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(54) Marginally powered motor drive for stapling using inertial assist

(57) An electric stapler (11) is provided with current at levels which would result in marginal operation of the stapler (11), but which would be sufficient to operate the stapler (11) if the load were averaged over a cycle of operation. A flywheel is added to the stapler (11) and builds momentum during an early part of the cycle of operation. When the load on the stapler (11) increases during a later part of the cycle of operation, the flywheel is decelerated, resulting in successful operation of the stapler (11).

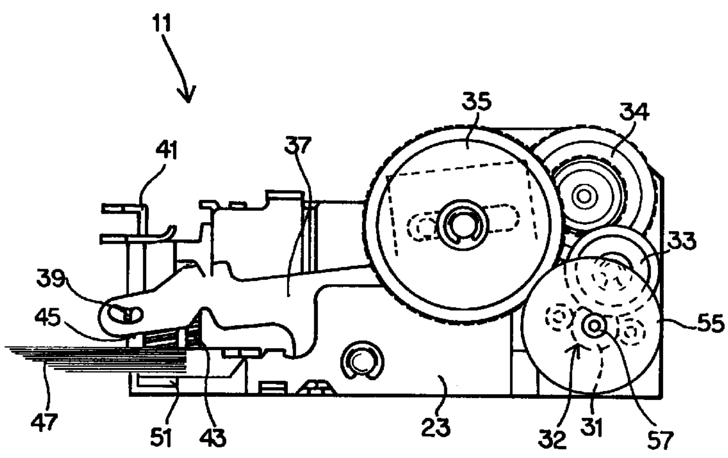


FIG. 2

EP 0 829 329 A1

Description

FIELD OF THE INVENTION

This invention relates to electric motor drives. More particularly, the invention relates to the use of flywheel inertial arrest to increase the output of a marginally-powered motor to drive staples and the like.

BACKGROUND OF THE INVENTION

This invention was developed as a result of a desire to provide improved automatic stapling of multiple paper sheets. The multiple paper sheets are provided as a result of operation of a paper handling machine such as an electrophotographic printer. The paper handling machine typically causes the paper to pass through a first process, such as printing, after which the paper is discharged to an output station. In many instances it is convenient to have the printer or other paper handling machine staple multiple sheets together.

While the invention can be used in a wide variety of applications, including staplers which are not associated with a larger paper handling machine, it will be described in connection with an electrophotographic printer. The printer has a, "mail boxing output device," which allows the printer's output to be sorted by categories. In some cases the mail boxing is sufficient to separate print jobs. In other instances, it is advantageous to provide the option of stapling print jobs, so that a stapled print job would be one of the printer output options.

It has been found that the stapling operation consists of the paper first being pressed to compress the stack. The paper is then punched, which consists of the staple being driven through successive sheets of paper in the stack. After the punch operation, the staple is clinched, wherein the ends of the staple are folded against an end stop, which functions as a collet. The pressing, punch and clinch operations are substantially contiguous, to that the same application of force results in the compress, punch and clinch (staple fold) operations. In addition, since a fixed collet is used, the staple continues to be driven through the paper during the clinch operation. The paper continues to apply friction against the staple, even though the actual punch operation is complete during the clinch operation. Therefore, one mechanism provides the compression, punching and clinching operations.

The compress operation further can be separated into three functions. The stapler motor must first accelerated a driver from a home position to engagement of the stapler head with the paper stack. The paper is then lightly pressed down. This is typically accomplished by a sleeve through which the staple is guided. The staple then continues to compress the paper as the staple engages the paper, which means the paper is further compressed at the location where the staple is to penetrate. The primary difference between the stages of the pressing operation is that the pressing is initially accomplished by a staple guide applying pressure to the stack of paper, and then is continued as a result of the staple driving mechanism engaging the paper with the staple.

One type of stapler uses an electric motor which drives a gear and lost motion mechanism which drives a staple hammer. The electric motor is the prime mover and the staple hammer functions as the driver for driving the stapler. Electric activation of the motor causes the hammer to drop over the lead staple of a staple supply through a staple guide. The staple guide drops with the hammer against a stack of papers and will continue to guide the staple against a stack of papers. The hammer is spring biased away from a staple position.

The power consumption of the electric stapler motor is initially high, as the motor starts, but immediately drops until such time as the stapler engages the paper during the compress operation. As the stapler continues through the compress, punch and fold operations, power consumption of the motor again increases. During the time between shortly after the start of the motor and the engagement of the paper, the power consumption of the motor is fairly low, as there is very little load imposed on the motor.

The stapler cycle of a linear motor electric stapler is similar, except that the movement of the hammer is proportional to the movement of the linear motor.

In operating an electric stapler, it is necessary to provide electrical power sufficient to drive the staple through the maximum thickness of paper anticipated for use of the stapler. In the instant case it was intended to penetrate 20 sheets of 0.13 mm (5.1 mil) paper such as 75 g/m^2 (20 lb.) copy paper or 105 g/m^2 (28 lb.) typing paper. The maximum amount of sheets may vary depending on the application, but in the past, the ability to penetrate through a large number of sheets has been largely dependent on the maximum electric power consumption of the stapler. If one wanted to be able to achieve greater penetration, a larger motor and/or a larger power supply was required.

In one particular apparatus, this power supply was used for an output sorting mechanism, although the source of power would be expected to vary with the particular paper handling machine. If a stapler were designed to penetrate a large thickness of paper it would also have a tendency to leave a substantial impression or "footprint" on a small stack, such as two to four sheets of standard weight paper. It is often desired to have a reduced impression on the paper.

Increasing maximum power consumption requires that, in the case of an electronically controlled device, the power supply be able to handle the increased current. The wiring to the stapler must be sized to handle the increased load. If the stapler is operated simultaneously with the major energy consumers of the electrophotographic printer, the line power must be sufficient supply the additional current draw of the stapler. Providing a larger capacity stapler also requires heaver equipment and associated costs.

The present invention uses a stapler which is marginally powered. This is because the combination of the stapler motor and the power supply to the stapler is inadequate to reliably complete a staple operation on a predetermined maximum thickness of sheet media, absent further modifications of the stapler mechanism. By "marginal" we mean that the equipment (without modifications according to the invention) would either not function as intended or would not reliably function as intended. This intentional operation includes an ability to exceed the specifications under test conditions, so that marginal equipment may or may not be able to staple the predetermined number of sheets. If the equipment does not perform satisfactorily according to our test criteria, it is considered to be inadequate, regardless of whether the equipment can be demonstrated to staple the specified number of sheets.

Various mechanical devices have been used to increase impact of electrical machinery. These tend to add complexity to the mechanism, and in many cases increase noise. Ideally, a stapler capable of penetrating a substantial thickness of sheets at a printer output should be quiet enough to be acceptable in the office environment, even if stapling is a frequently used function. In other words, it is not acceptable for the stapler on a printer to sound like a carpenter's tack hammer.

It is desired to increase the maximum capacity of the stapler without significantly increasing the time necessary to complete the stapling cycle. While the time to complete the stapling cycle is not significant when compared to the overall printing time cycle in an electrophotographic printer, the additional time of stapling is noticed by the user, often while the user is waiting by the printer. Therefore, this time should not be extended.

In choosing a particular stapler mechanism for use with a printer, we considered the convenience of designing the printer's output to accommodate the stapler, and power consumption. It is advantageous that the stapler receive its power from an existing power supply. While it is possible to drive the stapler at a higher current, this would have required providing a larger power supply or an energy storage device such as a capacitor. As mentioned above, the provision of a larger power supply would add to costs as a result of providing the necessary power handling capacity. In addition, the larger power supply would possibly increase the overall power consumption of the printer's output mechanism and possibly of the entire printer by a significant amount. In the case of an energy storage device, this would increase costs as the result of the necessary size of a capacitor or battery, as well as requiring an appropriate switching circuit.

It is also possible to increase the capacity of an electric stapler by controlling the power supply to the motor. This can be accomplished in some cases without altering the internal circuitry of the motor. This does, however, necessitate the additional expense of such control circuitry. It is also possible to increase the capacity of a stapler by redesigning the stapler to apply with more force by "gearing down" the stapler. This results in the stapler operating slower. This slower operation affects all staple jobs, regardless of whether the particular staple job required the additional force.

It is the intent of this invention to increase the maximum thickness of stacked paper which may be penetrated with an automatic stapler. It is further the intent to use a relatively small capacity electric motor and increase the capability of the motor to drive staples through the increased thickness of stacked paper. It is desired to accomplish this without increasing the peak current or power consumption of the stapler. It is further desired to reduce equipment costs to approximately that necessary to staple the relatively small stack and optimize the stapling process for the small stack, yet still be able to perform the stapling operation on the significantly thicker stack. It is desired to provide the selective stapling without significantly increasing the complexity of the stapler and without significantly increasing the complexity of a control circuit.

It is desired to provide a stapler for paper handling equipment which, when combined with its electrical power supply, is marginally powered. It is desired to do so without substantially increasing the cost or complexity of the stapler itself. This allows a stapler to be incorporated into the configuration of a device, such as the electrophotographic printer used in conjunction with the preferred embodiment, without a corresponding increase in the capacity of the power supply for that equipment. It is also desired to provide a stapler which performs its function reliably, without a substantial increase in cost. In accomplishing these goals, it is desired to take advantage of the time period between the start of the stapler motor and the substantial increase in load on the stapler motor caused by the stapler engaging a stack of paper or other sheet media.

SUMMARY OF THE INVENTION

In accordance with the present invention, a stapler is driven by an electric motor which has its effective output force increased by adding a flywheel in order to penetrate relatively thick stacks of paper. This allows the stapler to store energy during its operational cycle, particularly prior to engaging a stack of paper. The motor is supplied with power at a predetermined EMF and a predetermined maximum current.

By selecting a stapler which is optimally sized for a small stack of paper, the increased cost required to provide an ability to increase capacity for the thicker stack of paper is offset by avoiding the costs associated with providing a larger capacity stapler or power supply.

In one particular stapler, the motor required 1.3A (amperes) of current at 24 volts for normal operation in which two to ten sheets of 0.13 mm (5.1 mil) 75 g/m^2 (20 lb.) paper are stapled. The duration of the pulse is 370 -

400 ms. By adding a flywheel, the stapler could penetrate 20 sheets of 0.13 mm (5.1 mil) having a specification of 75 g/m^2 (20 lb.) or 105 g/m^2 (28 lb.). This results increases the thickness of paper that the stapler is capable of penetrating.

The thickness of the stack to be penetrated are limited by the physical ability of the staple to remain straight during the penetration operations and by the increased friction of the paper which may approach or exceed the force which can be applied by successive cycles of the drive. The geometry of the staple also places demands on the stapler. The legs need to bend in order to keep all the sheets of paper together.

DESCRIPTION OF THE DRAWINGS

Figure 1 shows an output section of a printer, in which a stapler is provided, as in the preferred embodiment of the invention;

Figure 2 shows a configuration of a stapler mechanism used with the preferred embodiment of the invention.

Figure 3 shows an end view of the stapler mechanism of Figure 2; and

Figure 4 graphically shows current supplied to the stapler, with a maximum limit on available current.

DETAILED DESCRIPTION OF THE INVENTION

This invention relates to a stapler mechanism 11, shown in Figures 1-3. In the preferred embodiment, the stapler mechanism 11 is used in an output sorter 13 of a printer as shown in Figure 1. The output sorter 13 has multiple output trays 17. Sheet media, typically paper which is processed by the printer, is selectively discharged into the different output trays 17. This configuration permits the printer to have a "mailbox" output, whereby printed sheets are selectively placed in different slots.

The inventive stapler forms a part of the output sorter 13, although it is possible to implement the invention separately from a printer or the output sorter 13. The stapler consists of body 23 (shown in Fig. 2) which is mounted to a stapler carrier 25. The stapler carrier 25 is preferably mounted to the output sorter 13 at a first output tray 19. This is advantageous because stapled print jobs are by definition pre-bundled, as opposed to being groups of loose sheets.

It is alternately possible to provide a stapling function such that the stapled print jobs may be discharged to any of the output trays 17. Alternatively, the stapler carrier 25 may be positioned such that if the output sorter 13 aligns an output tray 17 to receive the sheet media from the printer, the stapler carrier 25 is aligned with that particular tray 17. In that case, when the tray 17 has received printed sheets of sheet media, the stacked print media are aligned beneath the stapler mechanism 11.

Figure 2 shows a typical electric stapler mechanism 11 which is used in the preferred embodiment of the invention. In the preferred embodiment, the stapler body 23 is positioned at an angle above the discharge tray so that the stapling operation is accomplished by movement at the same angle from the discharge tray 17. As a matter of convention, the direction of motor movement toward the tray is considered to be "downward" and away from the tray is considered to be "upward." It is understood, however, that these references of "upward" and "downward" are at variance with the vertical by the angle of the discharge tray. The invention is not directly dependent on the position of the discharge tray, so that the angle of variation can be up to 360°.

The stapler mechanism 11 includes and supports a motor 31 and gears 32, 33, 34 and 35. A lost motion lever 37 is driven by the gears 32-35. The lever 37 actuates a pin 39 which directly engages a striking plate 41, which travels downward. The pin 39 indirectly engages a forming plate 45; that is, after the striking plate 41 has moved some distance, it engages the forming plate 45 and the latter starts to move. While the striking plate 41 pushes a staple (not shown) against the stack of paper 47, the forming plate bends another staple for future use. Also attached to the lost motion lever 37 is a ratchet mechanism (not shown) which actuates a roller (not shown), and this roller feeds a rack of staples to the front of the stapler. Gear 35 rotates one turn per stapling cycle.

The striking plate 41 in its downward movement also engages an individual staple from a supply of staples and drives the staple downward through the stack 47. A collet 51 is mounted on the discharge tray opposite the striking plate 41. This is the part of the stapler which receives the staple after the staple has penetrated the paper. Groves in the collet 51 fold the staple when the striking plate 41 continues to force the staple downward, thereby allowing the stapler 11 to complete the "clinch" operation.

A flywheel 55 is attached to the motor 31 by mounting the flywheel 55 to an output shaft 57 of the motor 31. The flywheel 55 therefore absorbs energy (momentum) when the motor 31 increases speed and releases the energy when the motor 31 decreases speed.

The stapler 11 achieves its purpose as a result of the force of the motor 31 driving the striking plate 41. In the preferred embodiment, the motor 31 is a DC motor, although it is possible to provide an AC motor. The motor behaves according to:

$$T_{ind} = K\phi I_A \quad (1)$$

$$E_A = K\phi\omega \quad (2)$$

$$I_A = (V_T - E_A)/R_A \quad (3),$$

where

T_{ind} is the induced torque; I_A is the magnetic coil current; E_A is the induced EMF (voltage); ω is the angular velocity; V_T is the applied EMF; and R_A is the magnetic coil resistance.

Let ω be the velocity of a motor 31 at V_T, for a given load (T_{load}). If T_{load} increases, ω decreases, which causes E_A to decrease. This is shown in equation (2). In a stable condition, $T_{ind} = T_{load}$. This shown in equation (1). A stalled condition occurs when I_A cannot be increased enough to reach the condition $T_{ind} = T_{load}$. In that case, the circumstance of $T_{ind} < T_{load}$, and the motor 31 is in a condition where the stapler stalls and therefore is no longer proceeding with the stapling function.

Thus, if the load increases with time in a discrete manner, the current will follow this behavior, and the motor will be able to hammer the staple until T_{ind} is less than that required to move the staple. As each step in the stapling operation occurs, the demand of current keeps increasing even though the previous step has already ended. This is because, even if the previous step has decelerated the motor and the motor generates electrical inductive reaction. (Inductors reject sharp current changes.)

It was determined that 1.34 amperes is a desired maximum current which will be supplied to the stapler mechanism 11 in the preferred embodiment. This current level was chosen in order to allow an existing power supply to be used to power the stapler mechanism 11. This current is applied for a pulse duration of 370 - 400 ms.

It was found that, without the flywheel 55, this application of power to the motor 31 was not sufficient to staple 20 sheets of 0.13 mm 75 g/m^2 (20 lb.) copy paper or 105 g/m^2 (28 lb.) typing paper. The duration of the pulse could be extended in order to complete the clinch operation, but if the stack were thick enough, the motor would stall and ω would go to zero. As a result, extending the 370 - 400 ms time period would not result in completing the stapling operation.

Energy conservation dictates that:

$$I\bar{\omega}_1^{\,2} = M\theta + I\bar{\omega}_2^{\,2}$$

Where:

I = Reflected mass moment of inertia at the motor shaft

ω_1 = Angular velocity of motor shaft before stapling

M = Torque at motor shaft

θ = Angle rotated by the motor shaft when stapling

$\bar{\omega}_2$ = Angular velocity of motor shaft after stapling

$I\bar{\omega}_1^2$ = Kinetic energy of the system before stapling

$M\theta$ = Energy used to perforate the stack of paper and bend the wire

$I\bar{\omega}_2^2$ = Kinetic energy of the system after stapling

From the above equation, we notice that the available energy for stapling is:

$$M\theta = I(\bar{\omega}_1^{\,2} - \bar{\omega}_2^{\,2})$$

The initial angular velocity is fixed by the motor, and the final velocity must be different from zero if we want to move out of the stapling position within a certain time. According to the invention, available energy for stapling is increased by increasing the mass moment of inertia, because it multiplies the difference of the square of the angular velocities. The increase in the mass moment of inertia is accomplished by adding the flywheel 55.

Figure 4 shows current applied to the motor over time. As the motor 31 is started, there is an initial high current draw as the motor 31 starts from a rest position, represented by t_1. This current draw decreases as the motor 31 increases in rotational speed. At a time represented by t_2, the motor 31 has approached its maximum RPM and has substantially reduced its acceleration. It is presumed that the motor continues to accelerate beyond the time indicated at t_2, but the current draw is substantially less. At time t_3, the load on the motor 31 increases. The load continues to increase up to a peak, indicated at t_4, and decreases at a time represented by t_5, until the completion of a cycle of the mechanism of the stapler 11, represented by time t_6. The initial time period between t_1 and t_3, and particularly the time period between t_1 and t_2, represent time during which current to the motor 31 is used to increase the speed and momentum of the motor 31. By providing the flywheel 55, a substantial amount of energy is consumed during that time period, that energy being stored in the rotational momentum of the flywheel 41. During the time between the initial engagement of the paper at t_3 and the maximum load on the motor 35, at t_4, the momentum of the flywheel 55 is decreased and provides additional force to drive the stapler 11, and particularly the striking plate 41. The momentum imparted on the stapler mechanism by the flywheel 55 is generally additive to the force supplied by applying potential to the motor 31. This is particularly applicable as the load doing the staple operation results in a decrease in the speed $\dot{\omega}$ of the motor 31. Even though the flywheel 55 is provided and is connected directly to the motor shaft 57, the motor speed will still decrease at times when the load exceeds the capacity of the motor 31.

While there is an initial high load on the motor 31 at t_1, the flywheel 55 does not present any particular problems. Unlike the peak load at t_4, the motor 31 and flywheel 55 are free to move even though the flywheel 55 slows the acceleration of the motor 31.

The momentum supplied to the flywheel 55 is supplied by the motor 31 during the initial time period t_1-t_2 and, to a lesser extent, between t_2 and t_3. This increases the load applied to the motor during that time t_1-t_3. There is also a time period between t_5 and t_6 during which the motor 31 is again accelerated and it is possible that the motor 31 is accelerated between t_4 and t_5, as well. While this also results in an acceleration of the flywheel 55, this is not considered to be significant, since the loads imposed on the stapler 11 are decreased at that time.

The above description relates specifically to the preferred embodiment of a rotary motor driving a stapler used in the output mechanism of a printer. It is possible to use the inventive concepts in other applications. By way of example, it is possible to use the inventive techniques to drive staples with a linear electric motor or with a pneumatic motor, or to drive staples through other than sheet media. The techniques can be used of other types of outputs. Accordingly, the invention should be read as limited in scope by the claims.

Claims

1. A method for operating a power stapler (11) for driving staples into media (47), the method comprising:

   a. initiating a staple operation by applying a energy to a prime mover (31), thereby accelerating the prime mover (31) and a stapling mechanism (23, 32-41);
   b. storing energy in an inertial mass (45);
   c. continuing to apply energy to the prime mover (31) during an increased load which results from the stapling mechanism (23, 32-41) performing a stapling function, said increased load resulting in deceleration of the prime mover (31): and
   d. assisting the prime mover (31) by converting energy stored in the inertial mass (45) to mechanical force and applying the force to the stapling mechanism (23, 32-41) when the prime mover (31) decelerates while driving the stapling mechanism (23, 32-41).

2. The method of claim 1, further comprising:

   using a flywheel attached to an electric motor drive as the inertial mass (45).

3. The method of claim 2, further comprising:

   a. using an electric motor which functions as the prime mover (31);
   b. supplying electric current to the motor in order to apply said energy at a power level insufficient to drive the stapling mechanism (23, 32-41) against a peak load for a predetermined maximum stack of media (47) for stapling, but sufficient to drive the stapling mechanism (23, 32-41) against the load averaged through a cycle of operation, so that the prime mover (31) increases speed during an acceleration time period prior to reaching the peak load, and then decreases speed during a time period subsequent to said acceleration time period; and
   c. using a flywheel attached to the electric motor drive as the inertial mass (45) and supplying additional force during said decrease in speed.

4. An electric stapler (11) comprising:

   a. an electric motor receiving power from a power supply;
   b. a stapling mechanism (23, 32-41) responsive to energization of the motor, wherein the stapling mechanism (23, 32-41) permits motor travel prior to the stapling mechanism (23, 32-41) reaching a peak load, so that the motor increases speed during an acceleration time period prior to reaching the peak load, and then decreases speed during a time period subsequent to said acceleration time period, and said motor inadequate or marginal in its ability to drive the stapling mechanism (23, 32-41) through said peak load at a predetermined maximum load value for the stapler;
   c. an inertial mass (45) connected to the motor, said inertial mass (45) storing inertial energy during said acceleration time period and transferring said stored energy to the stapling mechanism (23, 32-41) when said motor decreases speed under load from the stapling mechanism (23, 32-41).

5. Paper handling equipment having a paper discharge output and electric stapler (11) located at the paper discharge output for receiving sheet media (47) and stapling the sheet media (47), the stapler (11) comprising:

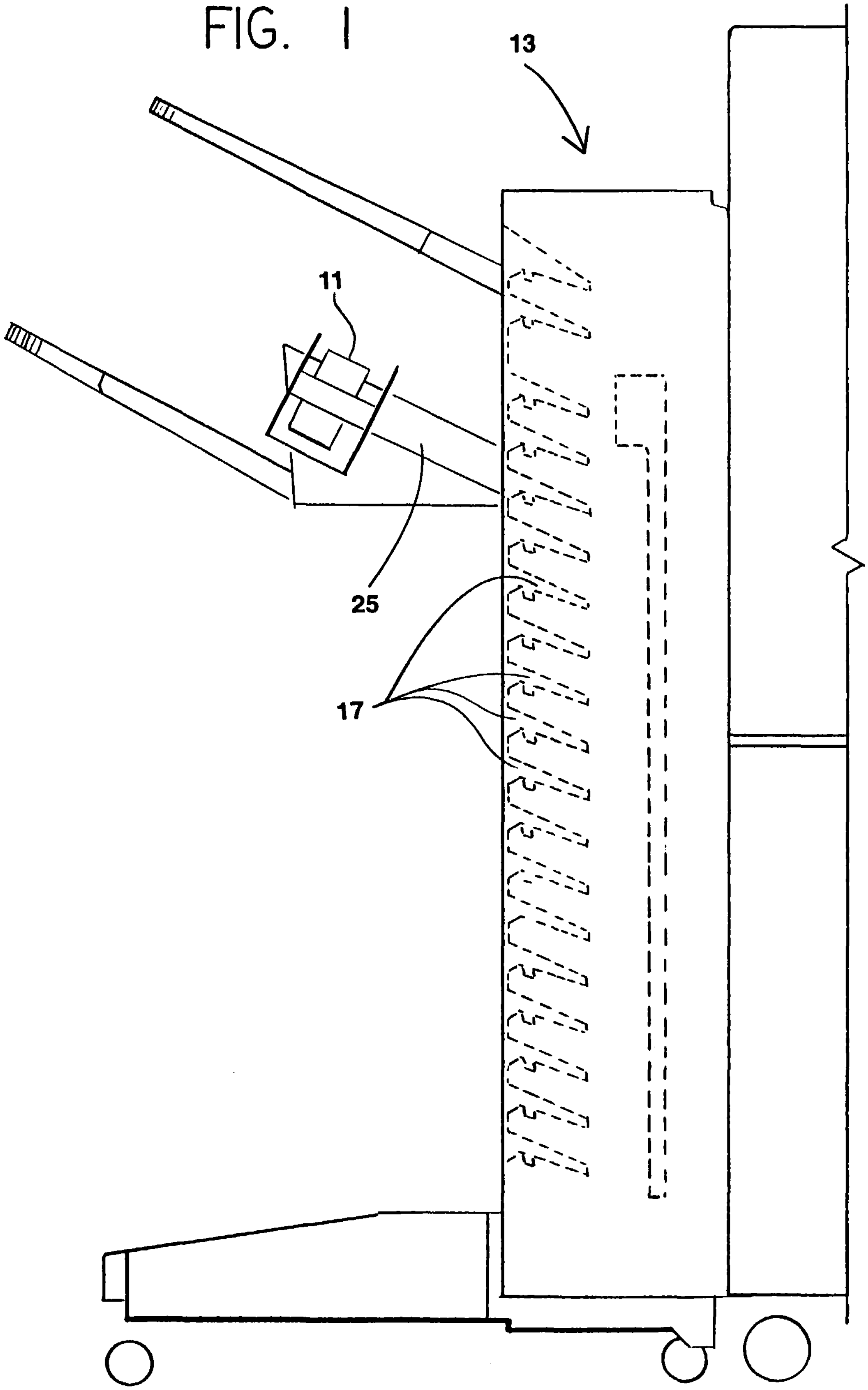
   a. a power supply supplying power to at least some components of the paper handling equipment;
   b. an electric motor receiving power from the power supply, said power resulting in marginal operation of the stapler (11) under a predetermined load;
   c. a stapling mechanism (23, 32-41) responsive to energization of the motor, wherein the stapling mechanism (23, 32-41) permits motor travel prior to the stapling mechanism (23, 32-41) reaching a peak load during a cycle of operation, so that the motor increases speed during an acceleration time period prior to reaching the peak load, and then decreases speed during a time period subsequent to said acceleration time period;
   d. an inertial mass (45) connected to the motor, said inertial mass (45) storing inertial energy

during said acceleration time period and transferring said stored energy to the stapling mechanism (23, 32-41) when said motor decreases speed under load from the stapling mechanism (23, 32-41).

6. The stapler (11) of claim 10 further comprising:

the inertial mass (45) including a flywheel mounted to a rotary portion of the electric motor.

FIG. 1



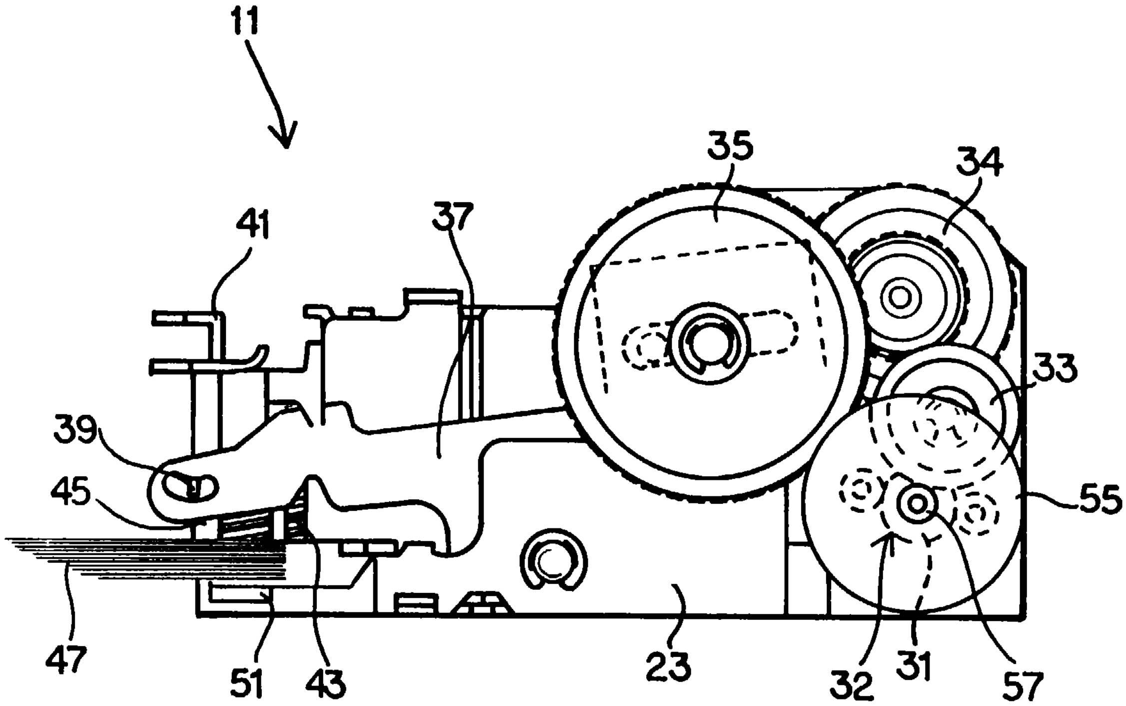


FIG. 2

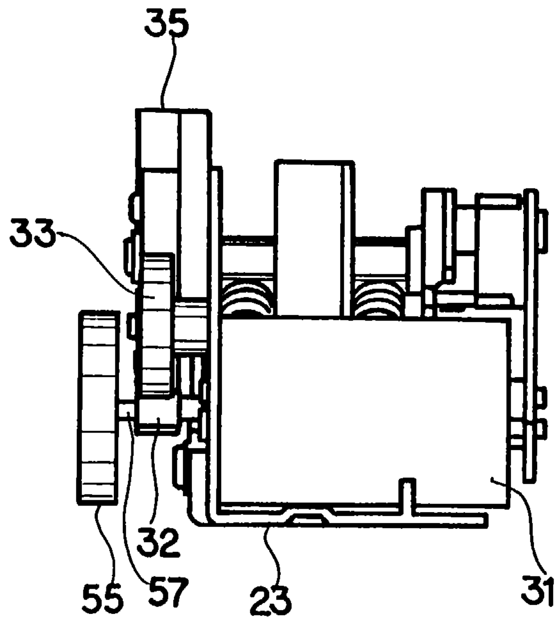


FIG. 3

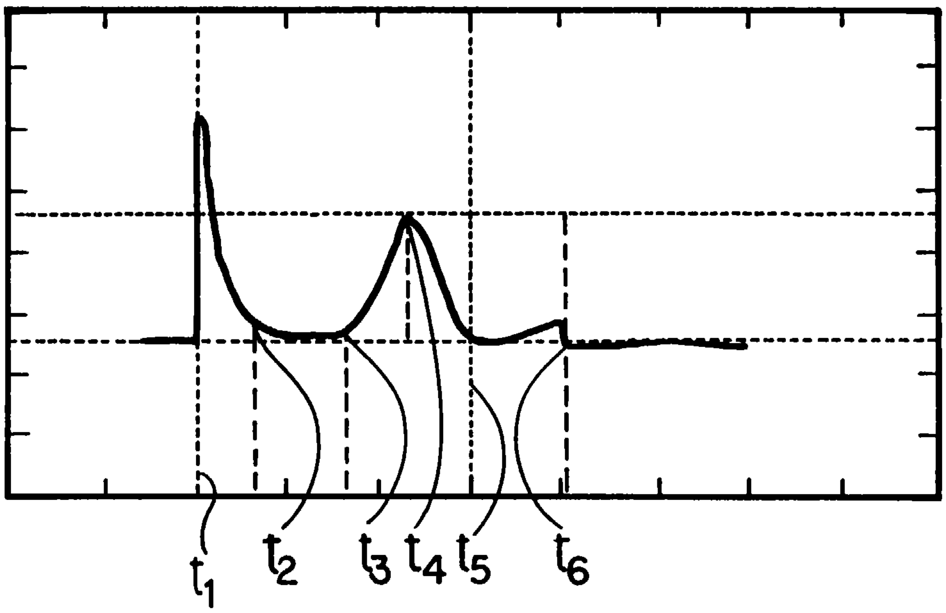


FIG. 4

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 97 10 4314

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	US 4 557 410 A (HOLDEN) * column 1, line 16-23 * * column 1, line 60 - column 2, line 37 * * column 3, line 43-46; figure 1 * ---	1-6	B25C5/15 B27F7/36
A	EP 0 009 964 A (XEROX) * page 1, line 1-3; figures 1,2 * -----	5	

TECHNICAL FIELDS SEARCHED (Int.Cl.6)
B25C
B27F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	6 January 1998	Matzdorf, U

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