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Seo et al.

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[54] **AUTOMATIC INDEX AND OPERATING CYCLE REGULATOR FOR A PUNCH**

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[21] Appl. No.: **414,505**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 398,455, Sept. 18, 1973, abandoned, which is a continuation of Ser. No. 173,914, Aug. 23, 1971, abandoned.

[30] **Foreign Application Priority Data**

Aug. 25, 1970 Japan 45-74031

[52] **U.S. Cl.** **318/309,** 318/39, 318/384

[51] **Int. Cl.** **H02p 5/16**

[58] **Field of Search** 318/39, 162, 163, 164, 318/309, 310, 321, 384, 393, 396

[56] **References Cited**

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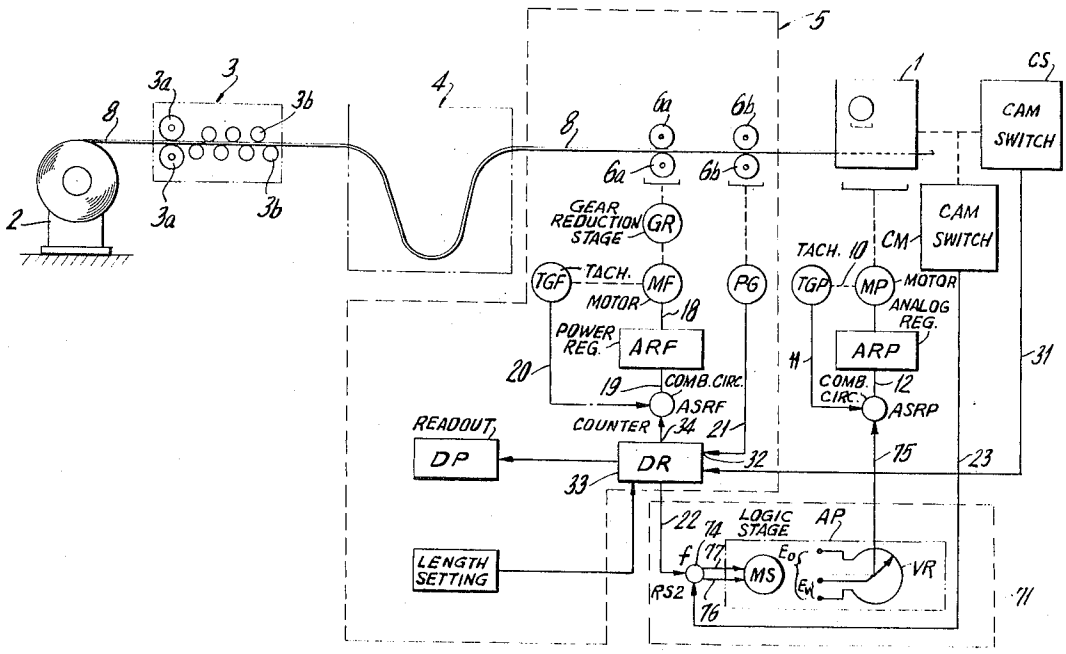
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Primary Examiner—Robert K. Schaffer
Assistant Examiner—W. E. Duncanson, Jr.
Attorney, Agent, or Firm—Toren, McGeady and Stanger

[57] **ABSTRACT**

A control system is described for automatically establishing an optimum relation between an operating cycle of a punch press and the length of each of a succession of fixed-length segments of a continuous sheet advanced into the press by an indexing mechanism. A first output indication generated by a monitoring device at the conclusion of advance of each segment is compared with a second output indication generated at a fixed point in each cycle of the press. When the cyclic rate of the press is low, the second indication is delayed relative to the first indication, and the control system responds to such delay to accelerate the press cycle and thereby reduce the delay of the second indication relative to the first. When such acceleration has progressed to the point where the second indication coincides with the first, the acceleration of the press is terminated and the press thereafter proceeds at constant speed. Facilities are included for decelerating the press if the second indication overshoots and tends to lead the first indication, and for increasing the repeatability of a preselected length of the successive sheet segments.

7 Claims, 9 Drawing Figures



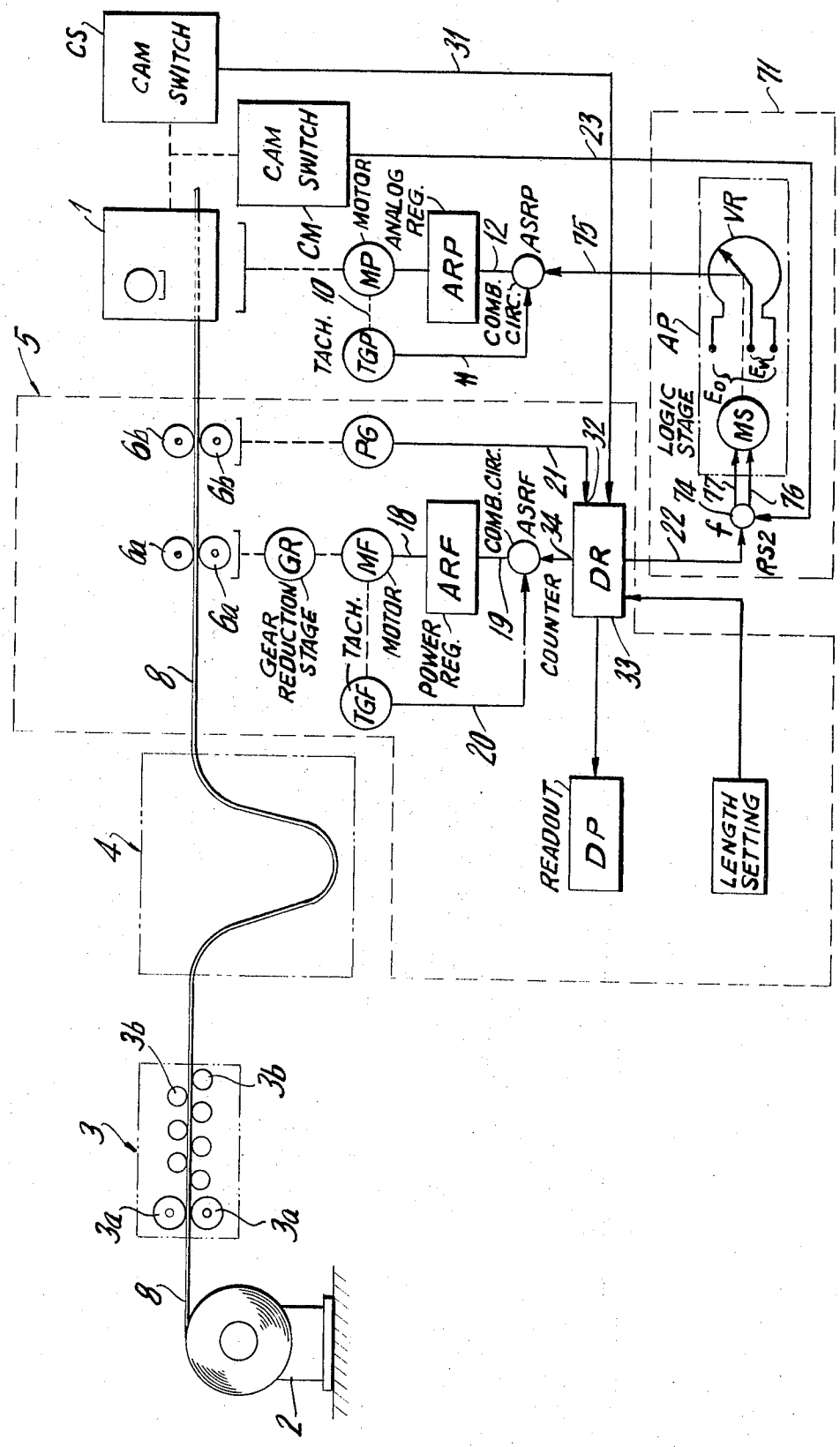

CS
CAM SWITCH
31
CAM SWITCH
23
71
1
CM
MOTOR
ANALOG REG.
ARP
12
ASRP
15
VR
10
MP
TACH.
TGP
COMB. CIRC.
14
AP
LOGIC STAGE
Eos
MS
5
6b
PG
32
6b
6a
21
74
77
22
f
RS2
76
6a
GR
MF
18
COMB.CIRC.
ASRF
34
DR
GEAR REDUCTION STAGE
TACH. MOTOR
ARF
19
COUNTER
8
TGF
POWER REG.
33
20
READOUT
DP
LENGTH SETTING
4
3b
3
3a
8
2

FIG. 1

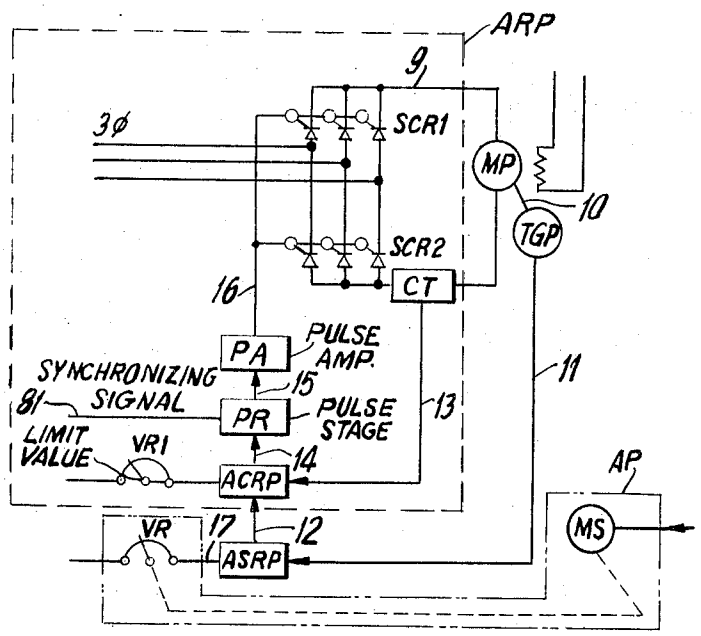


FIG. 2

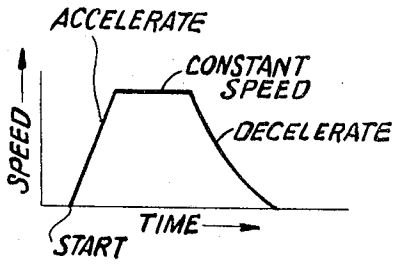


FIG. 3

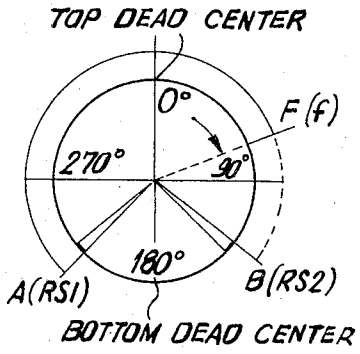


FIG. 4

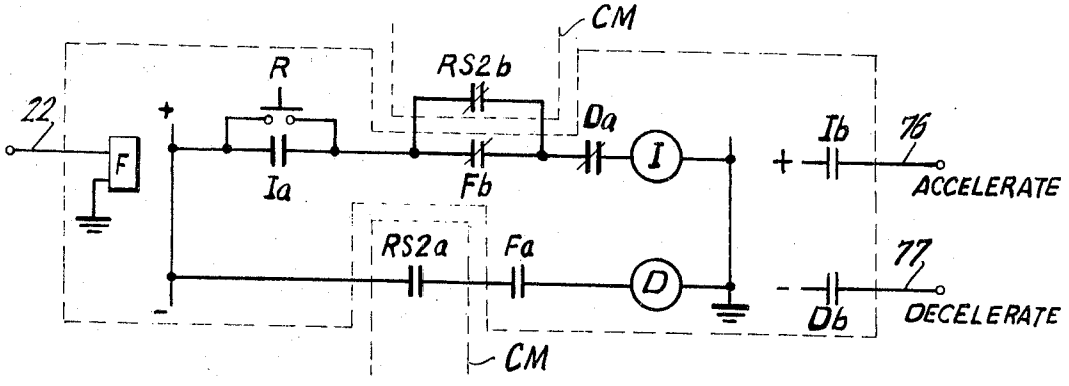


FIG. 5

FIG. 6a

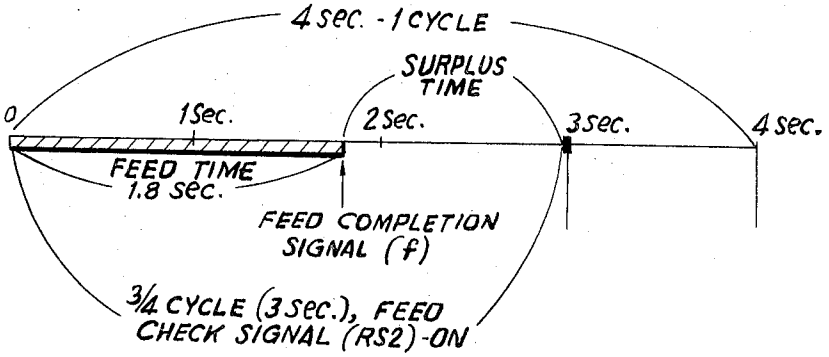


FIG. 6b

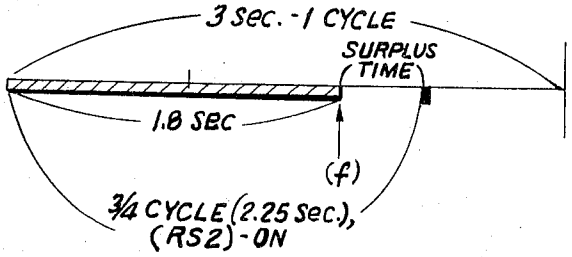


FIG. 6c

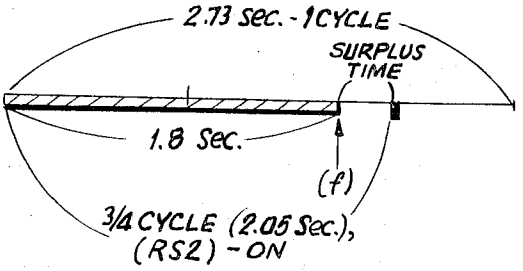
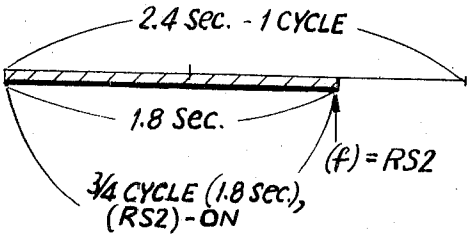


FIG. 6d



AUTOMATIC INDEX AND OPERATING CYCLE REGULATOR FOR A PUNCH

REFERENCE TO COPENDING APPLICATIONS

This is a continuation-in-part of our copending application Ser. No. 398,455 entitled Method for Controlling Coil Feed Lines, filed on Sept. 18, 1973, now abandoned. The latter copending application is a continuation of my application Ser. No. 173,914 filed Aug. 23, 1971 now abandoned and assigned to the same assignee as this application. The subject matter of those applications is hereby made a part of this application as is fully recited herein.

BACKGROUND OF THE INVENTION

In a typical manufacturing line employing a punch press to blank or shear material from discrete segments of a continuous sheet indexed into the press, it is necessary to initially establish a relationship between the number of punching operations of the press and the length of each discrete sheet segment advanced into the press. Such relationship is generally ascertained with the aid of a drawing or a diagram.

The usefulness of such ascertained relationship is dependent on the repeatability of the segment length over successive indexing operations. In an attempt to assure such repeatability presently known arrangements increment a digital counter as each incremental advance of the sheet proceeds until the counter has accumulated a count corresponding to a preset count representative of the desired segment length. At that instant, the counter produces an output signal that abruptly stops the indexing motor to terminate the advance.

Such arrangements have not proved accurate or reliable enough for optimum control, primarily because of residual variations in the segment length over successive indexing operations (particularly where high indexing rates are involved), and because of errors in setting up the speed of the variable speed press motor to instrument the press operating rate selected via the above-mentioned chart or diagram.

An object of the present invention is to provide an arrangement for automatically establishing an optimum relationship between the operating cycle speed of a punch press and the length of substantially fixed-length segments of a continuous sheet to be punched.

A related object is to provide a reliable, high speed indexing arrangement for advancing substantially invariant segment lengths of sheet material into a punch press.

SUMMARY OF THE INVENTION

These objects are accomplished with a feature of the present invention, wherein a circuit for automatically controlling the operating rate of the punch press is operatively associated with the sheet segment indexing arrangement. In one embodiment, the press is provided with facilities for generating a first output indication at a fixed point in each cycle. The control circuit compares each such first indication with a second output indication generated by a monitoring stage of the indexing arrangement at the conclusion of each indexing operation, and responds to an initial time lag between such quantities to accelerate the press and thereby increase its cyclic rate. Such acceleration continues until the first and second indication coincide, whereupon the acceleration of the press is terminated. The operation

of the press thereafter proceeds at a constant speed automatically corresponding to the optimum relation between cyclic rate and the segment length.

If the cyclic rate becomes too large (e.g., when the phase of the second indication tends to lead that of the first indication after coincidence is reached), the control circuit responds by decreasing the cyclic rate of the press until coincidence between the first and second indications is again reached.

According to another feature of the invention, the facilities within the control circuit for selectively increasing and decreasing the cyclic rate include a servomotor whose shaft is ganged to the wiper arm of a potentiometer that serves as the command speed input for the variable speed press motor. A logic stage within the control circuit is effective to cause the servomotor to position the wiper arm of the potentiometer in an appropriate one of two opposite directions. Such directions correspond respectively to an increase and decrease of the speed command voltage and thereby to a corresponding increase or decrease of the press motor speed.

According to another feature of the invention, increased accuracy in maintaining a fixed sheet segment length over successive indexing operations is accomplished with a digital regulator in the indexing portion of the arrangement. The regulator provides controllable changes in the speed command voltage for the variable speed motor that constitutes the indexing drive, and is effective to terminate each indexing operation in a repeatable, non-abrupt manner.

The various features of novelty which characterize the invention are pointed out with particularity in the claims annexed to and forming a part of this disclosure. For a better understanding of the invention, its operating advantages and specific objects attained by its use, reference should be had to the accompanying drawings and descriptive matter in which there are illustrated and described preferred embodiments of the invention.

BRIEF DESCRIPTIONS OF THE DRAWINGS

The invention will be described further in the following detailed description taken in connection with the appended drawings, in which:

FIG. **1** is a combined block and schematic diagram of a sheet punching system employing facilities for automatically setting an optimum cyclic rate of the punch press in accordance with the invention;

FIG. **2** is a combined block and schematic diagram of a power regulator for operating the variable speed press motor in the arrangement of FIG. **1**;

FIG. **3** is a graph illustrating a cycle of operation of an improved sheet indexing mechanism suitable for use in the arrangement of FIG. **1**;

FIG. **4** is a pictorial diagram illustrating typical phase relations among the control indications employed in the arrangement of FIG. **1**;

FIG. **5** is a schematic diagram illustrating one form of logic circuit responsive to the control indications of FIG. **4** for regulating the cyclic rate of the press, and

FIGS. **6***a* to **6***d* are graphs illustrating the operation of the system at various speeds.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

In the drawings, FIG. **1** illustrates a manufacturing line wherein a continuous sheet **8** of material to be

blanked or sheared by a suitable punch press 1 is unwound from a drum 2 via an unwinding section 3. The section 3, which includes a pair of feed rolls 3*a* and a pair of strain compensating rolls 3*b*, is driven by a variable speed motor (not shown.)

From the unwinding section, the sheet 8 is conveyed to an indexing section 5 powered by a normally disabled variable speed motor MF. The motor MF is triggerable into operation in response to an indication RS1. The indication RS1 is conventionally generated by a cam-operated microswitch CS on the press crankshaft CR at a fixed point in the operating cycle of the press 1. The indication RS1 is coupled to the indexing section 5 over a line 31.

The portion of the sheet 8 between the unwinding section 8 and the indexing section 5 is maintained in a slack state by a looping mechanism 4 to prevent stresses normally caused by relative variations in the speeds at which the sections 3 and 5 are respectively driven.

The indexing section 5 is arranged to advance ideally fixed-length segments of the sheet 8 into the press 1 to be punched. For this purpose, the section 5 includes a pair of feed rolls 6*a* coupled to the motor MF via a gear reduction stage GR, and a pair of detecting rolls 6*b* coupled to a length monitoring stage including a pulse generator PG and a digital counter DR.

The rolls 6*b* are operatively associated with the input of the generator PG, which produces a sequence of pulses at a regular rate over each interval during which the rolls 6*b* sense and advance of the sheet 8 therethrough.

The output of the generator PG is coupled via a line 21 to a counting input 32 of the counter DR; the counter is stepped one count for each count so applied to the input 32. A selectable reference count, corresponding to a desired preset length of sheet segment, is entered into a setting input 33 of the counter. Such reference count may be visually displayed in a suitable readout device DP.

In order to assure repeatability of the preset segment length, the counter DR is advantageously employed as a speed regulator for the motor MF so that the speed characteristic of the motor MF is varied over a typical indexing interval in a controlled and non-abrupt manner as depicted in FIG. 3.

In particular, the counter DR is provided with facilities for generating, on an output line 34, a speed command voltage proportional to the instantaneous difference between the reference count entered into the setting input 33 and the accumulated count entered into the counting input 32. The line 34 is coupled to a speed command input of a combining circuit ASRF, which produces a voltage proportional to the instantaneous difference between the actual speed of the motor MF (as generated by a tachometer TGF) and the speed command voltage on the line 34. The output of the circuit ASRF is coupled to the input of an analog power regulator ARF, whose construction may be similar to that of the regulator ARP described below in connection with FIG. 2.

When the total count accumulated in the counter DR coincides with the reference count, the speed command voltage on the line 34 is reduced to zero and the motor MF is disabled.

The cyclic rate of the press 1 is determined by the speed of rotation of a variable speed motor MP which is coupled to the output of the above-mentioned power regulator ARP. The input of the regulator ARP is excited by the output of a combining circuit ASRP. The circuit ASRP produces an output voltage proportional to the instantaneous difference between the actual speed of the motor MP (as generated in a tachometer TGP) and a speed command voltage Ev generated in a control circuit 71 to be described in detail below.

The speed of the motor MP is determined by the voltage Ev. the latter is determined by the position in which a motor MS in the circuit 71 places a wiper arm of a potentiometer VR. A source energizes the terminals of the potentiometer VR with a voltage Eo. The wiper arm extracts the proportion of the voltage Eo established by forward and reverse movement of the motor MS in the control circuit 71.

As shown in FIG. 2, the regulator ARP includes two banks of silicon controlled rectifiers SCR1 and SCR2. The transconductive paths of the SCR's are coupled in a conventional manner to three-phase AC power mains. The point in each power cycle at which the SCR's commence conduction, and thereby the total current through the motor MP during such power cycle, is determined by the time of occurrence of a control pulse (applied in parallel to the control electrodes of the SCR's via a line 16) relative to the fixed time of occurrence of a synchronizing signal incident on a line 81. The control pulses are generated in a pulse stage PR and are coupled to the line 16 through a pulse amplifier PA.

The time of occurrence of each such control pulse relative to that of the corresponding synchronizing pulse is proportional to the voltage present on an input line 14 to the stage PR. Such voltage is normally provided by the speed command output line 12 of the combining circuit ASRP; for overload protection purposes, however, the output line 12 is coupled to the input of the stage PR through an additional combining circuit ACRP. The circuit ACRP establishes a minimum interval between the occurrence of each synchronizing pulse and the occurrence of the next control pulse to assure that the current through the motor MP (as detected by a current transformer GT) does not exceed a selectable limit value appearing at the wiper arm of a schematically depicted potentiometer VR1.

In accordance with the invention, the control system 71 in the arrangement of FIG. 1 includes facilities for automatically establishing a desired relationship between the cyclic rate of the press 1 and the preset length of the successive segments advanced into the press. An output indication F generated on an output line 22 of the counter DR when the count accumulated in the counter via its input 32 coincides with the reference count preset therein is applied to a first input of the control system 71. A cam limit or control switch CM driven by a cam mounted on the main shaft at the press 1, produces a feed check signal RS2 at a second fixed point in each cycle of the press 1. A line 23 couples the indication RS2 to a second input 73 of the control circuit 71. Illustratively, the indication RS2 is selected to occur three-quarters of a cycle after the time of generation of the indexing initiation signal RS1. Like the signal RS1, the signal RS2 is generated by a cam switch which is in the form of a microswitch operated by a cam suitably mounted on the press crankshaft. In general, when the cyclic rate of the press is low, each occurrence of the output indication RS2 is delayed

with respect to the occurrence of the output indication F from the digital regulator DR.

The relative times of occurrence of the indications F and RS2 are compared in a logic stage **74** of the control circuit **71.** The output of the logic stage is associated with a motorized voltage setting stage AP, which produces on a line **75** a voltage that serves as the speed command input of the combining circuit ASRP. The stage AP includes a servomotor MS having complementary, rotation-effecting inputs respectively coupled to a pair of outputs **76** and **77** of the logic stage **74.** The stage **74** responds to a relative time delay between the indications F and RS2 to drive the servomotor MS in one of two respectively opposite directions when the indication RS2 lags or leads, respectively, the indication F. The stage **74** exhibits no output when the indications F and RS2 coincide.

The shaft of the servomotor MS is ganged via a link **78** to the wiper arm of the schematically depicted potentiometer VR. Such wiper arm is coupled via line **75** to the speed command input of the combining circuit ASRP. The link **78** is arranged so that the rotation of the servomotor in a direction corresponding to a time lag of the indication RS2 relative to the indication F serves to increase the voltage at the wiper arm of the potentiometer VR2, thereby commanding an increase of the speed of the press motor MP. In like manner, the rotation of the servomotor in the opposite direction, i.e. the direction corresponding to a time lead of the indication RS2 relative to the indication F, serves to decrease the wiper arm voltage and thereby command a decrease in the speed of the motor MP.

The phase relationship between the indications F and RS2 when the press runs at a low speed is shown in the press cycle diagram of FIG. **4.** The point in the press cycle (point B) at which the indication RS2 is generated occurs three-quarters of a cycle after the point in the cycle (point A) at which the indication RS1 is generated, irrespective of the instantaneous cyclic rate. However, the indication F (shown at point F of the diagram) will be generated at a progressively later time of each press cycle as the cyclic rate increases, and therefore the depicted time delay between the indications F and RS2 will decrease as the speed of the press increases.

With this background, the manner in which the control system **71** operates to establish a desired relation between the operating speed of the press and the selected fixed length of each sheet segment will be described in connection with FIGS. **1, 4** and **5** for the usual case where one cycle of press operation is to correspond to one indexing movement of the sheet. It will be assumed that the control circuit **71** is initially disabled and that the initial cyclic rate of the press **1** is low, so that the indication RS2 is delayed by a significant amount relative to the indication F.

Each indication RS2 is in the form of operation of two contacts RS2*a* and RS2*b* which connect to stage **74** in FIG. **5.** Physically the normally-open contact RS2*a*and the normally-closed contact RS2*b* are part of the cam limit switch CM. Effectuation of the indication RS2 constitutes the operation of normally open cam contact RS2*a* and normally closed cam contact RS2*b*. Moreover, each indication F generated by the indexing section **5** serves to activate the coil of a relay F, thereby operating contacts F*a* and F*b*. Thus, during the initial conditions assumed, either or both of the contacts RS2*b* and F*b* will be closed at any given time.

If under these circumstances push button R in the logic stage **74** is depressed to operate the control circuit **71,** an excitation path will be completed for a relay I. Such excitation in turn closes and latches normally open relay contacts I*a* so that the push button R may be released. Excitation of the relay I also closes normally-open contacts Ib to complete via line **76,** an "ACCELERATE" command path to the servomotor MS, i.e, a path that drives the servomotor in a direction to increase the speed of the press motor MP. The corresponding increase in the cyclic rate of the press serves to decrease the time delay between points B and F in FIG. **4.**

When the acceleration of the motor MP has progressed far enough so that the point B of FIG. **4** coincides with point F, the relay F and switch RS2 (FIG. **5**) will be excited simultaneously. Accordingly, the contacts F*b* and RS2*b* will each open to disable the excitation path of the relay I, thereby opening the contacts I*a* and I*b* and disabling the "ACCELERATE" command path to the servomotor MS. The wiper arm of the potentiometer VR (FIG. **1**) will now come to rest and will thereafter provide a steady command signal to the motor MP to operate the motor at constant speed. Such constant speed will be automatically optimum for the selected fixed length of the sheet segment, and will be maintained so long as the indications *f* and RS2 continue to coincide.

The occurrence of a coincidence between the indications F and RS2 also operate the contacts F*a* and RS2*a* (FIG. **5**) to enable an excitation path of a relay D, which in turn operates contacts D*a* and D*b*. The latter effects the enabling of a "DECELERATE" command path to the servomotor over line **77.** Therefore, any tendency for the speed of the motor MP to increase past the point corresponding to a coincidence of the indications F and RS2 will be opposed by the initiation of rotation of the servomotor in a direction tending to decrease the motor speed. In this way, the control system **71** automatically adjusts the cyclic rate of the press **1** to maintain a coincidence between the indications F and RS2.

To illustrate the operation of the depicted arrangement in a numerical example, it will be assumed that the indexing stage **5** is programmed in the manner indicated above to advance a 1000 meter segment of the sheet **8** into the press **1** in a total time of 1.8 seconds. Consequently, the indication *f* will be generated 1.8 seconds after the corresponding initiation signal RS1 is applied to the indexing means **5.** That is, after starting it will take 1.8 seconds for the count at **32** to reach the reference count at **33.** It will be further assumed that the cyclic rate of the press **1** is initially limited to 15 RPM, so that the press cycle period is 4 seconds. Accordingly, the indication RS2 (which is generated three-fourths of a cycle after the signal RS1) will be generated 3 seconds (three-fourths of the 4 second cycle) after the occurrence of the indication RS1. Operation of this speed is depicted in FIG. **6***a*.

When the control system **71** is activated under these conditions by depressing the pushbotton R (FIG. **5**), the initial time delay of 1.2 seconds between the indication *f* and the following indication RS2 permits the relay I to be energized as described above. The resultant rotation of the servomotor MS in the ACCELER-

ATE direction increases the value Ev and causes the press cycle rate to increase.

When the press speed has increased to say, 20 RPM, the cycle period is 3 seconds and the indication RS2 now occurs 2.25 seconds after the indication RS1. Since at this point there is still a lag of 0.45 seconds between the indication *f* and the following indication RS2, the relay I remains energized to continue the rotation of the servomotor MS in the ACCELERATE direction, increases Ev, and the press cycle continues to speed up. Operation at 20 RPM is depicted in FIG. 6*b*.

At 22 RPM, the indication RS2 will still lag the indication *f* by 0.25 seconds and the acceleration of the press cycle continues. See FIG. 6*c*. At 25 RPM, however, when the cycle period has been reduced to 2.4 seconds, the indications *f* and RS2 will each occur 1.8 seconds after the indication RS1. See FIG. 6*d*. In response to such coincidence, the normally closed contacts *f*b and R RS2*b* (FIG. 5) will open to disable the energizing path of the relay I and stop the acceleration of the press. The press will now continue to operate at the constant optimum speed of 25 RPM corresponding to the preselected feed length and indexing interval.

In the foregoing, the invention has been exemplified by a preferred arrangement. Many variations and modifications will now be evident to those skilled in the art. For example, the contacts RS2*a* and RS2*b*, instead of being embodied as limit switches CM operated by cams on the press crankshaft may be embodied as contacts on a separate relay coil triggered by closing of a limit switch operated by a cam on the press crankshaft, such as the limit switch CS, which switch produces the signal RS2. Also, the pushbutton R may be provided with auxiliary contacts in the line 31 that couples the index initiation signal RS1 to the indexing means 5, so that the indexing means remain disabled until the control circuit 71 is energized. Additionally, the logic stage 74 itself may be instrumented by electronic components in place of the electromechanical components shown. All such variations and modifications are considered to be within the spirit and scope of the invention; accordingly, it is desired that the scope of the appended claims not be limited to the specific disclosure herein contained.

While specific embodiments of the invention have been shown and described in detail to illustrate the application of the inventive principles, it will be understood that the invention may be embodied otherwise without departing from such principles.

What is claimed is:

1. In a manufacturing line wherein successive ideally fixed-length segments of sheet material are advanced into a punch press operating at a variable and initially low cyclic rate, the improvement which comprises means rendered effective at the completion of advance of each segment into the press for generating a first output indication; means operative at a fixed point in each press cycle for generating a second output indication, each second output indication being initially delayed relative to the corresponding first output indication, normally disabled means rendered effective during each press cycle that the second output indication is delayed relative to the first output indication for increasing the cyclic rate to decrease the time delay between the first and second indications; and means responsive to a coincidence of the first and second output indications for disabling the rate increasing means.

2. The improvement as defined in claim 1, further comprising means responsive to a coincidence of the first and second output indications for initiating a decrease of the cyclic rate.

3. In a manufacturing line wherein successive ideally fixed-length segments of sheet material are advanced by a normally disabled indexing means into a punch press that is operable at a variable and initially low cyclic rate to subject each successive segment to at least one punching operation, apparatus for automatically establishing an optimum relation between the cyclic press rate and the ideally fixed length of the sheet segment comprising, in combination, means rendered effective at a first fixed point of each press cycle for enabling the indexing means; segment length monitoring means effective at the conclusion of advance of each segment into the press for disabling the indexing means and for producing a first output indication; means rendered effective at a second fixed point of each press cycle for generating a second output indication, each second output indication being initially delayed relative to the corresponding first output indication; normally disabled means rendered effective during each press cycle that the second output indication is delayed relative to the first output indication for increasing the cyclic rate to decrease the time delay between the first and second output indications; and means responsive to a coincidence of the first and second output indications for disabling the rate increasing means.

4. Apparatus as defined in claim 3, further comprising means responsive to a coincidence of the first and second output indications for initiating a decrease of the cyclic rate.

5. Apparatus as defined in claim 3, in which the cyclic rate of the press is established by a variable speed motor, and in which the rate increasing means comprises, in combination, a servomotor; means controlled by the output of the servomotor for applying to the input of the variable speed motor a first voltage that increases when the servomotor is driven in a first direction and decreases when the servomotor is driven in the opposite direction; and means operative during each cycle that the second output indication is delayed with respect to the first output indication for driving the servomotor in the first direction.

6. Apparatus as claimed in claim 5, in which the applying means comprises, in combination, means for generating a second voltage proportional to the speed of the variable speed motor; a potentiometer to the shaft of the servomotor; and means responsive to the difference between the second voltage and the voltage at the wiper arm of the potentiometer for driving the variable speed motor at a rate determined by the last-mentioned difference.

7. Apparatus as defined in claim 3, in which the indexing means comprises a variable speed motor, and in which the monitoring means comprises, in combination, a digital counter having a setting input, a counting input and means for generating a first voltage proportional to the difference between a count entered into the counter via the setting input and an accumulated count entered into the counter via the counting input; means for applying to the setting input of the counter a count corresponding to a desired fixed length of each sheet segment; means responsive to the advance of

each segment for generating a succession of pulses at a fixed rate during such advance; means for coupling the output of the pulse generating means to the counting input of the counter; means for generating a second voltage proportional to the speed of the variable speed motor; and means responsive to the difference between the first voltage and the second voltage for driving the variable speed motor at a rate determined by the last-mentioned difference.

* * * * *