United States Patent [19]

Fujimaki et al.

[11] 3,843,871

[45] Oct. 22, 1974

[54] **APPARATUS FOR DETECTING BREAKAGE OF BLADE OF ROTARY CUTTER**

[75] Inventors: **Masaru Fujimaki; Takehiko Okamoto; Mikio Tashiro,** all of Matsushima, Japan

[73] Assignee: **Teijin Limited,** Osaka, Japan

[22] Filed: **Feb. 14, 1973**

[21] Appl. No.: **332,380**

[30] **Foreign Application Priority Data**

Mar. 3, 1972 Japan 47-22050

[52] **U.S. Cl.** .... **235/92 PD,** 235/92 V, 235/92 R, 83/62.1

[51] **Int. Cl.** **G06m 3/02**

[58] **Field of Search**.......... 235/92 PD, 92 PE, 92 V, 235/92 EC, 92 PB; 83/62, 522, 62.1

[56] **References Cited**

UNITED STATES PATENTS

3,019,346	1/1962	Laycak	235/92 V
3,234,360	2/1966	Schooley	235/92 PE
3,652,987	3/1972	McCarthy	235/92 EC
3,659,081	4/1972	Piccione	235/92 PE

Primary Examiner—Paul J. Henon

Assistant Examiner—Joseph M. Thesz, Jr.

Attorney, Agent, or Firm—Wenderoth, Lind & Ponack

[57] **ABSTRACT**

An apparatus is provided for detecting breakage of at least one of blades of a rotary cutter for a tow. The apparatus comprises a first detector which produces a pulse for every pass of a tip of the cutter blade across a predetermined position, a second detector which produces a pulse or the definite number of pulses for every rotation or every definite number of rotations of the rotary cutter, and a discriminator receiving the output pulses from the both detectors to produce an abnormal signal when the number of pulses produced by the first detector during a period of time of the pulses produced by the second detector is smaller than a predetermined value.

14 Claims, 18 Drawing Figures

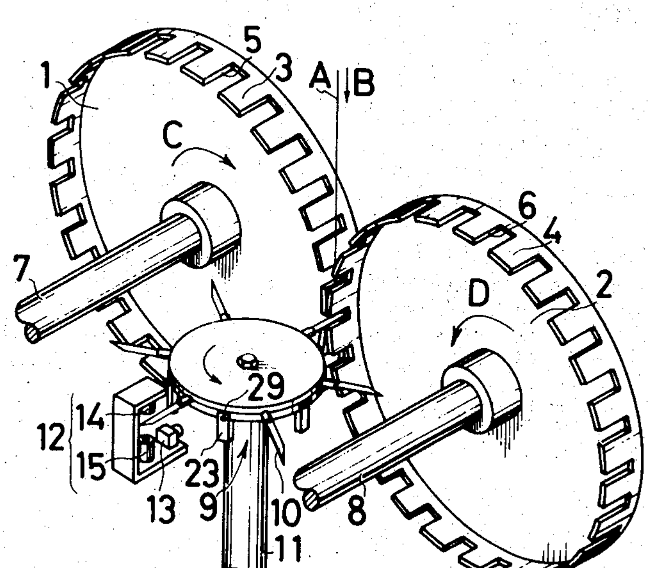


FIG.1

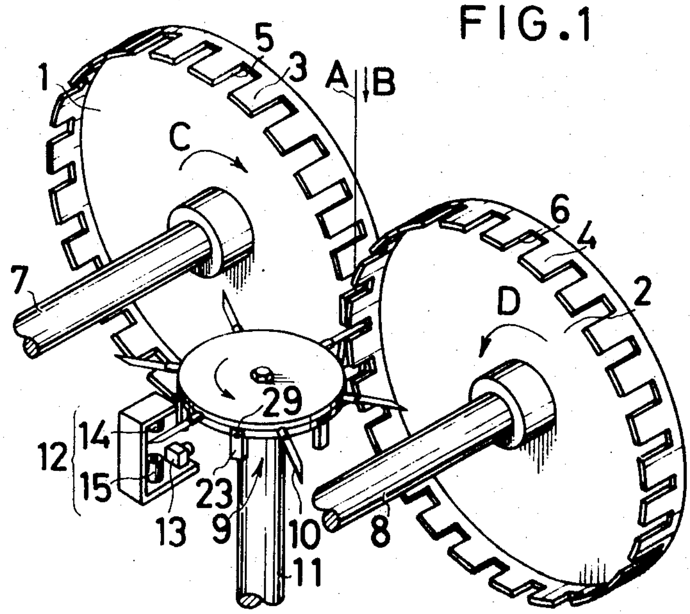


FIG.2

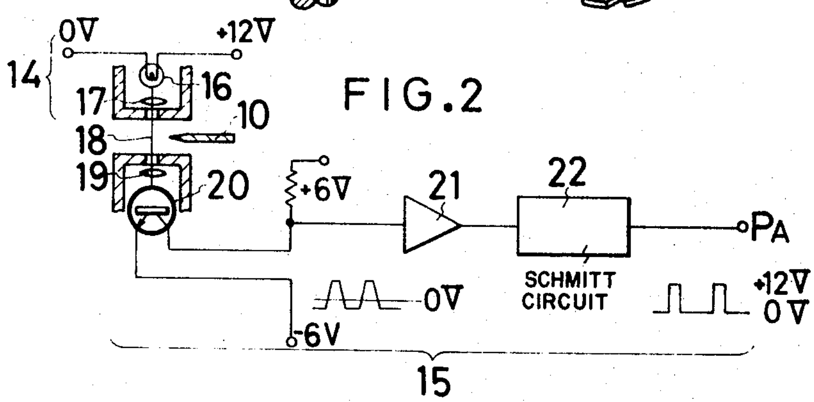


FIG.3

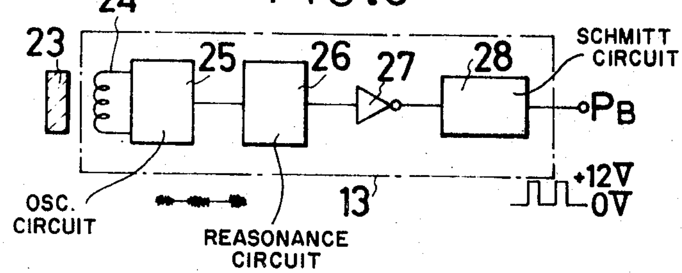


FIG.4(a)

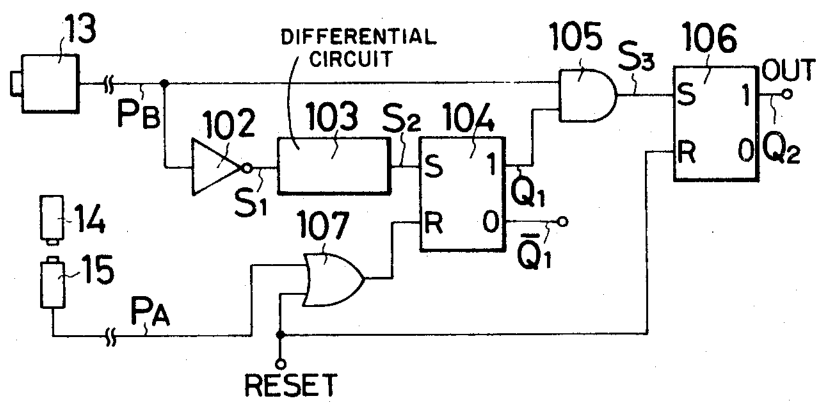

13
DIFFERENTIAL CIRCUIT
105
S3
106
OUT
PB
102
103
S2
104
S
1
R
0
Q1
Q2
S1
107
14
15
PA
RESET

FIG.4(b)

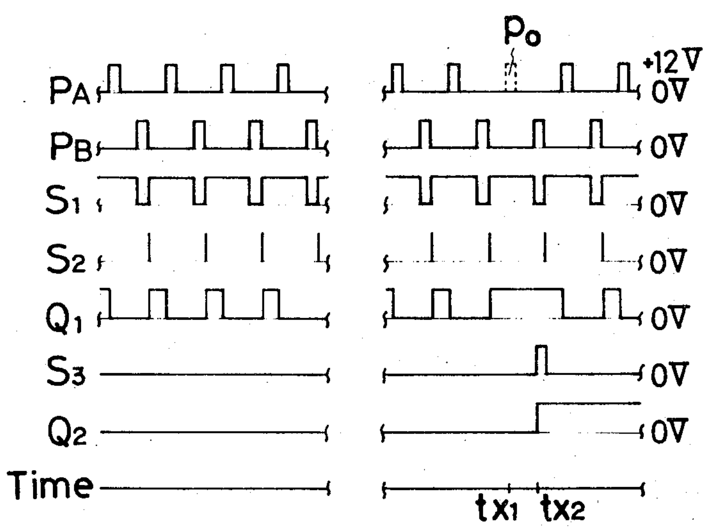

Po
+12V
PA
0V
PB
S1
S2
Q1
S3
Q2
Time
tx1
tx2

FIG.5(a)

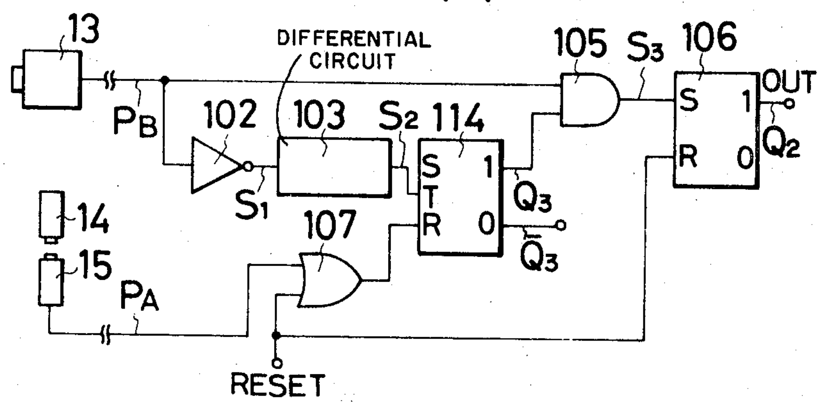

13
DIFFERENTIAL CIRCUIT
105
S3
106
PB
102
103
S2
114
S
1
OUT
R
0
Q2
T
S1
107
Q3
14
15
PA
RESET

FIG.5(b)

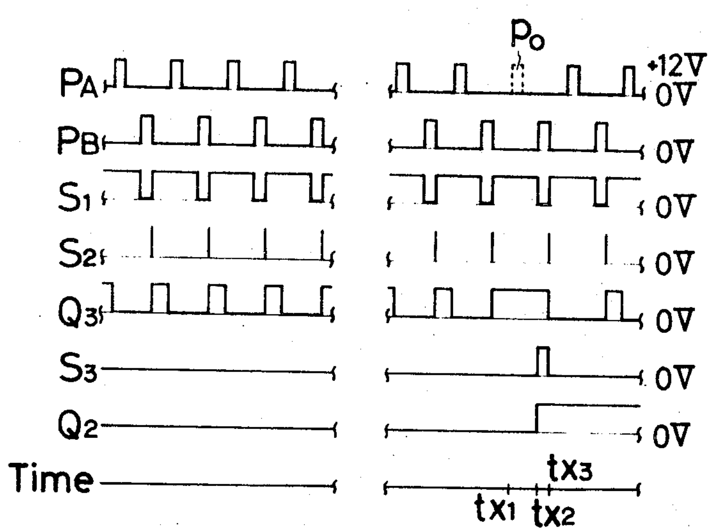

Po
PA
PB
S1
S2
Q3
S3
Q2
Time
+12V
0V
tx1
tx2
tx3

FIG.6(a)

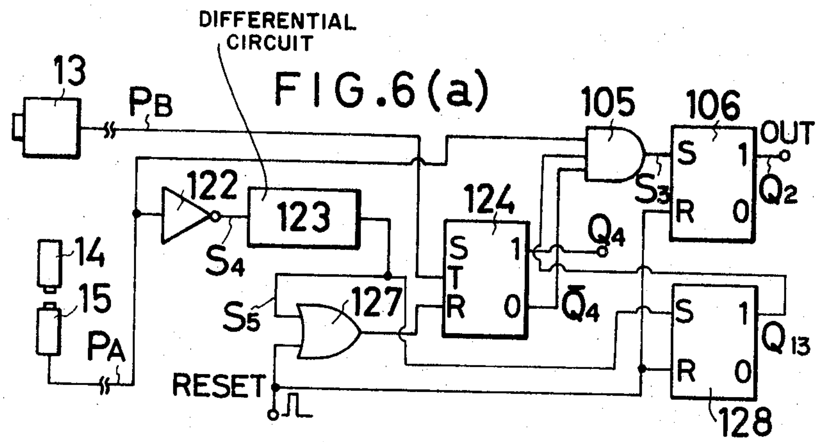


FIG.6(b)

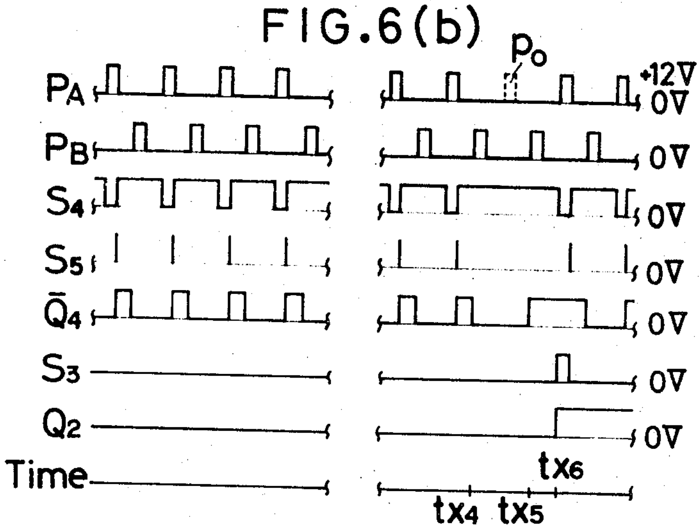


FIG.10

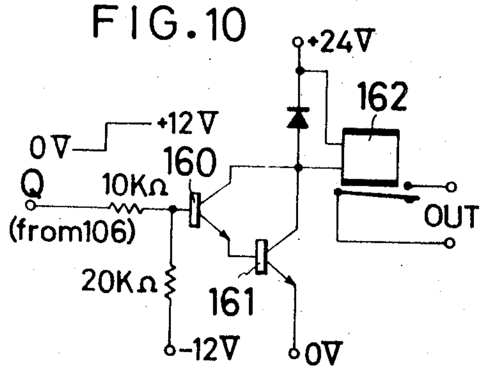


FIG.11

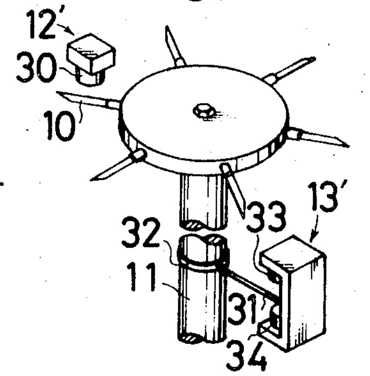


FIG.7(a)

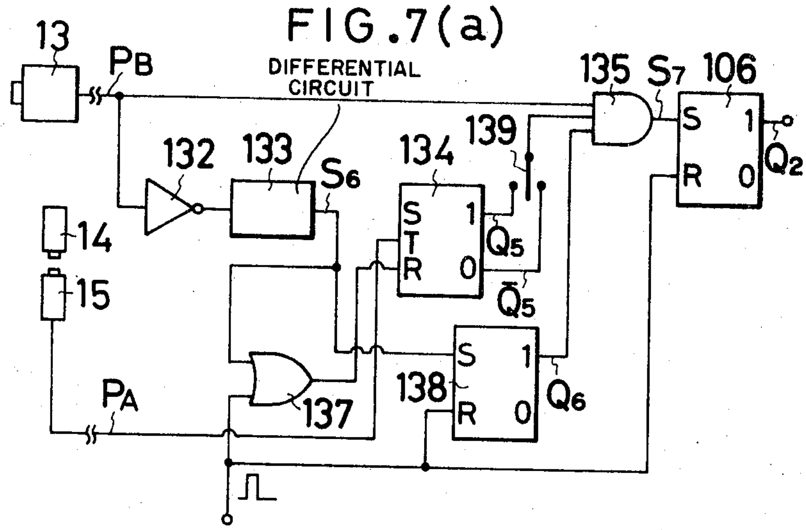


FIG.7(b)

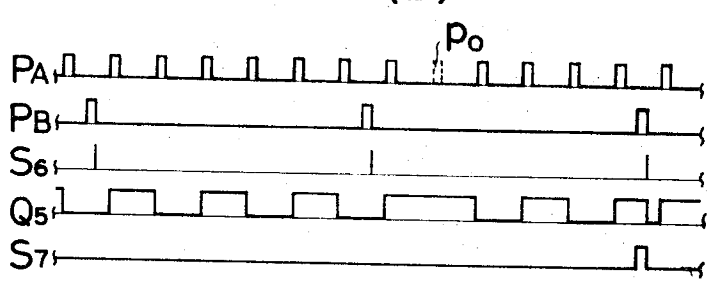


FIG.7(c)

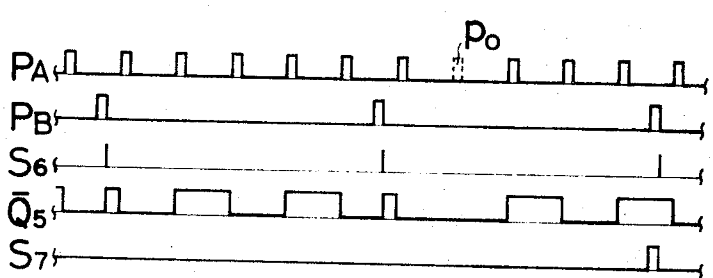


FIG.8(a)

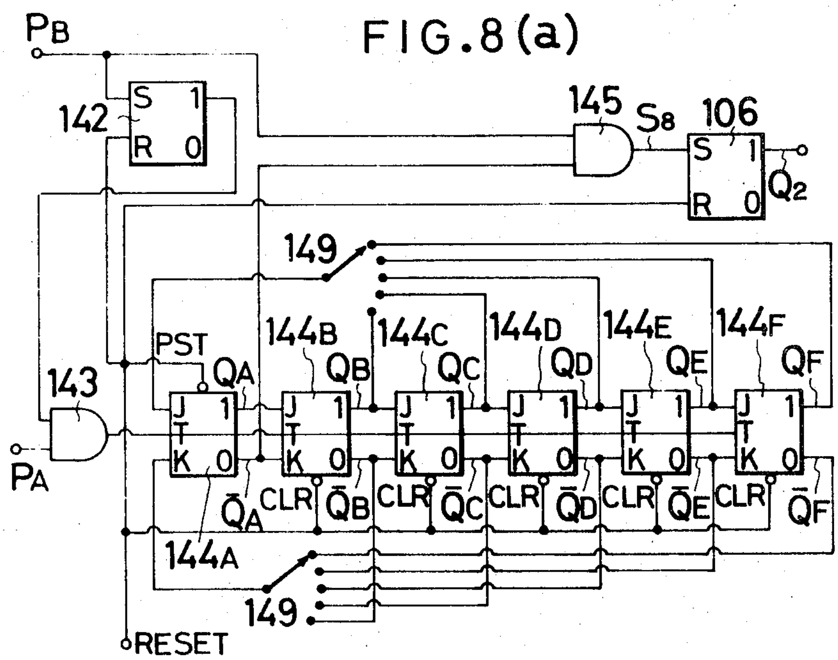

PB
142
S 1
R 0
145
S8
106
Q2
149
144B
144C
144D
144E
144F
PST
QA
QB
QC
QD
QE
QF
143
PA
J T K
CLR
144A
RESET

FIG.8(b)

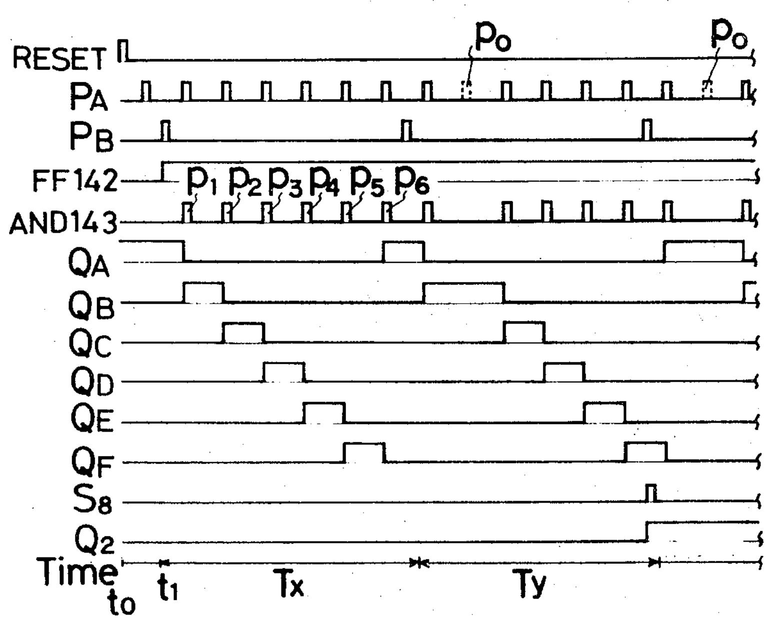

RESET
Po
PA
PB
FF142
P1 P2 P3 P4 P5 P6
AND143
QA
QB
QC
QD
QE
QF
S8
Q2
Time
to
t1
Tx
Ty

FIG.9(a)

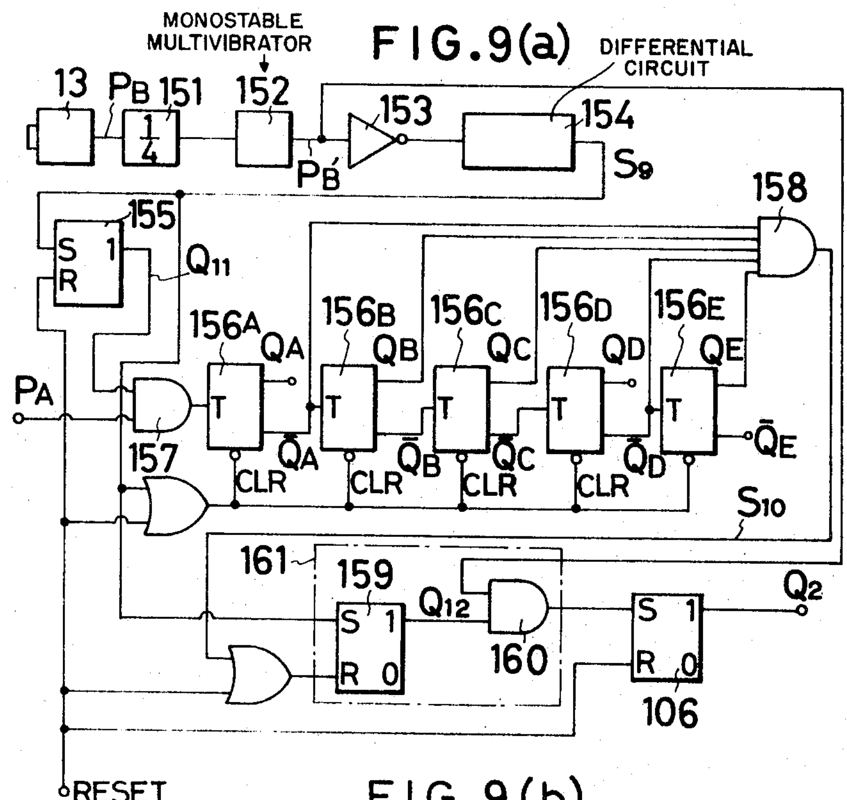
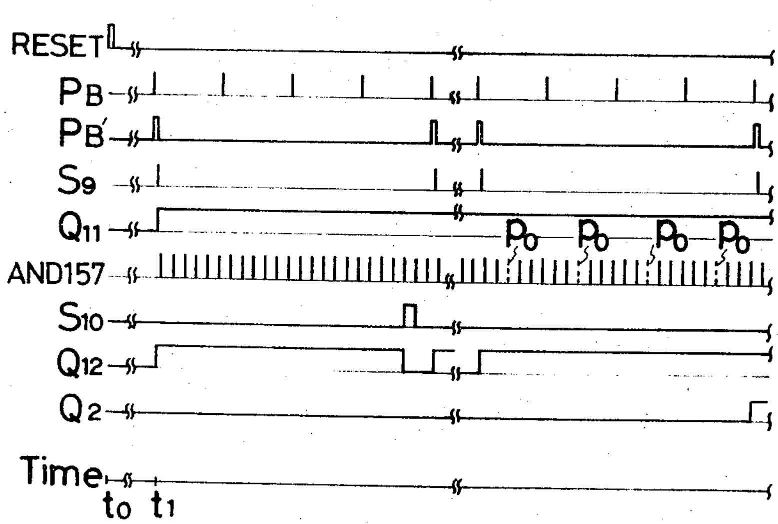

MONOSTABLE MULTIVIBRATOR
DIFFERENTIAL CIRCUIT
13
PB
151
1/4
152
PB'
153
154
S9
155
S
1
R
Q11
158
156A
156B
156C
156D
156E
QA
QB
QC
QD
QE
T
PA
157
CLR
S10
161
159
Q12
160
R 0
S 1
Q2
106
RESET

FIG.9(b)


RESET
PB
PB'
S9
Q11
AND157
S10
Q12
Q2
Po
Time
to
t1

APPARATUS FOR DETECTING BREAKAGE OF BLADE OF ROTARY CUTTER

This invention relates to an apparatus for detecting breakage of at least one of blades of a rotary cutter for a tow.

Widely known typical apparatus for cutting a tow or the like to a predetermined length comprises a pair of shallow tub-shaped cylindrical disks and a rotating cutter having a plurality of radially extending blades. Each disk has slots along a cylindrical flange thereof. The slots of the two disks are so disposed as to come into alignment with each other successively as the two disks rotate in the opposite directions, and the tow to be cut is fed between the flanges of the two disks. The cutter blades pass through the aligned slots to cut the tow to a predetermined length.

The cutter blade usually develops very small or fine cracks at the base of the blade due to distortion caused while the blade material is being processed, grinding of the blade, or impact at the time of cutting the tow. Furthermore, wear due to stress will be accumulated during the time of cutting the tow and the blade tends to be broken at the base of the blade in which cracks developed.

Breakage of the cutting blade while the rotary cutter is in operation does not at all affect the operation itself. Hence the operators often do not find the occurrence of such breakage of the blade and continue the operation. As a result, if it is assumed that only one blade is broken, the tow across which the blade would have passed remains uncut, resulting in, say, "double-length cut" abnormal products having twice the predetermined length. Such "double-length cut" abnormal products often cause trouble in spinning or in other processings.

Accordingly, an object of this invention is to provide an apparatus for detecting breakage of the blade of a rotary cutter at an early time.

Another object of this invention is to provide a detecting apparatus which does not require adjustment even if the cutting speed is varied.

Still another object of this invention is to provide a detecting apparatus which allows for easy adjustment when the number of cutter blades is changed.

A further object of this invention is to minimize the production of "double-length cut" abnormal products, thereby omitting regular checking work by operators.

To achieve the above-mentioned objects, the present invention provides an apparatus for detecting breakage of at least one of the blades of a rotary cutter for a tow in which n (an integer of **2** or more) blades are radially disposed, comprising: a first detector which produces a pulse for every pass of a tip of the cutter blade across a predetermined position; a second detector which produces a pulse or a definite number of pulses for every rotation or every definite number of rotations of said rotary cutter, said pulses being produced to have a period of time during which the number of pulses produced by said first detector normally reaches a predetermined value; and a discriminator receiving the output pulses from said both detectors to produce an abnormal signal when the number of pulses produced by the first detector during said period of time defined by said pulses produced by said second detector is smaller than a predetermined value.

By specifying the interrelationships among such first detector, second detector, and the discriminator, the present invention may be embodied as follows:

First, the second detector produces n units of pulses for every rotation of the rotary cutter, the pulses being produced to have a period of time during which one pulse is produced by said first detector. The discriminator receives the output pulses from both detectors to produce an abnormal signal when no pulse is received from the first detector during the pulse period of the second detector.

Second, the second detector produces one pulse for every rotation of the rotary cutter, the pulses being produced in a period of time during which n units of pulses are produced by the first detector. The discriminator receives the output pulses from the both detector to produce an abnormal signal when the number of pulses produced by the first detector during the period of time defined by pulses produced by the second detector is smaller than n units.

Third, the second detector produces one pulse for every m (an integer of 2 or more) revolutions of the rotary cutter, the pulse being produced to have a period of time during which $n\ m$ units of pulses are produced by the first detector. The discriminator receives the output pulses from both detectors to produce an abnormal signal when the number of pulses produced by the first detector over a period of time determined by pulses; produced by the second detector is smaller than reference value determined at near the center between $n\ m$ and $(n-1)$m.

As a detecting means to be used in the above-mentioned first and second detectors, a known photoelectric switch or an proximity switch which is magnetically actuated when a ferromagnetic metal piece approaches may be used.

The above and further novel features and objects of this invention will appear more fully from the following detailed description when the same is read in connection with the accompanying drawings, and the novel features will be particularly pointed out in the appended claims.

In the figures where like elements are referenced alike:

FIG. **1** is a perspective view showing major portions of an apparatus for detecting broken blades of a rotary cutter.

FIG. **2** is a circuit diagram of the first detector shown in FIG. **1.**

FIG. **3** is a circuit diagram of the second detector shown in FIG. **1.**

FIG. **4***a* to FIG. **9***a* are circuit diagrams of different discriminators which receive output signals from the first and second detectors.

FIG. **4***b* to FIG. **9***b* and FIG. **7***c* are time charts of the circuit diagrams of FIG. **4***a* to FIG. **9***b*.

FIG. **10** shows a switch circuit which is operated by the abnormal signals from the above-mentioned discriminators, and

FIG. **11** is a perspective view showing another embodiment of the first detector and the second detector.

Referring to FIG. **1,** a conventional apparatus comprises a pair of shallow tub-shaped cylindrical disks **1** and **2** of identical shape having one side open. Slots **5** and **6** of the same length and width are equidistantly spaced from each other along the curved cylindrical flanges **3** and **4** of said disks, said slots being parallel to the shafts **7** and **8** upon which the disks are mounted. One end of each of the slots opens out of the side edge of the flange **3** and **4.** These disks are so disposed that when the open sides face in the same direction and the curved flange surfaces are adjacent each other, corresponding slots **5** and **6** are in alignment with each other. The disks **1** and **2** are of the same size and they rotate at the same speed in the directions of arrows C and D respectively. A tow A that is delivered from the direction of arrow B is held between the curved flanges of the disks.

A rotating cutter **9** having a plurality of radially extending blades **10** is disposed adjacent said contacting curved flange surfaces **5, 6,** the cutter blades being adapted to pass during their rotation through a channel formed by two aligned slots **5, 6** to cut the tow which has been fed between the curved flange surfaces. The shaft **11** of the cutter and the shafts **7** and **8** of the disks are linked to a single induction motor via a gear mechanism (not shown), so that the revolution ratio of the disks to the rotating cutter is constant. Though the revolution speed of the rotating cutter varies in accordance with conditions, it is about 600 r.p.m. Two detectors **12** and **13** are incorporated to such rotary cutter apparatus; The first detector **12** produces electric pulses equal in number to the number of cutter blades **10** which pass thereover while the rotary cutter **9** rotates, once and the second detector **13** produces a predetermined number of pulses while the rotary cutter **9** rotates once.

FIG. 2 shows the first detector **12** constructed by using a conventional photoelectric switch. A light-emitting portion **14** and a light-receiving portion **15** are so arranged as to face to each other, and the cutter **10** is allowed to pass between the two portions **14** and **15.** The portion **14** has a light-emitting element in which the light **18** is from a lamp **16** through a lens **17.** The emitted light **18** emitted is received by the light-receiving portion **15** as far as not interrupted by the cutter blade **10.** The portion **15** comprises a lens **19,** phototransistor **20,** amplifier **21,** and Schmitt circuit **22.** When the light **18** is not interrupted by the cutter blade **10,** the collector potential of the phototransistor **20** will be negative so that the output potential of the Schmitt circuit **22** will be zero volts. When the light **18** is interrupted by the cutter blade **10,** the collector potential becomes positive so that the output potential of the Schmitt circuit **22** will be +12 volts.

FIG. 3 shows a circuit of the second detector having a proximity switch. Referring to this circuit, an oscillation coil **24,** which works together with ferromagnetic metal pieces **23** (see FIG. 1) attached by means of a screw **29** to a blade bed of the rotary cutter **9,** is enclosed in a head of the second detector **13.** When the metal piece **23** approaches the oscillation coil **24** as shown in the Figure, due to a change in inductance and a change in loss, the oscillator circuit **25** stops its oscillation. As the metal piece **23** retreats from the oscillation. Coil **24,** the oscillator circuit **25** restores and maintains its oscillation. Resonance circuit **26,** NOT circuit **27,** and Schmitt circuit **28** are coupled to the oscillator circuit **25** seriatim, so that when the oscillator circuit **25** is not oscillating, the output potential will be plus 12 volts, and when oscillating, the output potential will be zero volt.

Accordingly, when the first and second detectors produce pulses, the potential of the output signal from the first or the second detector will be +12 volts. When the output pulses of these detectors distinguish, the potential of the output signal drops from +12 to 0 volt.

For simplification, the output signals from the first and the second detectors hereinafter are referred to as P_A and P_B.

A discriminator to determine breakage of the cutter blades by using pulse signals P_A and P_B is illustrated below with reference to several embodiments. In the following illustration, the "0" state and "1" state stand, respectively, for 0 volt and +12 volts.

In a first embodiment, six ferromagnetic metal pieces **23** are each attached by screw **29** to the blade bed between the space defined by six cutter blades, so that the pulses are produced alternately in time series manner by the first and second detectors. In this embodiment a discriminator shown in FIG. **4***a* is employed in which a pulse signal P_B is turned to its opposite pulse signal S_1 through NOT circuit **102,** and is further converted into a positive impulse signal S_2 through a differential circuit **103.** The impulse signal S_2 is fed to a set terminal of a flip-flop **104.** To a reset terminal of the flip-flop **104** are fed a pulse signal P_A through OR circuit **107** and an external reset signal. The time at which the flip-flop **104** is set and output signal Q_1 is turned from 0 to 1 is delayed slightly with respect to the time at which the pulse signal P_B is turned from 1 to 0. This delay or lag is caused by the functioning time of the NOT circuit **102,** the differential circuit **103,** and the flip-flop **104.**

The signal Q_1 and the pulse signal P_B are fed to AND circuit **105,** and output signal S_3 of the AND circuit **105** is fed to a set terminal of flip-flop **106** which receives the external reset signal as a reset signal.

The above-mentioned external reset signal is a pulse which will be produced when either a push button for starting the rotary cutter or a push button for resetting an alarm (not shown) is pushed.

As shown on the left half of FIG. **4***b*, where there are no broken cutter blades, the flip-flop **104** will have been reset by the pulse signal P_A and its output signal Q_1 will be in 0 state before the pulse signal P_B is turned from 0 to 1 state. On the other hand, as mentioned above, the signal Q_1 will turn from 0 to 1 immediately after the pulse signal P_B has turned from 1 to 0.

Hence both the output signal S_3 of the AND circuit **105** and the output signal Q_2 of the flip-flop **106** remain in the 0 state. But if one of the cutter blades has been broken, the light will not be interrupted when the broken cutter blade has passed near the photoelectric switch, so that the first detector does not produce the pulse. Pulse Po shown by dotted line on the right of FIG. **4***b* stands for such "not produced" pulse. This means that the flip-flop **104** at the time tx_1, is not reset and remains in the "set" state, and its output Q_1 remains in the 1 state. By further rotation of the blade bed, when the ferromagnetic metal piece **23** approaches the second detector **13** at the time tx_2, the second detector produces a pulse P_B, whereby the output signal S_3 of the AND circuit **105** is set to the 1 state, and the signal S_3 sets the flip-flop **106** so that its output Q_2 is in the 1 state. This state will continue until the above-mentioned external reset signal is received.

The R-S type flip-flop **104** of FIG. **4***a* is replaceable with a J-K type flip-flop or an R-S-T type flip-flop. FIg.

5*a* shows a discriminator which employs the R-S-T type flip-flop. Briefly illustrating, this discriminator resembles the above-mentioned embodiment in that the pulse signal P_B is converted into an impulse signal S_2, but is different in that the impulse signal S_2 of this circuit triggers the R-S-T flip-flop **114**, which is reset by the pulse signal P_A, and reverses the state. Accordingly, in its operation, the state of output signal Q_3 of the flip-flop **114** as far as there is no breakage in the cutter blades is equal to the output signal Q_1 of the flip-flop **104** shown in the left half of FIG. 4*b*, and is as shown in the left half of FIG. 5*b*. But if a cutter blade is broken, and pulse Po is not produced, the flip-flop **114** will not be reset (the output signal Q_3 remains in the 1 state). At time tx_2; the pulse signal P_B is switched to the 1 state and the output signal S_3; of the AND circuit **105** becomes 1, which makes the output signal Q_2 of the flip-flop **106** 1. The flip-flop **114** will be triggered at time tx_3 by the next received pulse and will be reset.

In the embodiments of FIG. 4*a* and FIG. 5*a* the pulse signal P_B was employed as one of the input signals to the AND circuit **105**. But this pulse P_B may be replaced by a pulse signal P_A. An embodiment of a discriminator using such a pulse signal P_A is; shown in FIG. 6*a*. In the circuit of FIG. 6*a*, the pulse signal P_A is fed to the AND circuit **105** and, at the same time, is converted into an impulse signal S_5 through NOT circuit **122** and differential circuit **123**, which is fed to a set terminal of R-S type flip-flop **128** and to a reset terminal of R-S-T type flip-flop **124** through OR circuit **127**. An external reset signal is fed to OR circuit **127** and to the reset terminals of flip-flops **106** and **128**. Pulse signal P_B is fed to a trigger terminal of the flip-flop **124**. Output signal $\overline{Q}_4$ of the flop-flop **124** which when reset produces a 1 output, is fed to AND circuit **105**. Output signal S_3 of the AND circuit **105** is fed to a set terminal of flip-flop **106**. Output signal Q_{13} of the flop-flop **128** is fed to the AND circuit **105**.

When the rotary cutter is started, the discriminator receives the external reset signal, whereby the three flip-flops **124**, **106**, and **128** are reset. Once the flip-flop **128** has been reset, the output signal S_3 of the AND circuit **105** remains in the 0 state, regardless of the state of the pulse signal P_B and the signal $\overline{Q}_4$.

Immediately after the rotary cutter is started, the first detector starts to produce pulses. When the first pulse of these pulses has extinguished, the flip-flop **128** will be set by the first impulse of the impulse signals S_5. Therefore, the output signal Q_{13} of the flip-flop **128** will remain in the 1 state until an external reset signal is received. Consequently, the AND circuit **105** will be placed in the condition where it is capable of distinguishing whether the other two inputs P_A and $\overline{Q}_4$ are simultaneously in the 1 state. At the same time, the flip-flop is reset.

Where there is no breakage of the cutter blades, the pulse signal P_A and the signal $\overline{Q}_4$ are not simultaneously in the 1 state, as shown in the left half of FIG. 6*b*. Accordingly the output signal S_3 of the AND circuit **105** is the 0 state. However, if a cutter blade is broken, the impulse signal S_5 corresponding to the disappeared pulse Po, i.e., the reset input will not be fed to the flip-flop **124**, and hence pulse signals P_B as trigger inputs will successively be fed to the flip-flop **124** at times tx_4 and tx_5 as shown in the right half of FIG. 6*b*. The flip-flop **124** at the time tx_5, therefore, maintains unchanged state, i.e., equal to when being reset (output signal $\overline{Q}_4$ is in the 1 state). As the time passes to tx_6 and the pule signal P_A of the 1 state is fed to the AND circuit **105**, the output signal S_3 of the AND circuit **105** and the output signal Q_2 of the flip-flop **106**, respectively, are set to the 1 state.

The discriminators shown above in FIGS. 4*a*, 5*a* and 6*a* can be modified appropriately. For example, the pulse signals P_A and P_B to the flip-flop **104** of FIG. 4*a* may be fed in opposite relation, and the signal $\overline{Q}_1$ opposite to the output signal Q_1 of the flip-flop **104** may be fed as the input signal to the AND circuit **105**, thereby functioning in substantially the same manner as that shown in the time chart of FIG. 4*b*. Also, the outputs of OR circuits **107**, **127** shown in FIGS. 5*a* and 6*a* may be fed to the set terminals of the flip-flops **114**, **124**, and the outputs $\overline{Q}_3$ and Q_4 of these flip-flops may be fed to the AND circuit **105**. Furthermore, the AND circuit **105** shown in FIGS. 4*a*, 5*a* and 6*a* may be replaced by an OR circuit or a NOR circuit. Likewise, AND circuits **135** and **245** shown respectively in FIG. 7*a* and 8*a*, which will be described hereinafter, may be replaced by an OR circuit or a NOR circuit.

In the embodiments mentioned above, the first and the second detectors produced pulses alternatingly in time series manner.

In a second embodiment, one ferromagnetic metal piece **23** is attached to the blade bed of the rotary cutter so that the second detector produces one pulse per revolution of the rotary cutter. A signal to inform the breakage of the cutter blade is produced when an even number (or odd number) of output pulse produced from the first detector, corresponding to the number of cutter blades which should be present during the period of time when the pulses are produced by the second detector is changed into an odd number (or even number).

Referring to FIG. 7*a*, the pulse signal P_A is fed to a trigger terminal of R-S-T type flip-flop **134**. The pulse signal P_B from the proximity switch which is actuated by the single metal piece **23** is fed to AND circuit **135**, and at the same time the pulse P_B is converted into an impulse signal S_6 through NOT circuit **132** and differential circuit **133**, and is fed as a set input to flip-flop **138**, and fed as a reset input to the flip-flop **134** through OR circuit **137**. An external signal is fed to the OR circuit **137** and to the reset terminals of the two flip-flops **138** and **106**. Either one of output signals Q_5 or $\overline{Q}_5$ of the R-S-T type flip-flop is fed via a switch **139** to the AND circuit **135**. The AND circuit **135** receives an output signal Q_6 from the flip-flop **138**. An output signal S_7 of the AND circuit **135** is fed to a set terminal of the flip-flop **106**.

The discriminator in this embodiment includes the R-S type flip-flop **138** which has the same function as the flip-flop **128** in FIG. 6*a*. Accordingly, after the flip-flop **138** has been set by the first impulse of the impulse S_6 produced by starting the rotary cutter, the AND circuit **135** will be placed in a condition where it is capable of distinguishing whether the pulse signal P_B and the signal Q_5 (or $\overline{Q}_5$) are simultaneously in the 1 state.

The flip-flop **134**, on the other hand, is reset by the impulse signal S_6 and is triggered by the pulse signal P_A, to reverse its own state successively. The flip-flop **134**, after being reset and reversed an odd number of times, will be in the reset state. That is, the output signals Q_5 and $\overline{Q}_5$ at this time will be in 0 and 1 states, respectively. In this way, even if the impulse signal S_6 is fed to the reset terminal of the flip-flop **134** which has been in the reset state, its state will remain unchanged. But the flip-flop **134**, after being reset and reversed odd number of times, will be in a state opposite to the reset state. That is, the output signals Q_5 and $\overline{Q}_5$ at this time will, respectively, be 1 and 0. If the impulse signal S_6 is fed to the reset terminal of the flip-flop **134** under this state, flip-flop **134** will necessarily be placed in the reset state.

Where the number n of cutter blades is an even number, for example, six, the switch **139** should be so set that the output signal Q_5 of the flip-flop **134** is fed to the AND circuit **135.** In this case, as shown on the left side of FIG. **7***b*, if there is no breakage of the cutter blades, the output signal Q_5 of the flip-flop **134** fed to the AND circuit **135** via the switch **139** at the time when the pulse signal P_B is just turning to 1 is already in the 0 state. Hence the output signal S_7 of the AND circuit **135** remains in the 0 state. But if it is assumed that only one cutter blade has been broken, the number of times the flip-flop **134** has reversed will be reduced by one. Accordingly, as shown on the right side of FIG. **7***b*, when the pulse signal P_B is just turning to 1, the output signal Q_5 of the flip-flop **134** connected to the AND circuit **135** will already be in the 1 state. Hence the output signal S_7 of the AND circuit **135** will 1, which makes the output signal Q_2 flip-flop **106** 1.

Where the number n of cutter blades is odd, for example, five blades, the switch **139** should be set so that the output signal $\overline{Q}_5$ from the flip-flop **134** is fed to the AND circuit **135.** In this case, where there is no breakage of the blades, the output signal $\overline{Q}_5$ at the time when the pulse signal P_B is just turning into 1 will already be in the 0 state, and the output signal S_7 will remain in the 0 state. But if breakage occurs on the blade, the output signals Q_5, s_7 and Q_2 are changed to the 1 state at the time when the pulse signal P_B is changing into 1.

Thus, in this embodiment, where the number of the cutter blades is even (or odd), the abnormal signal will be or will not be produced at the time when the pulse signal P_B is turning into the 1 state depending on whether the flip-flop **134** has been reset (or can be reset) or can be reset (or has been reset).

The discriminator shown in FIG. **8***a* constitutes a ring counter, in which J-K type flip-flops **144**A – **144**F in number equal to the number of the cutter blades used, for example, six blades are connected like a ring by means of switches **149.** This ring counter comprises a flip-flop **142** which is reset by an external reset signal and will be set by the pulse signal P_B, and AND gate **143** which receives as inputs an output signal from the flip-flop **142** and the pulse signal P_A and feeds its (AND gate **143**) output as trigger inputs to the flip-flops **144**A – **144**F constituting the above-mentioned ring counter. If the R-S flip-flop **142** is reset by the external reset signal before the pulse signal P_B is produced, i.e., when the cutting device is being started (timet_0), the AND gate **143** will be closed. Simultaneously, the external reset signal causes the flip-flop **144**A to be preset so that its output signal Q_A becomes the 1, and causes other flip-flops **144**B – **144**F to be cleared so that their respective output signals Q_B–Q_F become 0. Then if the pulse signal P_B for the first time becomes 1 at time t_1, the flip-flop **142** will be reset, and the AND gate **143** will be opened. As a result, the pulse signal P_A passed through the AND gate **143** triggers every J-K flip-flop **144**A – **144**F. Since J-K flip-flops **144**A – **144**F the ring counter, the first pulse p_1 of said pulse signals P_A will set the output signal Q_A of the J-K flip-flop **144**A to the 0 state, and will set the output signal Q_B of the next flip-flop **144**B to the 1 state. The second pulse p_2 then sets the output signal Q_B to the 0 state and the output signal Q_C of the following flip-flop **144**C to the 1 state. In this way, the third, fourth and fifth pulses p_3, P_4, and P_5 successively set the output signals Q_D, Q_E, and Q_F the 1 state. The sixth pulse P_6 then sets the output signal Q_F to the 0 state and the output signal Q_A to the 1 state. When there is no breakage of the cutter blades, six pulses will pass through the AND gate **143** during each period between successive pulse signals P_B. The above-mentioned operation will be repeated, and every one of the J-K flip-flops **144**A – **144**F will function as shown in the time intervel Tx of FIG. **8***b*. In this way, where the pulse signal P_B is in the 1 state, the output signal Q_A will be in the 1 state and its opposite signal $\overline{Q}_A$ will be in the 0 state.

The discriminator has an AND circuit **145** which receives as inputs the output signal $\overline{Q}_A$ of the flip-flop **144**A and the pulse signal P_B. Output signal S_8 of the AND circuit **145** sets the flip-flop **106,** and the flip-flop **106** is reset by the external reset signal. When there is no breakage of the cutter blades, and where the pulse signal P_B is in the 1 state, the output signal $\overline{Q}_A$ will be in the **0** state as mentioned above. Hence the output signal S_8 of the AND circuit **145** will always be in the 0 state. But if one of the cutter blades breaks, as shown in the time interval Ty of FIG. **8***b*, only five pulses will pass through the AND gate **143** during one cycle (or period) of the pulse signal P_B. Accordingly, the time required for the output signal Q_B to turn itself into the 1 state will double compared to the normal instance, and the change of the output signals Q_C, Q_D, Q_E, and Q_F will be delayed a little compared to their normal response. Therefore, when the pulse signal P_B is just turning into the 1 state, the output signal Q_F will be in the 1 state, and the output signal Q_A will be still in the 0 state (output signal $\overline{Q}_A$ is in the 1 state). Hence the output signal S_8 of the AND circuit **145** will be switched to the 1 state, and the output signal Q_2 of the R-S flip-flop will be set to the 1 state.

Although the time interval following the interval Ty has not been shown in FIG. **8***b*, when the pulse signal P_B is just becoming 1, the output signal Q_E in this interval (following the interval Ty) will be in the 1 state. Furthermore, in the next interval, when the pulse signal P_B is just becoming 1 the output signal Q_D will be in the 1 state. Accordingly, in place of the output signal $\overline{Q}_A$, any one of the output signals Q_B, Q_C, Q_D, Q_E, or Q_F may be put into the AND circuit **145.** Also, instead of putting the signal $\overline{Q}_A$ into the AND circuit **145,** the output signals Q_B, Q_C, Q_D, Q_E, and Q_F may be put into one OR circuit, and the output signal of the OR circuit may be put into the AND circuit **145.**

In this embodiment, when the number of the cutting blades is to be changed, for example, from six to five blades, one needs only to advance the switch **149** for one step in the clockwise direction.

A final embodiment employing a discriminator shown in FIG. **9***a* shall be described hereinafter. In this embodiment, a pulse is produced from the first detector as each cutter blade passes a predetermined point. However, this embodiment is different from the above-mentioned first and second embodiments in that the second detector produces one pulse for every m (an integer of 2 or more) rotations of the cutter blades. In the embodiment shown in the Figure, a frequency divider **151** which divides frequency into $1/m$ is provided on the output side of a proximity switch which is actuated by a single metal piece **23,** so that when m 32 4, every time when the frequency divider **151** received four pulses from the approach switch, the frequency divider **151** triggers a monostable multivibrator **152** once, thereby causing the monostable multivibrator **152** to produce a pulse several milliseconds in width. The output signal from this monostable multivibrator **152** shall be hereinafter referred to as pulse signal $P_{B'}$. Of course an auxiliary shaft driven by the cutter shaft through a reduction gear having a reduction ratio of $1/m$ may be used in place of the frequency divider **151** to produce a single pulse $P_{B'}$ for every rotation of the auxiliary shaft. This discriminator has a binary counter comprising five flip-flops **156A – 156E** to count the pulse signals P_A fed through AND gate **157.** The value of the counter will return to zero if the counter is cleared by signal S_9 which is converted from said pulse signal $P_{B'}$ through NOT circuit **153** and differential circuit **154.** The pulse signal P_A can pass the AND gate **157** after an R-S type flip-flop **155** reset at time to by an external reset signal, is set by the first impulse signal S_9 at time t_1.

A setting means **158** composed of an AND circuit receives every output signals $\overline{Q}_A$, Q_B, Q_C, $\overline{Q}_D$, and Q_E from flip-flops **156A – 156E** forming a counter, and the output pulse S_{10} thereof becomes the 1 state when these output signals are all in the 1 state.

R-S fip-flop **159** is set by the impulse signal S_9 produced when the pulse signal $P_{B'}$ turns from 1 state to 0 state and is reset by the signal S_{10}. Output signal Q_{12} from the flip-flop **159** is fed to AND circuit **160** together with the pulse signal $P_{B'}$. This flip-flop **159** and the AND circuit **160** form a gate circuit **161** to determine whether the pulse signal $P_{B'}$ is permitted to pass through toward a flip-flop **106.** It will easily be understood that the gate circuit **161** is opened by the impulse signal S_9 and closed by the signal S_{10}.

If none of the six cutter blades break, the counter **156** will count 6 × 4, i.e., 24 pulses while the rotary cutter rotates four times. Hence, after the pulse is produced from the monostable multivibrator **152,** the counter **156** will count **22** pulses before the rotary cutter rotates four times thereby establishing a relation $\overline{Q}_A=Q_B=Q_C=\overline{Q}_D=Q_E=1$. Accordingly, the output signal S_{10} of the setting means **158** is 1, which closes the gate circuit **161.** Hence if the rotary cutter has rotated four times, and a pulse is produced again from the monostable multivibrator **152,** said pulse cannot pass through the gate circuit **161.**

But if it is assumed that one of six cutter blades is broken, the counter will count only (6 – 1) × 4, i.e., 20 pulses P_A while the rotary cutter rotates four times. Hence when the rotary cutter has rotated four times after the pulse has been produced from the monostable multivibrator **152,** the counter cannot hold a relation $\overline{Q}_A=Q_B=Q_C=\overline{Q}_D=Q_E=1$. Hence the gate circuit **161** will be left open. And when the rotary cutter has rotated four times and the monostable multivibrator **152** has produced a pulse, said pulse will pass through the gate circuit **161,** setting the flip-flop **106,** so that the output signal Q_2 is set to 1.

If the number of the cutter blades employed is n, a setpoint α of the setting means **158** will most desirably be $(n-½)m$ which is a central value between $n-m$ and $(n-1)$m. But if m is an odd number, the setpoint α may be $(n-½)m+½$ or $(n-½)m-½$. But where m is greater than 4, the setpoint α need not be set strictly to the central value, but may be set near the central value. Also, where the number of the cutter blades is changed, the setpoint α may be increased or decreased by a multiple of m. If illustrated with $m=4$, the switch can be operated easily to select signals as shown in the table below so as to give inputs to the setting means **158.**

n	input to 158	α
4	$\overline{Q}_E$, Q_D, Q_C, Q_B, $\overline{Q}_A$	14
5	Q_E, $\overline{Q}_D$, $\overline{Q}_C$, Q_B, $\overline{Q}_A$	18
6	Q_E, $\overline{Q}_D$, Q_C, Q_B, $\overline{Q}_A$	22
7	Q_E, Q_D, $\overline{Q}_C$, Q_B, $\overline{Q}_A$	26
8	Q_E, Q_D, Q_C, Q_B, $\overline{Q}_A$	30

The discriminator according to this embodiment has such an advantage that, even when the fiber scattered from the tow having been cut passes through the photoelectric switch of the first detector **12** to cause additional pulses to be superposed onto the pulse signal P_A, or even where more electric noise is present in the first detector compared to the second detector, no abnormal signal Q_2 will be developed, provided the number of superposed pulse or noise is smaller than $\alpha-(n-1)m$ or $nm-\alpha$.

The final output signal Q_2 produced by the discriminator mentioned above in all cases remains in the 0 state so long as the cutter blade **9** remain unbroken, and is set to 1 when; the breakage occurs on the cutter blades **9.** It will be relatively easy to actuate an alarm or to automatically stop the rotary cutter by means of the output signal Q_2 which is in the 1 state. FIG. **10** shows such a circuit.

Referring to FIG. **10,** where the output signal Q_2 is in the 0 state, i.e., zero volts, transistors **160, 161** will be in the "cut off" state and relay **162** is not excited. But if the output signal Q_2 is in the 1 state, i.e., +12 volts, the both transistors **160, 161** will be made conductive, so that the relay **162** is excited, and the contact point output will be rendered conductive. The contact point output actuates the alarm bell (not shown) or cuts off the power switch connected to the motor driving the rotary cutter.

In the foregoing are illustrated embodiments of this invention, but the detecting means of the first detector **12** shall not be limited to the photoelectric switch. Since the material of the cutter blades **10** are usually made of a magnetic metal, a proximity switch which is magnetically actuated may be employed. FIG. **11** shows an embodiment in which the proximity switch **30** is employed as the detecting means of the first detector **12'**. However, if the proximity switch **12'** is adapted to a bias cut in which the cutter blades are alternatingly attached at different angles, for example 20°, with respect to vertical planes, two such approach switches will be required. That is, one is for detecting half the number of the blades in one direction, and the other is for detecting the remaining blades in the other direction. In contrast, only one photoelectric switch will be sufficient even for the bias cut.

The detecting means of the second detector **13** shall not be limited to the proximity switch either and may be replaced by a photoelectric switch. In the embodiment shown in FIG. 11, a detecting means of the second detector 13′ comprises a band 32 secured to the shaft 11 of the rotary cutter or another shaft operatively connected to the rotary shaft and a rod 31 radially extending from the band. The rod 31 is rotated and interrupts the light between the opposing light-emitting portion 33 and light-receiving portion 34 of the second detector 13′. Preferably, the photoelectric switch is mounted to be free from the scattered fiber from the tow having been cut, for example, at a place adjacent the lower portion of the rotary shaft 11.

What is claimed is:

1. An apparatus for detecting broken blades in a rotary cutter for a tow having at least two radially disposed cutter blades, comprising:

a first detecting member operatively positioned relative to said rotary cutter for producing a pulse each time a cutter blade passes a predetermined location;

a second detecting member operatively positioned relative to said rotary cutter for producing at least one pulse, the exact number thereof being predetermined, for every predetermined number of revolutions of said rotary cutter, said pulses from said second detecting member defining a time period during which the number of pulses produced by said first detector normally reaches the predetermined number;

and a discriminator member connected to said first and second detector members and producing an abnormal indication signal when the number of pulses produced by said first detector in said time period is less than the predetermined number.

2. An apparatus as claimed in claim 1, wherein said first detector comprises a photoelectric switch having a light-emitting element and an opposing light-receiving element, said elements allowing the tips of the cutter blades to pass through.

3. An apparatus as claimed in claim 1, wherein said first detector comprises a proximity switch which is magnetically actuated when the tip of said cutter blade approach thereto.

4. An apparatus as claimed in claim 1, wherein said second detector comprises a ferromagnetic metal piece which rotates with the rotation of said rotary cutter, and a proximity switch which is magnetically actuated when said metal piece approaches thereto.

5. An apparatus as claimed in claim 1 wherein said second detector comprises a photoelectric switch having a light-emitting element and an opposing light-receiving element, and a light shielding member rotating with the rotation of said rotary cutter and passing between both elements to intermittently interrupt the light received by said light emitting element.

6. An apparatus for detecting breakage of at least one of the blades of a rotary cutter for a tow in which N cutter blades are radially disposed, N being greater than 1, comprising:

a first detector which produces a pulse for every pass of a tip of the cutter blade across a predetermined position:

a second detector which produces n pulses for every revolution of said rotary cutter, the time interval between successive ones of said n pulses per revolution being a period of time during which one pulse is normally produced by said first detector; and

a discriminator receiving the output pulses from the first and second detectors to produce an abnormal indication signal when no pulse is received from said first detector during said period of time between successive pulses produced by said second detector.

7. An apparatus as claimed in claim 6 wherein said discriminator comprises:

a flip-flop which receives, as a set input, the output pulse from said second detector and receives, as a reset input, the output pulse from said first detector, and

an AND circuit which receives, as inputs, an output rectangular wave from said flip-flop and the output pulse from said second detector, said AND circuit producing a pulse signal only when said flip-flop has already been in a set state but at the time when the output pulse is received from said second detector, said abnormal indication signal being the output pulse of said AND circuit.

8. An apparatus as claimed in claim 6 wherein said discriminator comprises:

a flip-flop which receives, as a trigger input, the output pulse from said second detector, and receives, as a reset input, the output pulse from said first detector, and

an AND circuit which receives, as inputs, an output rectangular wave from said flip-flop and the output pulse from said second detector, said AND circuit producing a pulse signal only when said flip-flop is in a state contrary to a reset state but at the time when the output pulse is received from said second detector, said abnormal signal being the output pulse of said AND circuit.

9. An apparatus as claimed in claim 6, wherein said discriminator comprises:

a flip-flop which receives, as a trigger input, the output pulse from said second detector and receives, as a reset input, the output pulse from said first detector, and

an AND circuit which receives, as inputs, an output rectangular wave from said flip-flop and the output pulse from said first detector, said AND circuit producing a pulse signal only when said flip-flop has already been in a reset state but at the time when the output pulse is received from said first detector, said abnormal indication signal being the output pulse of said AND circuit.

10. An apparatus for detecting breakage of at least one of blades of a rotary cutter for a tow in which n(an integer of 2 or more) cutter blades are radally disposed, comprising:

a first detector which produces a pulse for every pass of a tip of the cutter blade across a predetermined position,

a second detector which produces one pulse for every rotation of said rotary cutter, said pulses being produced to have a period of time during which n units of pulses are normally produced by said first detector, and

a discriminator receiving the output pulses from said first and second detectors to produce an abnormal indication signal when the number of pulses produced by the first detector during said period of time of said pulses produced by said second detector is smaller than n.

11. An apparatus as claimed in claim **10**, wherein said discriminator comprises:

a flip-flop which receives the output pulses from said first and said second detectors, respectively, as a trigger input and reset input, and

and AND circuit which receives as inputs an output rectangular wave from said flip-flop and the output pulse of said second detector, wherein said AND circuit upon receipt of the pulse from said second detector produces a pulse with said flip-flop either in a state opposite to a reset state or in a reset state, depending on whether n is an even or odd number, said abnormal indication signal being the output pulse of said AND circuit.

12. An apparatus as claimed in claim **10**, wherein said discriminator comprises:

a ring counter having n units of flip-flops connected in a ring form, wherein a determined flip-flop is preset to 1 before said second detector produces a first pulse and the other flip-flops are cleared to 0, said ring counter being triggered by the output pulse of said first detector after said second detector has produced the first pulse, and

an AND circuit which receives, as inputs, an output rectangular wave contrary to the output of said flip-flop and the output pulse from said second detector, said abnormal indication signal being the output pulse of said AND circuit.

13. An apparatus for detecting breakage of at least one of blades of a rotary cutter for a tow in which n(an integer of 2 or more) cutter blades are radially disposed, comprising:

a first detector which produces a pulse for every pass of a tip of the cutter blade across a predetermined position,

a second detector which produces one pulse for m(an integer of 2 or more) times of the number of revolutions of said rotary cutter, said pulse being produced to have a period of time during which nm units of pulses are normally produced by said first detector, and

a discriminator receiving the output pulses from said first and second detectors to produce an abnormal indication signal when the number of pulses produced by the first detector during the period of time of said pulses produced by said second detector is smaller than reference value determined near the center between nm and $(n-1)m$.

14. An apparatus as claimed in claim **13**, wherein said discriminator comprises:

a counter which is cleared to 0 by the pulse signal from said second detector and counts the pulse signals produced by said first detector, and

a gate circuit which is closed when the counted value of said counter reached said reference value, and is opened when the pulse signal from said second detector has extinguished, and receives, as an input, the pulse from said second detector, said abnormal indication signal being the pulse from said second detector passing through said gate circuit.

* * * * *