predetermined point 100 on web graphics 99 which is selected for use as a register indicia. The distance from the trailing edge of the bar code to the point 100 on the selected register indicia 99 is measured and is used for selecting an operating interval t_a of photoeye unit 98. The interval t_a is selected such that the register indicia sensor 98 will be switched on a short period of time before a register indicia 99 passes below it and for a short interval after such passage. A relatively short interval is selected such that other indicia or smudges on the web will not mistakenly generate a register indicia pulse. The actuation interval t_a may be initiated immediately upon the leading edge of the bar code pulse signal 222 or may be initiated at some predetermined interval after the occurrence of the leading edge of the bar code pulse signal depending on the graphics configuration of the particular web involved. The interval t_a is preferable selected based upon a count of web encoder pulse signals occurring after the occurrence of the leading edge of a bar code pulse signal 222 but could alternatively be selected based upon clock pulses in an apparatus which operates at a relatively fixed line speed.

Register indicia pulse signals 232 and web encoder pulse signals 242 are used for determining web repeat length. Specifically, web repeat length is determined by counting the number of web encoder pulse signals occurring in each time interval tr_1, tr_2, etc. between register indicia pulse signals 232.

Web speed may be determined by counting the number of web encoder pulse signals occurring in a predetermined number of clock pulses.

Print cylinder surface speed may be determined by counting the number of print cylinder encoder pulses occurring in a predetermined number of clock pulse signals.

Fig. 7 illustrates the basic control functions performed by computer 90 to control the relative speed of the print cylinder to provide an effective print cylinder repeat length which matches the repeat length of the web. Initially the circumference of the print cylinder is input to computer 90 by an operator using a conventional input device such as a keyboard 91 or a thumb wheel. The computer continuously determines the web repeat length by counting the number of web encoder pulses occurring between register indicia pulses as described above. In one preferred embodiment of the invention, the actual web repeat length value which is used in subsequent calculations is based upon a number of web repeat length measurements, e.g. an average of the preceding ten web repeat length measurements with the two largest and two smallest measurements disregarded. The web speed is constantly sampled and updated. The actual web speed value used for any particular calculation may also be based upon an average of several immediately preceding web speed samplings. A print cylinder speed value may also be based upon multiple previous samplings. The computer 90 determines the speed at which the print cylinder should presently be operating by multiplying the current web speed value by the print cylinder circumference divided by the current web repeat length value. The computer compares this desired print cylinder speed to the currently measured print cylinder speed and issues a speed control command to the print cylinder to either increase or decrease its speed based upon the comparison in order to operate the print cylinder at the determined desired speed. Conventional control algorithms may be utilized for selecting the relative gain, etc. associated with print cylinder speed adjustment.

Although it is preferable to adjust print cylinder speed rather than web speed in order to achieve the desired speed ratio discussed above it would also be possible in some situations to adjust web speed with respect to print cylinder speed to achieve the same printing results.

Data processor 90 is programmed to produce the above print cylinder speed control automatically. Based upon this speed control a base reference speed of print cylinder 70 is achieved. However after a proper base reference speed has been established it is still necessary to accurately phase the print cylinder 72 with respect to the preprinted web graphics such that each graphics portion printed by cylinder 72 will occur in the predetermined region 130 on the associated web repeat lengths as illustrated in Fig. 5. The basic phasing operations performed by the apparatus 10 is illustrated in Fig. 8.

Proper phasing is initially achieved by temporarily decelerating or accelerating the print cylinder 70 below or above its determined base speed to move the graphics pattern printed by the print cylinder 72 either relatively forwardly or rearwardly within the repeat length. As previously described, this result may be achieved by an operator's actuation of a selection unit 120 to selectively accelerate or decelerate the print cylinder 70 until a selected portion of cylinder 72 printed web graphics are aligned with a cross hair 118 provided on display monitor 116. The computer "records" this phasing relationship by counting the number of web encoder pulses 242 which occur between the occurrence of the last register indicia pulse 232 and the point at which the operator releases the button of selection unit 120, and by counting the number of cylinder encoder pulses 262 which occur between the occurrence of the last absolute cylinder encoder pulse 263 and the point at which the operator releases the button of selection unit 120. These two phasing selection data values are stored in computer memory.

After the phasing selection data values are stored the computer continuously monitors the occurrence of the two selected phase points by counting encoder pulses. It counts web encoder pulses 242 occurring after each register indicia pulse 222 up to the stored data value associated with the web for determining the occurrence of the web phase point and it counts cylinder encoder pulses 262 occurring after each absolute encoder pulse 263 up to the stored data value associated with the cylinder for determining the occurrence of the cylinder phase point. Any difference between the time of occurrence of the selected phase point of the web and the selected phase point of the cylinder is measured as by counting the number of web encoder pulses 242 or the number of cylinder encoder pulses 262 occurring between the two phase points. This differential value of encoder pulses represents a phasing error signal which is used by the computer as a basis for correcting the phasing. If the phase points do not occur simultaneously then the computer issues commands to the cylinder motor 42 such that the print cylinder is relatively accelerated or decelerated with respect to the web for a short phasing correction interval so as to bring the two phase points back into simultaneity. Conventional control algorithms well known in the art may be provided in computer software or firmware and used to implement this corrective operation. The gain setting of the phasing control software is preferably set such that phasing correction, even after a web splice, may be achieved within three or four repeat lengths of web travel. The use of conventional control algorithms and gain selection for such control algorithms is within the level of skill of a person of ordinary skill in the art.

While illustrative and presently

preferred embodiments of the invention have been described in detail herein, it is to be understood that the inventive concepts may be otherwise variously embodied and employed and that the appended claims are intended to be construed to include such variations except insofar as limited by the prior art. For example, although the invention is described in an embodiment in which one motor 40 is used to drive the web and another motor 42 is used to drive the print cylinder at a speed dependent upon the speed of motor 40, it will also be understood that a variable speed differential unit attached to the output shaft of motor 40 which receives that shaft speed as a base speed input and which has an output shaft which has a speed which is selectively adjustably variable relative to that base speed input could be used as an alternative to independent motor 42.

CLAIMS

1. A printing apparatus for printing repeat length portions of a continuous moving web with a predetermined print pattern comprising:

repeat length measuring means for measuring the current length of said repeat length portions of said web and generating a repeat length signal indicative thereof;

rotary print cylinder means having a peripheral printing surface for rotatingly engaging a first surface portion of said web and repeatingly printing said print pattern thereon;

print cylinder drive means for rotating said rotary print cylinder at a predetermined variable speed dependent on current web speed, said measured current repeat length and the circumference of said peripheral printing surface of said print cylinder means.

2. The invention of claim 1, said print cylinder drive means rotating said print cylinder means at a surface speed equal to said surface speed of said web multiplied by said circumference of said peripheral printing surface of said print cylinder means divided by said current repeat length of said web.

3. The invention of claim 2, further comprising:

web speed measuring means for measuring the current speed of said moving web and generating a signal in response thereto.

4. The invention of claim 1, wherein:

said repeat length measuring means comprises:

indicia detection means for detecting a repeating indicia on each repeat length portion of said web and generating an indicia detection signal pulse in response thereto;

first encoder means associated with said web for generating a first encoder signal having pulses indicative of web travel;

first counter means for counting the number of encoder pulses occurring between the detection signal pulses.

5. The invention of claim 4, further comprising print cylinder monitoring means.

6. The invention of claim 5, wherein said print cylinder monitoring means comprises:

second monitoring means associated with said print signal having pulses indicative of print cylinder surface travel.

7. The invention of claim 6, wherein said print cylinder monitoring means comprises:

second counter means for counting the number of second encoder pulses occurring between detection signal pulses.

8. The invention of claim 1, further comprising phasing means for phasing said print cylinder to said web whereby said predetermined print pattern is printed at a predetermined location within each repeat length portion of said web.

9. The invention of claim 8, said phasing means comprising means for temporarily accelerating or decelerating said print cylinder drive means relative to said web for temporarily rapidly changing the surface velocity of said print cylinder means with respect to the surface velocity of said web.

10. The invention of claim 9, said phasing means further comprising:

web indicia sensing means for sensing a repeating indicia within each repeat length portion of said web and generating an indicia sensing signal in response thereto;

strobe means for illuminating said web at a predetermined imaging station along said web in response to said indicia sensing signal; and

imaging means for imaging said web at said imaging station and generating an imaging signal in response thereto.

11. The invention of claim 10, said phasing means further comprising:

display means responsive to said imaging signal for displaying a current image of said web; and

target means on said display means adapted to be aligned with a predetermined portion of said print pattern on said displayed image of said web.

12. The invention of claim 11, said means for temporarily accelerating or decelerating said print cylinder drive means being manually actuatable means.

13. The invention of claim 8, said phasing means comprising:

means for initially selecting a phasing relationship between said web repeat length portions and said print cylinder;

means for automatically recording said selected phasing relationship;

means for monitoring said web and said cylinder for determining deviations from said selected phasing relationship and generating a signal representative of phasing error; and

means for automatically temporarily accelerating or decelerating at least one of said web and said print cylinder based upon said phasing error signal to maintain said selected phasing relationship.

14. The invention of claim 13, said print cylinder drive means normally rotating said print cylinder means at a surface speed equal to said surface speed of said web multiplied by said circumference of said peripheral printing surface of said print cylinder means divided by said current repeat length of said web.

15. A method of printing a repeating indicia pattern onto approximately equal length repeat length portions of a moving web using a print cylinder having a peripheral printing surface with a circumference which is nominally equal to the length of the repeat length portions of the web comprising:

determining the current surface speed of the web;

determining the current length of the repeat length portions of the web;

driving the print cylinder at a surface speed which is directly proportionate to the circumference of the print cylinder and the current surface speed of the web and inversely proportionate to the current length of the repeat length portions of the web.

16. The method of claim 15, wherein the step of driving the print cylinder comprises driving the print cylinder at a surface speed which is equal to the circumference of the print cylinder multiplied by the current surface speed of the web divided by the current length of the repeat length portions of the web.

17. The invention of claim 16, comprising the further step of phasing the print cylinder to the web such that the repeating indicia pattern is printed at a predetermined location within each repeat length portion of the web.

18. A method of printing a moving web

having a repeat length which differs from the circumference of an associated printing cylinder comprising:

determining the ratio of the circumference of the print cylinder to the repeat length of the web;

controllably deforming a repeating indicia pattern which is normally printed onto repeat length portions of the web by driving the printing cylinder at a surface speed different from the surface speed of the moving web and dependent upon the said web surface speed and said ratio.

19. The method of claim 18, comprising the further step of phasing the printing cylinder to the moving web such that the repeating indicia pattern is printed at a predetermined location within each repeat length portion of the moving web.

20. A method of phasing repeat length portions of a moving web to a print cylinder comprising:

generating a first data value representative of the position of a selected point within a web repeat length based upon a web travel signal;

generating a second data value representative of an angular position of the print cylinder which is in phase with the selected point within the web repeat length based upon a cylinder rotation signal;

storing the data values representative of the selected points;

in succeeding web repeat lengths monitoring the occurrence of the point which corresponds to the first data value;

in succeeding cylinder revolutions

monitoring the occurrence of the point corresponding to the second data value;

determining any difference between the occurrence of the monitored points corresponding to the first and second data values; and

temporarily relatively accelerating or decelerating the cylinder relative to the web based upon the determined difference so as to return the occurrences of the selected point in web graphics represented by the first data value and the corresponding angular position of the cylinder represented by the second data value to simultaneity.

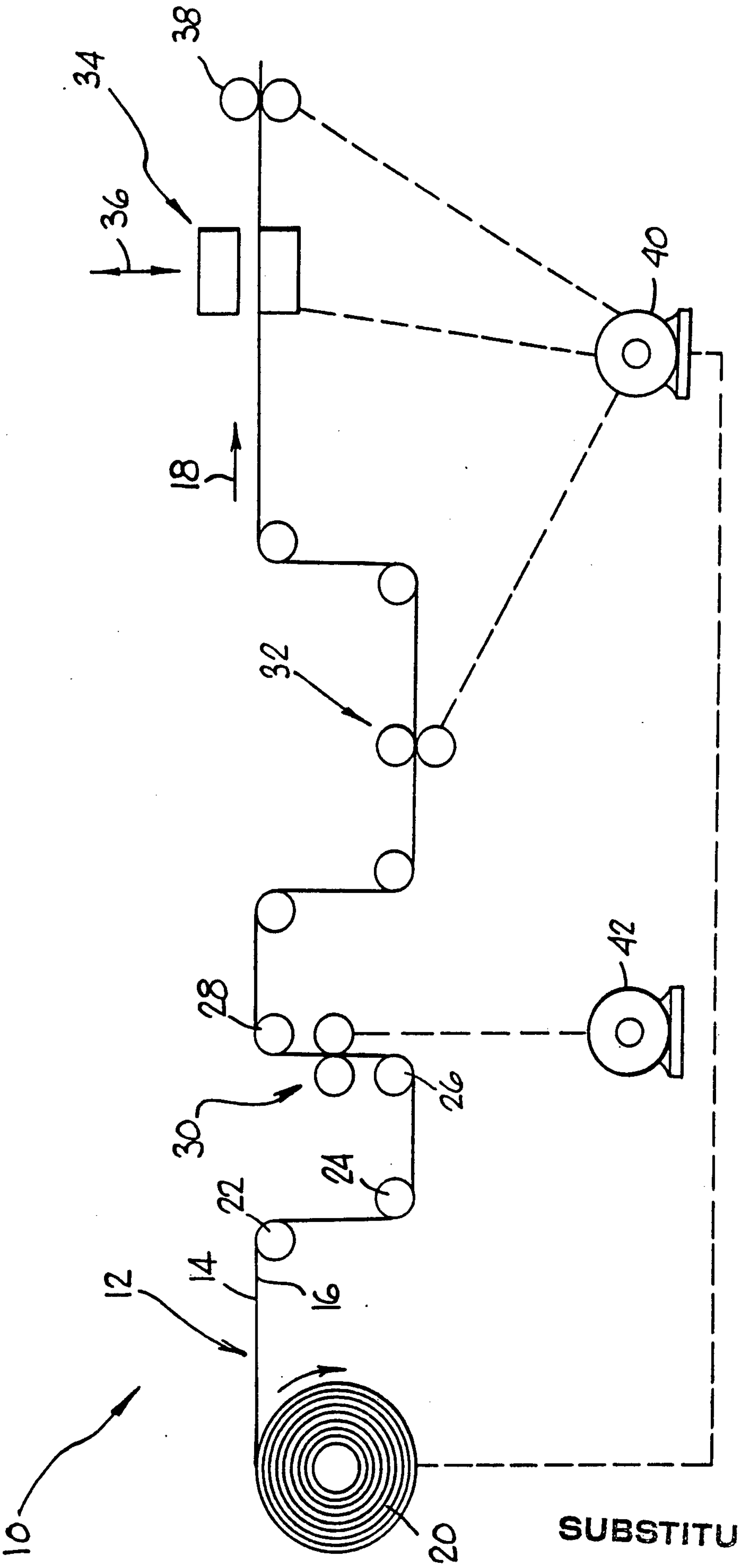
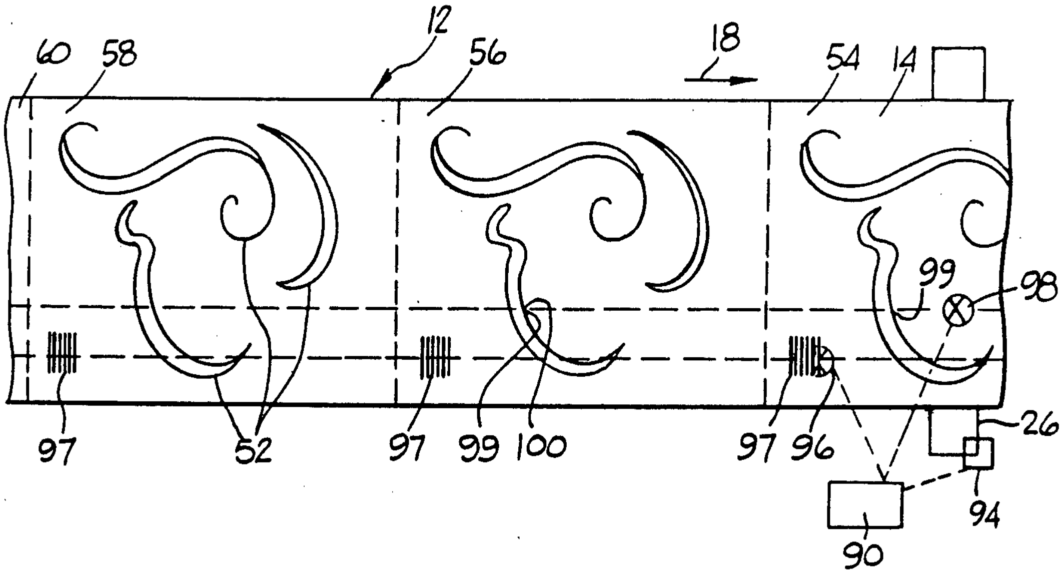


FIG.1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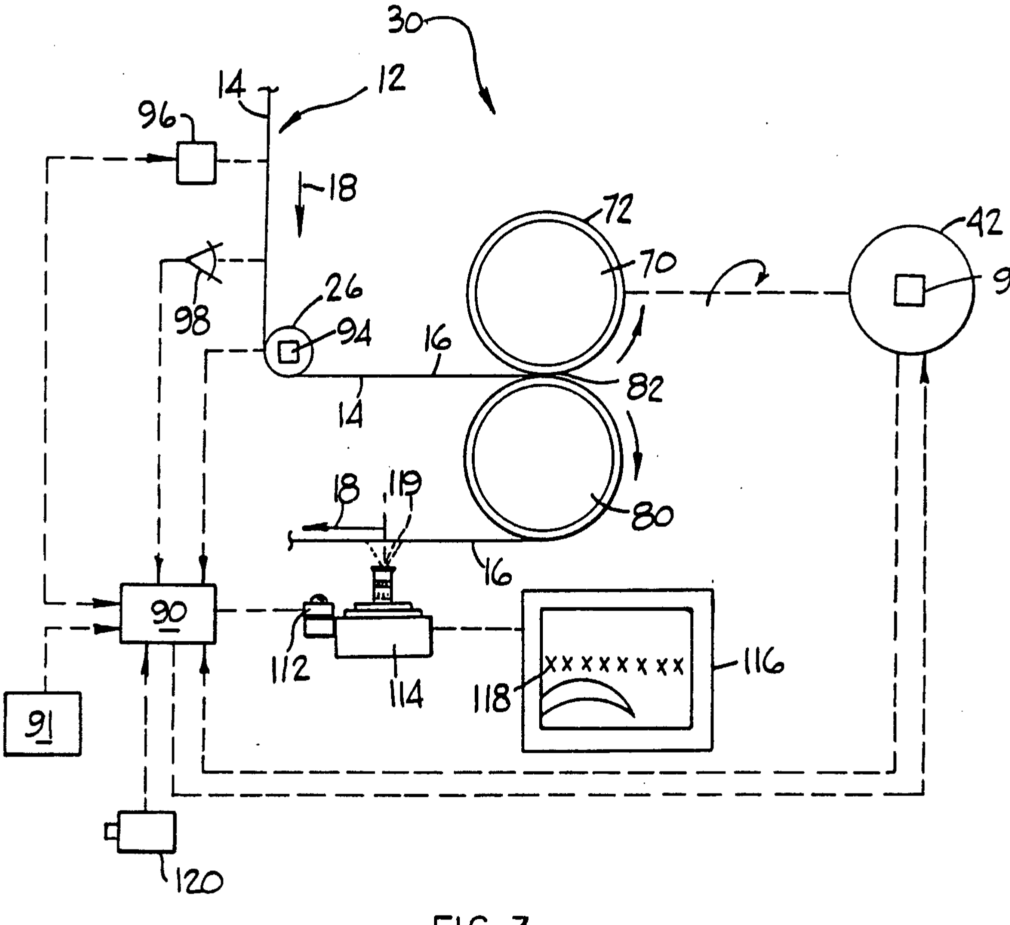
94
90

FIG. 2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116
118
91
120

FIG. 3

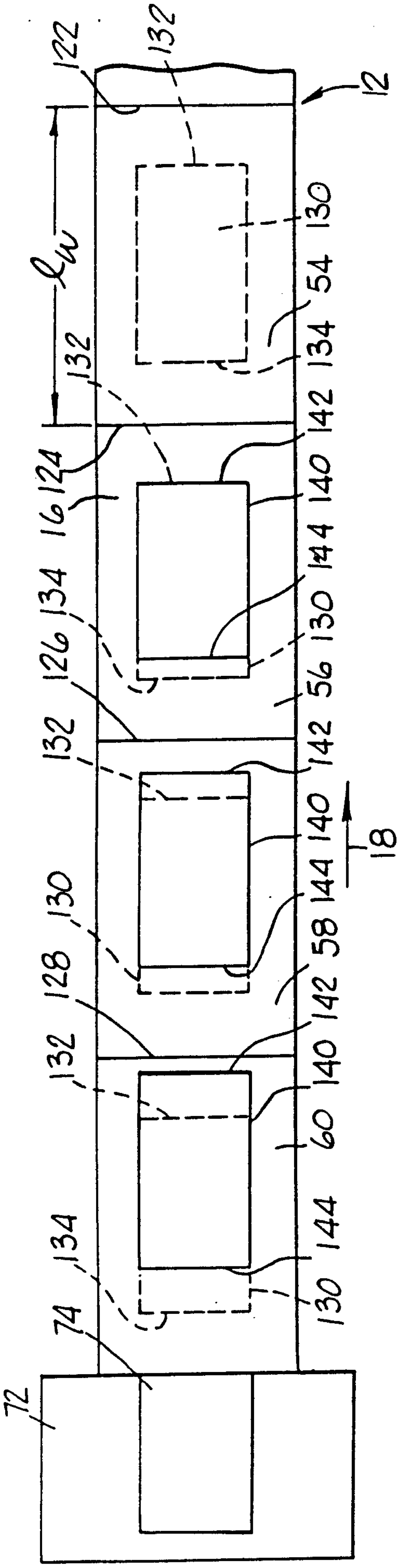
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FIG.4

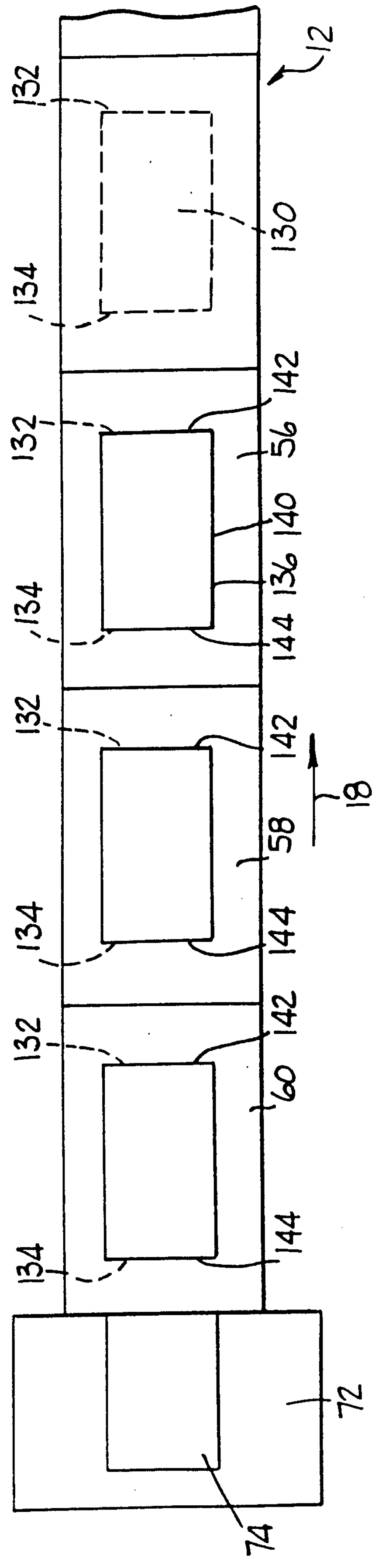
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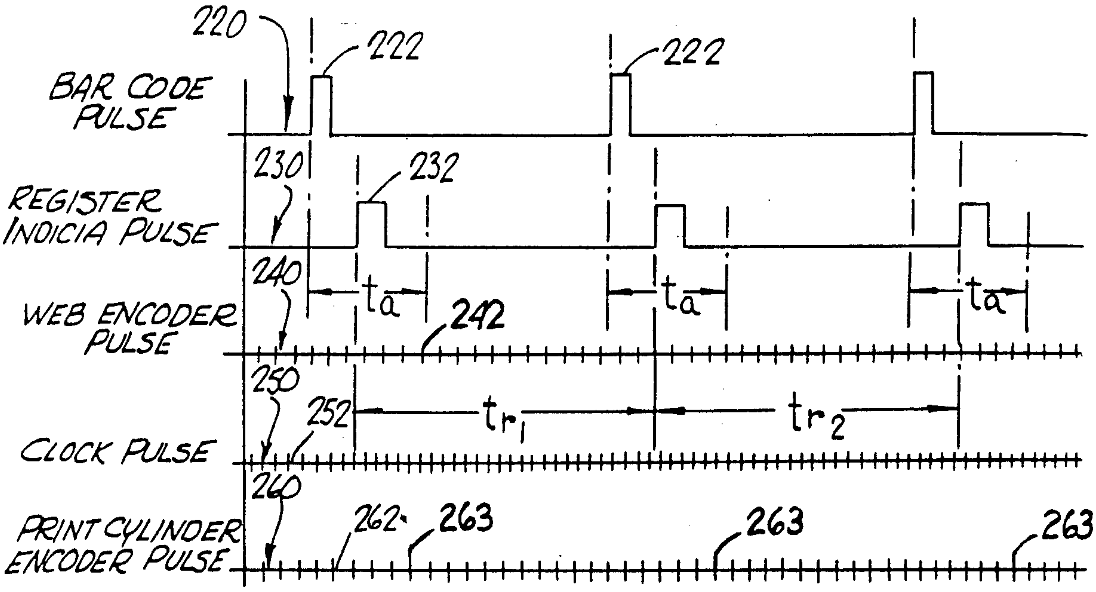
FIG 5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222
BAR CODE PULSE
230
232
REGISTER INDICIA PULSE
240
ta
ta
ta
WEB ENCODER PULSE
242
250
252
tr1
tr2
CLOCK PULSE
260
PRINT CYLINDER ENCODER PULSE
262
263
263
263

FIG. 6

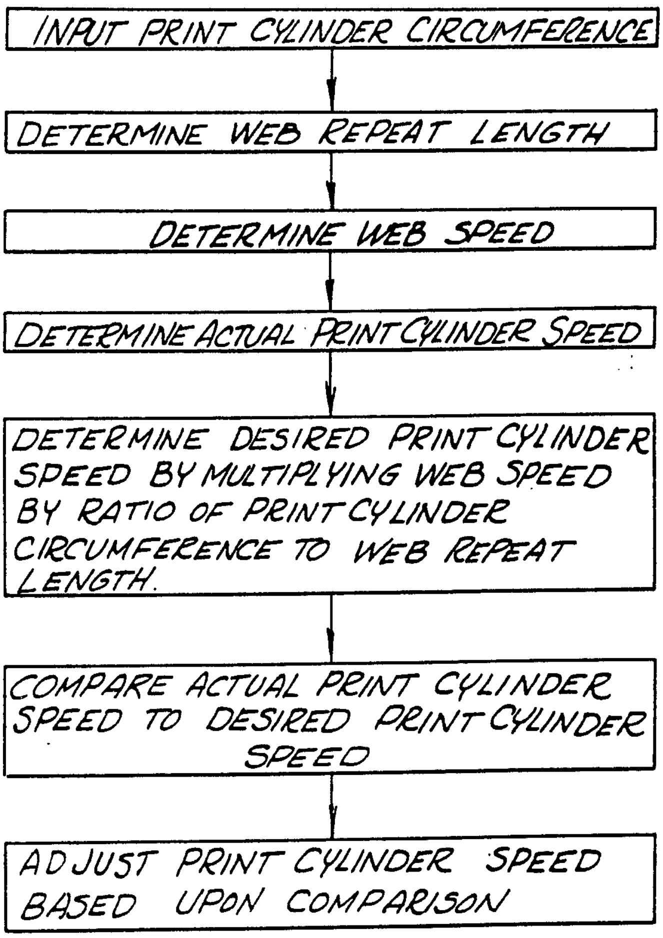
INPUT PRINT CYLINDER CIRCUMFERENCE
DETERMINE WEB REPEAT LENGTH
DETERMINE WEB SPEED
DETERMINE ACTUAL PRINT CYLINDER SPEED
DETERMINE DESIRED PRINT CYLINDER SPEED BY MULTIPLYING WEB SPEED BY RATIO OF PRINT CYLINDER CIRCUMFERENCE TO WEB REPEAT LENGTH.
COMPARE ACTUAL PRINT CYLINDER SPEED TO DESIRED PRINT CYLINDER SPEED
ADJUST PRINT CYLINDER SPEED BASED UPON COMPARISON

FIG. 7

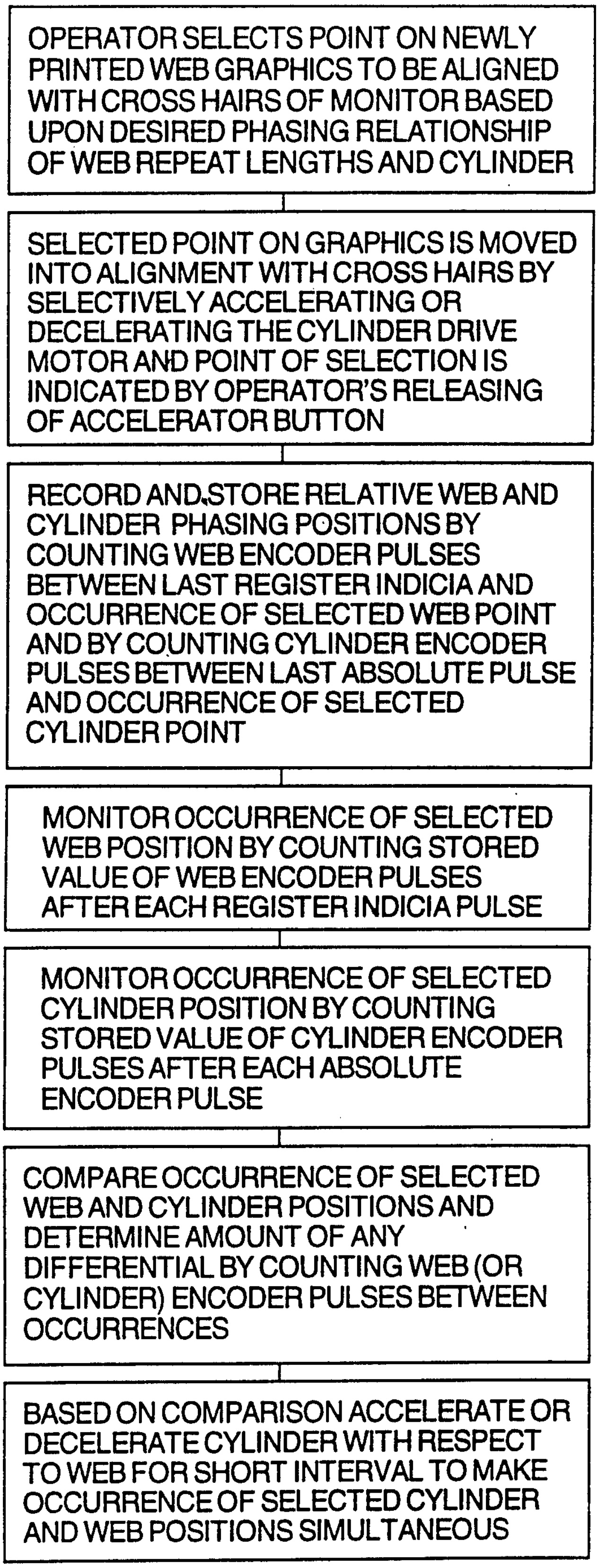
OPERATOR SELECTS POINT ON NEWLY PRINTED WEB GRAPHICS TO BE ALIGNED WITH CROSS HAIRS OF MONITOR BASED UPON DESIRED PHASING RELATIONSHIP OF WEB REPEAT LENGTHS AND CYLINDER
SELECTED POINT ON GRAPHICS IS MOVED INTO ALIGNMENT WITH CROSS HAIRS BY SELECTIVELY ACCELERATING OR DECELERATING THE CYLINDER DRIVE MOTOR AND POINT OF SELECTION IS INDICATED BY OPERATOR'S RELEASING OF ACCELERATOR BUTTON
RECORD AND STORE RELATIVE WEB AND CYLINDER PHASING POSITIONS BY COUNTING WEB ENCODER PULSES BETWEEN LAST REGISTER INDICIA AND OCCURRENCE OF SELECTED WEB POINT AND BY COUNTING CYLINDER ENCODER PULSES BETWEEN LAST ABSOLUTE PULSE AND OCCURRENCE OF SELECTED CYLINDER POINT
MONITOR OCCURRENCE OF SELECTED WEB POSITION BY COUNTING STORED VALUE OF WEB ENCODER PULSES AFTER EACH REGISTER INDICIA PULSE
MONITOR OCCURRENCE OF SELECTED CYLINDER POSITION BY COUNTING STORED VALUE OF CYLINDER ENCODER PULSES AFTER EACH ABSOLUTE ENCODER PULSE
COMPARE OCCURRENCE OF SELECTED WEB AND CYLINDER POSITIONS AND DETERMINE AMOUNT OF ANY DIFFERENTIAL BY COUNTING WEB (OR CYLINDER) ENCODER PULSES BETWEEN OCCURRENCES
BASED ON COMPARISON ACCELERATE OR DECELERATE CYLINDER WITH RESPECT TO WEB FOR SHORT INTERVAL TO MAKE OCCURRENCE OF SELECTED CYLINDER AND WEB POSITIONS SIMULTANEOUS

FIG. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US93/09016

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :B41F 5/04; B41F 13/14
US CL :101/181
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 101/181, 248, 219, 228, 183, 184, 485, 486, 484, 483;
226/2, 24, 28-31, 38-42; 364/469, 559; 250/548, 559, 561

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

None

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

None

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 4,781,317 (Ditto) 01 November 1988. See column 4, lines 22-68; column 5, lines 1-32.	1-20
Y	US, A, 4,528,630 (Sargent) 09 July 1985. See column 4, lines 50-66.	1-20
Y	US, A, 4,932,320 (Brunetti et al.) 12 June 1990. See column 3, lines 34-61.	10, 11
Y	US, A, 2,619,901 (Harrold) 02 December 1952. See column 7, lines 14-47.	18, 19

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be part of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 December 1993	04 FEB 1994
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	Authorized officer FISHER, J. REED
Facsimile No. NOT APPLICABLE	Telephone No. (703) 308-0858

Form PCT/ISA/210 (second sheet)(July 1992)★