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(54) Web cutting apparatus and method

(57) A web cutting apparatus comprises an upstream web drive (18) for continuously feeding a web (16) to be cut into a web buffer (24). A downstream web drive (38) intermittently feeds the web (16) from the web buffer (24) to a cutting station (44). Measuring devices (36, 38) measure the length of the web (16) fed into and from the web buffer (24), and the length (L_b) of web in the buffer is calculated therefrom. A control device (28) responsive to information received from this calculation controls operation of the downstream web drive (38) and of the cutting station (44). Accurate cutting of the web is thereby possible irrespective of any variations in the speed of the web arriving at the cutting apparatus.

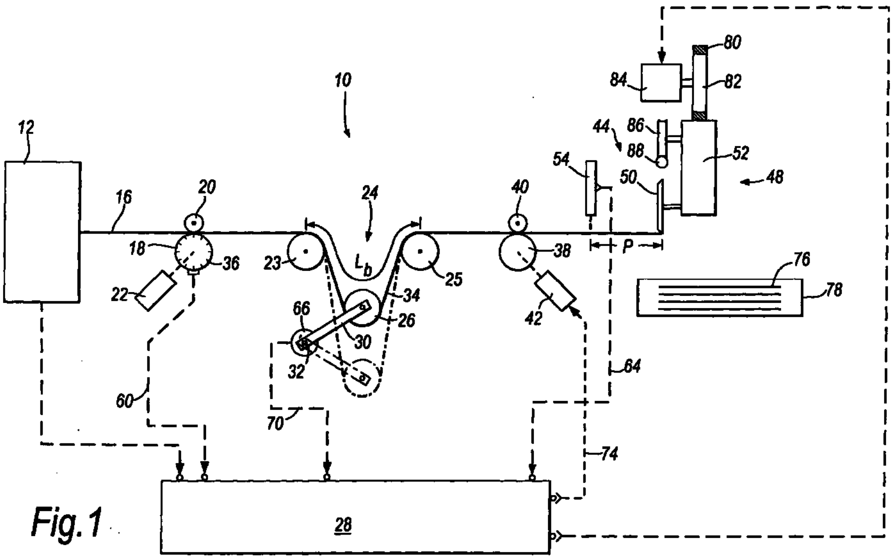

Fig.1

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Description

Field of the invention

[0001] The present invention relates to a web cutting apparatus, especially suitable for cutting the printed web output from a web-fed printing machine, into sheets.

Background of the invention

[0002] In web-fed printers, it is often desired for the output product to be in the form of sheets. As the printed webs exits the printer, it is necessary to cut the web into sheets at desired positions on the web, usually between discrete images. Although devices are known for cutting a web while it continues to move, they are difficult to control, and take no account of any variations in the speed of the web. It has therefore been proposed to stop the movement of the web while cutting takes place. Since the movement of the web through the printer cannot usually be stopped, a web buffer is provided between the printer and the cutting apparatus. An upstream web drive continuously feeds the web into the buffer. A downstream web drive intermittently feeds the web from the buffer to a cutting station. While the web is stationary in the cutting station, further web from the printer builds up in the buffer. The built-up quantity of web material in the buffer is run down between cutting actions. (As used herein, the terms "upstream" and "downstream" relate to positions relative to the web buffer.)

[0003] However, such an apparatus may only be capable of cutting with an accuracy of, say, ±0.5 mm. In some applications a higher accuracy of, say, ±0.2 mm is required.

[0004] The inaccuracy of the prior art devices derives, in part, from variations in the speed of the web leaving the printer, slippage of the web over the drive rollers, variations in the thickness of the web and variations in the elasticity of the web, possibly as a result of changing environmental conditions.

[0005] It is an object of the present invention to provide a web cutting apparatus, and a method for cutting a web, in which greater accuracy can be obtained.

SUMMARY OF THE INVENTION

[0006] We have discovered that this objective, and other useful benefits can be achieved by the provision of upstream and downstream measuring devices for measuring the nominal length of the web fed into and from the web buffer, to enable the length of the web in the web buffer to be calculated and a control device to control operation of the downstream web drive and of the cutting station, thereby to enable cutting of the web at the cutting station at predetermined locations on the web.

[0007] Thus, according to a first aspect of the invention, there is provided a web cutting apparatus comprising an upstream web drive for continuously feeding a web to be cut into a web buffer, and a downstream web drive for intermittently feeding the web from the buffer to a cutting station, characterised by an upstream measuring device for measuring the nominal length of the web fed into the web buffer, a downstream measuring device for measuring the nominal length of the web fed from the web buffer, and a control device responsive to information received from the upstream and downstream measuring devices to calculate the length of the web in the web buffer and to control operation of the downstream web drive and of the cutting station, in response thereto, thereby to enable cutting of the web at the cutting station at predetermined locations on the web.

[0008] According to a second aspect of the invention, there is provided a method of cutting a web comprising continuously feeding a web into a web buffer with an upstream web drive, intermittently feeding the web from the buffer to a cutting station with a downstream web drive, and cutting the web at the cutting station, characterised by calculating the length of the web in the web buffer by measuring the nominal length of the web fed into the buffer and measuring the nominal length of the web fed from the buffer, and controlling the operation of the downstream web drive and the cutting station in response thereto, thereby to enable cutting of the web at the cutting station at predetermined locations on the web.

[0009] The buffer may comprise a movable balance roller over which the web passes. A position sensing device, such as a servo potentiometer, may be included for determining the position of the movable roller and supplying information relating to the sensed position to the control device. Although the length of the web in the web buffer may theoretically be calculated from the difference between the nominal length of web fed into the buffer and the nominal length of web fed from the buffer, a number of factors contribute to the possibility of this calculation being in error. For example, slippage of the web at the upstream web drive may result in a shorter length of web being fed into the buffer. Slippage of the web at the downstream web drive may result in a shorter length of the web being fed from the buffer. Stretching of the web may result in a longer web length in the buffer. By determining the position of the movable roller in the web buffer, such errors can be identified and the control device can be programmed to respond thereto.

[0010] The apparatus may further comprise a sensor positioned between the downstream web drive and the cutting station to sense timing marks located on the web, the control device being responsive to information received from the sensor.

[0011] In one embodiment of the invention, signals from the sensor are responded to only during a period of time within which a timing mark is expected to arrive at the sensor. That is, the control device effectively opens a sensor window for a period when a timing mark is expected. By this provision, inadvertent operation of the cutting device by sensing of other marks on the web can be avoided. The timing marks need not therefore positioned in the lateral margins beyond the printed image on the web.

[0012] While it is known to provide timing marks in the margins of the printed web, where no other printing takes place, some applications prefer not to waste this space, but rather to provide the timing marks between the images. The sensing of such timing marks is however difficult, because the sensing devices used have to distinguish between the timing marks and the images. The present invention enables the use of timing marks in the spaces between the images enabling the control device to predict when an inter-image space is in the vicinity of the sensor and only to react to the timing marks at this time. In this manner, confusion between the timing marks and the images is avoided.

[0013] The control device controls the operation of a cutting device provided at the cutting station in response to information received from the upstream and downstream measuring devices. This feature enables the sensor to be spaced from the cutting station and enables the timing marks to be positioned, if desired, at a location other than the exact point where the web is to be cut.

[0014] Preferably, the downstream web drive is stopped, and the web is stationary, while the web is being cut at the cutting station.

[0015] A cutting knife is preferably provided at the cutting station and an associated knife transport device is provided for driving the knife across the width of the web, thereby to cut the web. A rotary cutting knife may be used, together with an associated knife transport device for driving the knife across the width of the web, thereby to cut the web into sheets. The knife transport device may comprise a movable carriage which carries the rotating cutting knife and which is supported from a continuous drive belt extending across the width of the apparatus. The drive belt is suitably driven by a stepping motor or by a DC motor with associated encoder. The carriage may be supported for movement across the width of the web by the engagement of a running wheel in a guide rail.

[0016] To reduce the time during which the web is stationary, the web cutting device may be adapted to cut the web in either direction of travel. Usually, a single knife is provided to make a single cut in the web. It is also possible to provide, for example, two knives, operating in parallel, adapted to cut away a strip of the web material. This may be useful if it is desired to cut away, and dispose of, that inter-image portion of the web in which the timing marks have been printed. This useful effect can also be obtained with a single knife construction, by operating the knife twice, i.e. back and forth, with an intermediate advancement of the web.

[0017] The apparatus according to the invention may be coupled to a printer capable of printing discrete images on the web, the control device being responsive to information indicative of the position of each discrete image on the web. In this manner, the apparatus is able to cut the web at desired locations, even when the size and spacing of the printed images are not constant.

[0018] The upstream measuring device may be in the form of an encoder device associated with the upstream web drive, such as a rotational encoder which produces pulses indicative of the rotation of an upstream web drive roller. The downstream web drive and the downstream measuring device are preferably constituted by a stepping motor. By the provision of these features, the web buffer may be stabilised.

[0019] Operation of the downstream web drive is preferably selected between at least three modes, namely:

(i) a first mode in which the downstream web drive is driven at a speed in relation to the speed of the upstream web drive such as to maintain a constant web path length in the buffer;

(ii) a second mode in which the downstream web drive is stopped while the web is being cut at the cutting station; and

(iii) a third mode in which the downstream web drive is driven at such a speed in relation to the speed of the upstream web drive as to reduce the web path length in the buffer.

[0020] Where the web buffer comprises a movable balance roller over which the web passes, the downstream web drive is preferably controlled so as to maintain a constant position for the balance roller during the first mode.

[0021] Preferably, the second and third modes follow a predetermined profile which defines the relationship between the speed of the downstream web drive and time.

[0022] In a preferred embodiment of the invention, the control device is programmed to take account of a number of factors, namely:

- the distance between the printer and the buffer,
- the distance between the buffer and the sensor,
- the length between the sensor and the cutting station,
- the relative position of the timing mark with respect to the desired position of the web cut;
- the nominal relationship between the circumference of the upstream web drive roller and the number of the pulses generated by the encoder per revolution of the upstream drive roller; and
- the nominal relationship between the circumference of the downstream web drive roller and the number of steps performed by the stepping motor per revolution of the downstream web drive roller.

[0023] The parameters associated with these factors may be determined by prior calibration of the apparatus.

[0024] The control device is preferably programmed with a correction factor, which takes account of any errors due to variations in the effective diameter of the drive rollers (the web thickness is indeed part of the effective driving diameter), slippage between the web and the drive rollers, and vibrations causing possible small encoder errors. This correction factor may be determined from time-to-time by comparing the expected position of a timing mark on the web with the actual position thereof or by comparing the total number of pulses received from the encoder with the total number of steps performed by the stepping motor for a period of time at the end of which the balance roller in the web buffer lies at the same balance position.

[0025] The speed of the web is measured solely through the position sensing device of the balance roller, which provides a less accurate measurement than an encoder positioned on the upstream web drive in the short term, but a more accurate measurement in the long term. Thus it is simply necessary to regulate the speed of the downstream web drive so as to keep the position of the balance roller constant. This arrangement provides a more accurate long term measurement, because the balance roller position integrates every error in time. Thus, even if the error between the web speed and the encoder output were to be very small, the balance roller eventually would move out of its balance position.

[0026] On the other hand, the encoder on the upstream web drive is useful because it provides a more accurate measurement in the short term, when it comes to predicting the position of timing marks in the first few metres of web length. The encoder on the upstream web drive is also useful for calculating the correction factor to be applied by comparing the expected position of a timing mark on the web with its actual position. Although the length of the web in the buffer could be calculated from the encoder output over time, more processing time and capacity would be required compared with the direct measurement which characterises the present invention.

[0027] The invention will now be further described, purely by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a schematic illustration of a web cutting apparatus according to the invention, coupled to a printer;

Figure 2 is a perspective view of an embodiment of the invention as schematically illustrated in Figure 1; and

Figure 3 is an illustration of a portion of a web passing through the apparatus shown in Figure 1, the web carrying images of variable length.

[0028] As shown in Figure 1, a web cutting apparatus 10 is coupled to a printer 12 capable of printing discrete images 14 on a web 16 (see Figure 3). The apparatus comprises an upstream web drive roller 18, in contact with an opposing nip counter roller 20, driven by a motor 22 which is in turn controlled by the control system (not shown) of the printer 12. The web drive roller 18 continuously feeds the web 16 from the printer 12 over a freely rotating upstream guide roller 23 into a web buffer 24. The buffer 24 comprises a freely rotating balance roller 26 over which the web 16 passes. The balance roller 26 is carried on one end of an arm 30, the other end of which is pivoted about a fixed point 32. The balance roller 26 thereby constitutes a movable roller, the vertical position of which determines the length L_b of the web path 34 in the buffer 24.

[0029] A rotational encoder 36 is mounted on the web drive roller 18. The encoder 36 produces pulses indicative of the rotation of the web drive roller 18.

[0030] The web passes from the web buffer 24 over a freely rotating downstream guide roller 25 to a downstream web drive roller 38, in contact with an opposing nip counter roller 40, driven by a stepper motor 42, is provided for intermittently feeding the web 16 from the buffer 24 to a cutting station 44.

[0031] Although it is possible to use the web drive rollers 18 and 38 at the entrance to the web buffer 24, thereby dispensing with the guide rollers 23 and 25, we prefer the arrangement shown in Figure 1 where the web drive rollers 18 and 38 operate on a portion of the web which is substantially straight. This arrangement avoids errors arising due to variations in the thickness of the web.

[0032] A cutting device 48 is provided at the cutting station 44. The cutting device includes a cutting knife 50 and an associated knife transport device for driving the knife 50 across the width of the web 16, thereby to cut the web 16 into sheets 76 which fall into a sheet tray 78. As seen more clearly in Figure 2, the knife transport device comprises a movable carriage 52 which carries the rotating cutting knife 50. The carriage 52 is supported from a continuous drive belt 80 which extends across the width of the apparatus. The drive belt 80 passes over a pulley 82 driven by a stepping motor 84. The carriage 52 is supported for movement across the width of the web by the engagement of a running wheel 86 in a guide rail 88.

[0033] A sensor 54 is positioned between the web drive 38 and the cutting station 44 to sense timing marks 56 located on the web 16. As seen in Figure 3, the timing marks 56 are located between the discrete images 14 on the web 16, that is within the inter-image spaces 58 on the web. The timing marks 56 are spaced from each other by a distance D, which may, or may not, be constant, depending upon the nature of the images to be printed.

[0034] Referring back to Figure 1, a control device 28 in the form of a microprocessor, is provided to control operation of the web drive roller 38. The control device 28 receives pulses from the rotational encoder 36 via line 60 and signals from the sensor 54 via line 64. The control device 28 also receives information from the printer 12 indicative of the position of each discrete image 14 on the web 16. A servo potentiometer 66 sensitive to the position of the arm 30, is connected to the control device 28 by line 70. The control device 28 sends stepping instructions to the stepper motor 42 via line 74.

[0035] The apparatus operates as follows.

[0036] The web 16 is continuously fed from the printer 12 into the buffer 24 by the web drive roller 18. The web drive roller 18 operates at the speed of the printer which, while continuous, is not necessarily constant. The encoder device 36 generates pulses indicative of the operation of the web drive roller 18 and passes these pulses via line 60 to the control device 28.

[0037] The web 16 is intermittently fed from the buffer 24 to the cutting station 44 by the web drive roller 38 driven by the stepping motor 42 in response to signals from the control device 28 via line 74.

[0038] The web 16 is cut at the cutting station 44. The control device is programmed to control the stepping motor 42 of the web drive roller 38 to ensure that cutting of the web 16 at the cutting station 44 takes place at predetermined locations on the web 16.

[0039] The control device controls the operation of the web drive roller 38 as follows.

[0040] Initially, the control device 28 causes the web drive roller 38 to be driven at the same speed (as measured in terms of web displacement per unit time) as that of the web drive roller 18, as sensed by the servo potentiometer 66. Thereby, a constant web path length L_b is maintained in the buffer 24, as indicated by solid lines in Figure 1. During this phase, the position of the balance roller 26 is theoretically constant, at a balance position. Should any change in the web path length occur despite the web drive rollers 18 and 38 running at the same speed, perhaps due to some slippage or localised stretching of the web, the consequential upward or downward movement of the arm 30 is sensed by the servo potentiometer 66 and the control device 28 reacts to increase or decrease the speed of the web drive roller 38 in compensation. In this manner, the web buffer 24 is stabilized.

[0041] The control device 28 is programmed for example as set out below, to calculate when the web needs to be cut. From the information received from the printer 12, the control device 28 can calculate the distance which a timing mark 56 printed on the web 16 by the printer 12 has to travel from the printer 12 before being expected to be positioned beneath the sensor 54. After feeding the calculated number of pulses to the downstream web drive motor 42 the web 16 has been advanced so that an inter-image space 58 has reached the vicinity of the sensor 54. The timing mark 56, located in this inter-image space 58 on the web 16, is sensed by the sensor 54. Signals from the sensor 54 are passed to the control device 28. Given a constant web path distance P between the sensor 54 and the cutting station 44 and knowing the displacement of the timing marks relative to desired cutting position on the web, the control device is able to calculate how many further pulses need to be fed to the motor 42 to feed sufficient further web to the cutting station 44 in order to ensure that the web is cut at the desired position. At this point, the control device 28 initiates a predefined web control and cutting sequence. This may include a predefined slow-down phase for the downstream web drive motor 42 until the web drive roller 38 stops. As a consequence, the web 16 in the cutting station is then stationary. At the same moment, the control device 28 triggers operation of the cutting knife 50. The web 16 is stationary while it is being cut.

[0042] During this time however, the web drive roller 18 continues to run at the speed of the printer 12, thereby feeding web material into the buffer 24. The web path length L_b in the buffer 24 therefore increases, enabling the movable balance roller 26 to fall under its own weight, the arm 30 carrying this roller pivoting about the fixed point 32. This position is shown in broken lines in Figure 1.

[0043] After the web has been cut, the predefined web control and cutting sequence includes a speed up phase for the downstream web drive motor 42 to, for example, double normal speed, so as to reduce the web path length L_b in the buffer 24. This causes the movable balance roller 26 to be pulled upwards as viewed in Figure 1, with the arm 30 pivoting about the fixed point 32. This upward movement of the balance roller 26 continues so long as the downstream web drive roller 38 is driven at a greater speed than the upstream web drive roller 18. The web control and cutting sequence then includes a slow-down phase for the downstream web drive motor 42 to normal speed. Once the normal speed is reached, the balance roller 26 ceases to rise and the web buffer 24 is again stabilized, until the next cutting operation occurs.

[0044] The control device is programmed to respond to the following relationship:

$$L = L_a + L_b + L_c,$$

where:

L = the distance (e.g. in mm) which a timing mark printed on the web by the printer 12 has to travel from the printer 12 before being expected to be positioned beneath the sensor 54,

L_a = the distance (mm) between the printer 12 and the buffer 24,

L_b = the length (mm) of the web in the buffer 24, and

L_c = the distance (mm) between the buffer 24 and the sensor 54.

[0045] The parameters L_a, and L_c are constant and can be determined by prior calibration of the apparatus. The length L_b of the web in the buffer 24 is calculated from the cumulative count of the upstream encoder 36 (from the beginning of web movement) and the total number of pulses fed to the downstream drive motor 42. The encoder count is thereby converted into an equivalent motor step count through the use of a calibration factor which takes into account any tolerances of the mechanical components. The calculated length is further subjected to a correction based upon measurements of previous marker position errors, if any.

[0046] In an alternative embodiment, the length L_b of the web in the buffer 24 is calculated on the basis of the cumulative count of the encoder 36, the total number of pulses fed to the drive motor 42, the signal from the potentiometer 66, a timing signal from the printer 12 and previous marker position measurements. This process uses a calibration factor which includes the relationship between encoder and downstream motor counts for a given length of web movement, thereby including all mechanical tolerances. The process also uses a mathematical relationship between the balance roller position and the approximate web length in the buffer. All these signals are combined into an L_b-estimation with an accuracy high enough to allow accurate cutting of a printed web without the need for timing marks.

[0047] Having determined L, the number of pulses which need to be fed to the motor 42 before opening the sensor detection window can be determined. Once the mark is detected, the number of further pulses which need to be fed to the motor 42 to bring the web into the cutting position is calculated by the relationship:

$$K_{out} \Sigma S = P + L_d,$$

where

ΣS = the total number of steps to be performed by the stepping motor 42 (pulses),

K_{out} = the nominal relationship between the circumference of the downstream web drive roller 38 and the number of steps performed by the stepping motor 42 per revolution of the downstream web drive roller 38 (mm/pulse),

P = the web path distance (mm) between the sensor 54 and the cutting station 44, and

L_d = the displacement (mm) of the timing marks relative to desired cutting position on the web.

[0048] At a predetermined moment during the feeding of these further pulses to the motor 42, a slow-down profile is initiated so that the speed of the motor 42 reaches zero when all these further pulses have been fed thereto.

[0049] In a further alternative embodiment, a reference table is generated containing values for L_b corresponding to predetermined positions of the balance roller 26. The length L_b of the web in the buffer 24 is calculated from the cumulative count of the upstream encoder 36 and the total number of pulses fed to the downstream drive motor 42. The signal from the potentiometer 66 is measured and a corresponding reference value of L_b is determined from the reference table. This reference value of L_b is compared with the calculated value of L_b and when appropriate a corresponding correction may be performed. This approach may obviate the need of measuring timing marks.

Reference Number List

[0050]

web cutting apparatus 10
printer 12
discrete images 14
web 16
web drive roller 18
nip counter roller 20
motor 22
web buffer 24
balance roller 26
control device 28
arm 30
fixed point 32
length L_b
web path 34
rotational encoder 36
web drive roller 38
nip counter roller 40
stepper motor 42
cutting station 44
cutting device 48
knife 50
carriage 52
sensor 54
timing marks 56
inter-image spaces 58
line 60
line 64
servo potentiometer 66
line 70
line 74
sheets 76
tray 78
drive belt 80
pulley 82
stepping motor 84
running wheel 86
guide rail 88
distance D
web path distance P

Claims

1. A web cutting apparatus comprising an upstream web drive (18) for continuously feeding a web (16) to be cut into a web buffer (24), and a downstream web drive (38) for intermittently feeding said web (16) from said web buffer (24) to a cutting station (44), characterised by an upstream measuring device (36) for measuring the nominal length of said web (16) fed into said web buffer (24), a downstream measuring device (38) for measuring the nominal length of said web (16) fed from said web buffer (24) and a control device (28) responsive to information received from said upstream and downstream measuring devices (36, 38) to calculate the length (L_b) of said web (16) in said web buffer (24) and to control operation of said downstream web drive (38) and of said cutting station (44) in response thereto, thereby to enable cutting of said web (16) at said cutting station (44) at predetermined locations on said web (16).

2. An apparatus according to claim 1, wherein said web buffer (24) comprises a movable balance roller (26) over which said web (16) passes.

3. An apparatus according to claim 2 further comprising a position sensing device (66) for sensing the position of said movable balance roller (26) and supplying information relating to said position to said control device.

4. An apparatus according to any preceding claim, further comprising a sensor (54) positioned between said downstream web drive (38) and said cutting station (44) to sense timing marks (56) located on said web (16), said control device (28) being responsive to information received from said sensor (54).

5. An apparatus according to claim 1, wherein said upstream measuring device is an encoder device (36) associated with said upstream web drive (18).

6. An apparatus according to any preceding claim, wherein said downstream web drive and said downstream measuring device are constituted by a stepping motor (38).

7. An apparatus according to any preceding claim, wherein a cutting knife (50) is provided at said cutting station (44) and an associated knife transport drive device (52) is provided for driving said knife (50) across the width of said web (16), thereby to cut said web (16).

8. An apparatus according to any preceding claim coupled to a printer (12) capable of printing discrete images (14) on said web (16), said control device (28) being responsive to information indicative of the position of each discrete image (14) on said web (16).

9. A method of cutting a web comprising continuously feeding a web (16) into a web buffer (24) with an upstream web drive (18), intermittently feeding said web (16) from said web buffer (24) to a cutting station (44) with a downstream web drive (38), and cutting said web (16) at said cutting station (44), characterised by calculating the length (L_b) of said web (16) in said web buffer (24) by measuring the nominal length of said web (16) fed into said web buffer (24), and measuring the nominal length of said web (16) fed from said web buffer (24), and controlling the operation of said downstream web drive (38) and said cutting station (44) in response thereto, thereby to enable cutting of said web (16) at said cutting station (44) at predetermined locations on said web (16).

10. A method according to claim 9, wherein said web buffer (24) comprises a movable balance roller (26) over which said web (16) passes, said calculation of the length (L_b) of said web (16) in said web buffer (24) taking account of the sensed position of said balance roller (26).

11. A method according to claim 9 or 10, wherein said downstream web drive (38) is stopped, and said web (16) is stationary, while said web (16) is being cut at said cutting station (44).

12. A method according to claim 11, wherein operation of said downstream web drive (38) is selected between at least three modes, namely:

    (i) a first mode in which said downstream web drive (38) is driven at a speed in relation to the speed of said upstream web drive (18) such as to maintain a constant web path length (L_b) in said buffer (24);
    (ii) a second mode in which said downstream web drive (38) is stopped while said web (16) is being cut at said cutting station (44); and
    (iii) a third mode in which said downstream web drive (38) is driven at such a speed in relation to the speed of said upstream web drive (18) as to reduce said web path length (L_b) in said buffer (24).

13. A method according to claim 9, further comprising sensing timing marks (56) located on said web (16) by use of a sensor (54) positioned between said downstream web drive (38) and said cutting station (44), and controlling said downstream web drive (38) in response to information received from said

sensor (54).

14. A method according to claim 13, wherein signals from said sensor (54) are responded to only during a period of time within which a timing mark (56) is expected to arrive at said sensor (54).

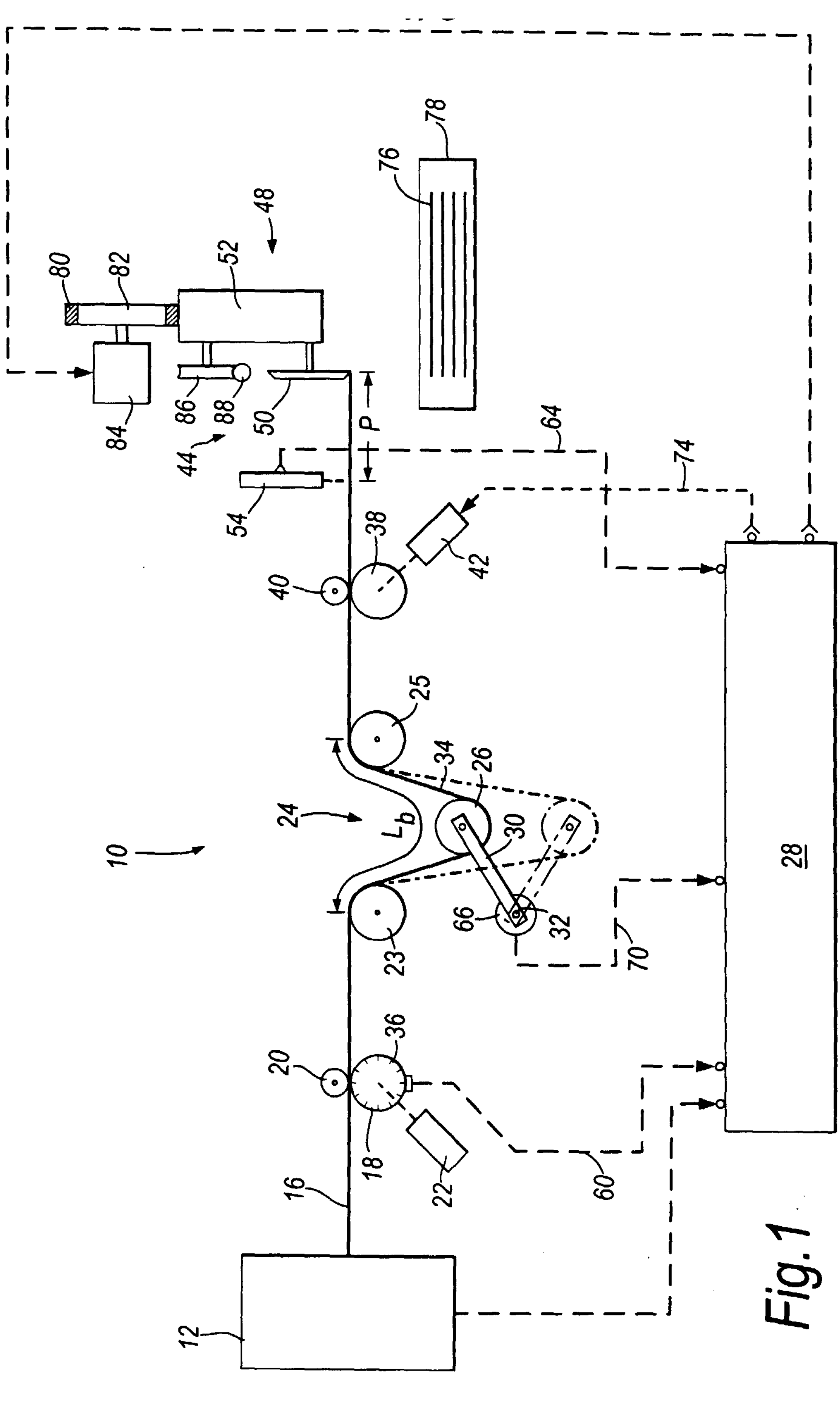

Fig.1

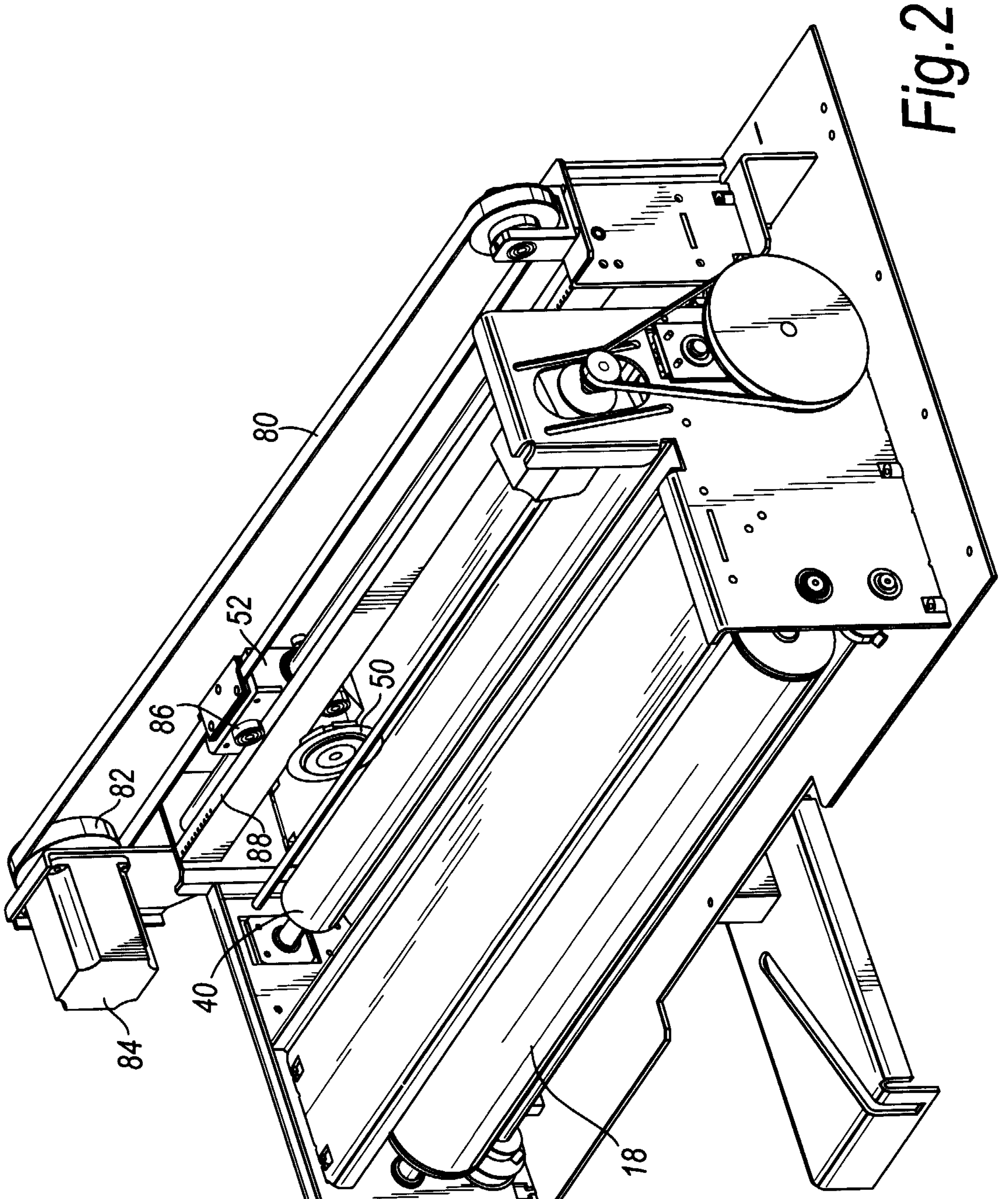

Fig.2

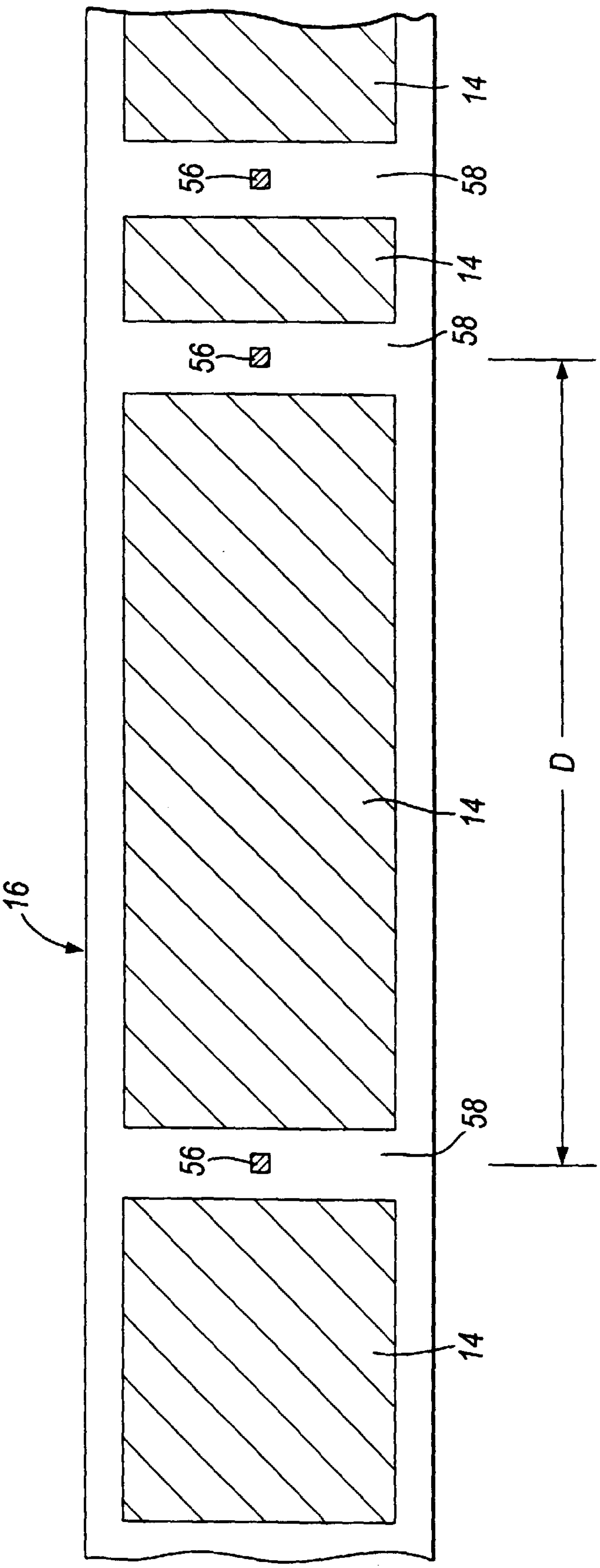

Fig.3