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(71) Applicant
Mitsubishi Denki Kabushiki Kaisha

(Incorporated in Japan)

2-3 Marunouchi 2-chome, Chiyoda-ku, Tokyo, Japan

(72) Inventor
Hisao Kato

(74) Agent and/or Address for Service
Marks & Clerk
57-60 Lincoln's Inn Fields, London, WC2A 3LS, United Kingdom

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G01R 31/02, G01B 7/00

(52) UK CL (Edition K)
G1U UR3102
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U1S S1881 S2055

(56) Documents cited
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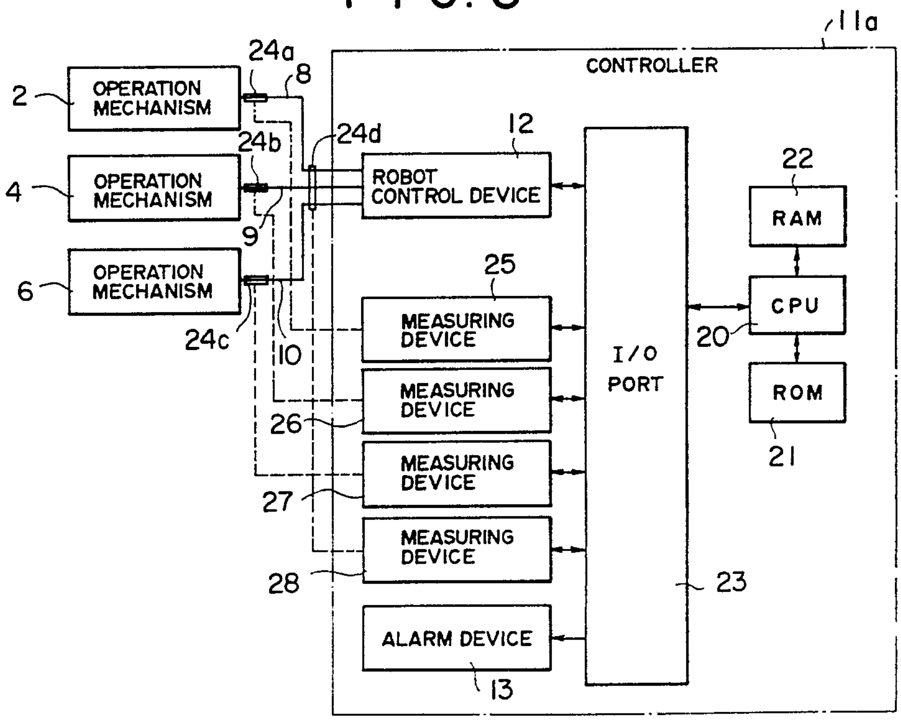
EP 0266519 A1 **EP 0150622 A2** **WO 86/07159 A1**
US 4647844 A

(58) Field of search
UK CL (Edition J) **G1U UC3C UC3D**
INT CL[4] **G01R 31/02**

(54) **Apparatus for predicting the lifetime of a cable**

(57) An apparatus for predicting the lifetime of cables (8, 9, 10) for movable portions of an industrial robot comprises measuring devices (17, 18, 19) for measuring electric characteristics of the cables or of conductive members (24) attached to them; and a CPU (20) for making comparisons between results of measurements obtained by the measuring devices and predetermined reference values to determine that the cable lifetime has expired if the results of the measurements exceed the predetermined reference values. In another embodiment (Fig 11 not shown) the CPU adds the total bending and torsion of the cables as the robot arm moves and compares the sum total with a reference value to determine expiry of the cable life.

F I G. 8



GB 2 227 328 A

F I G. 1

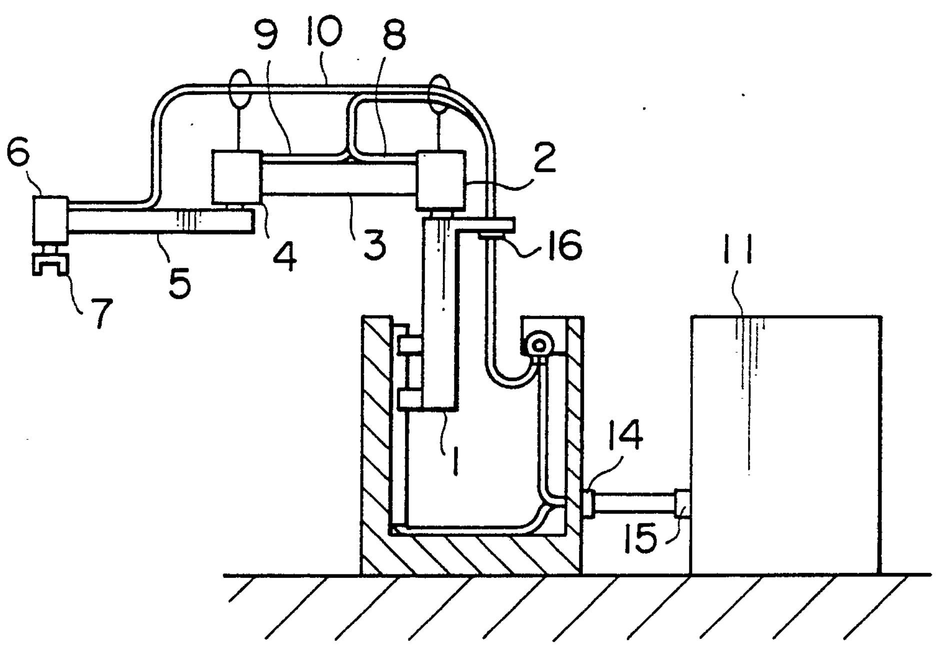
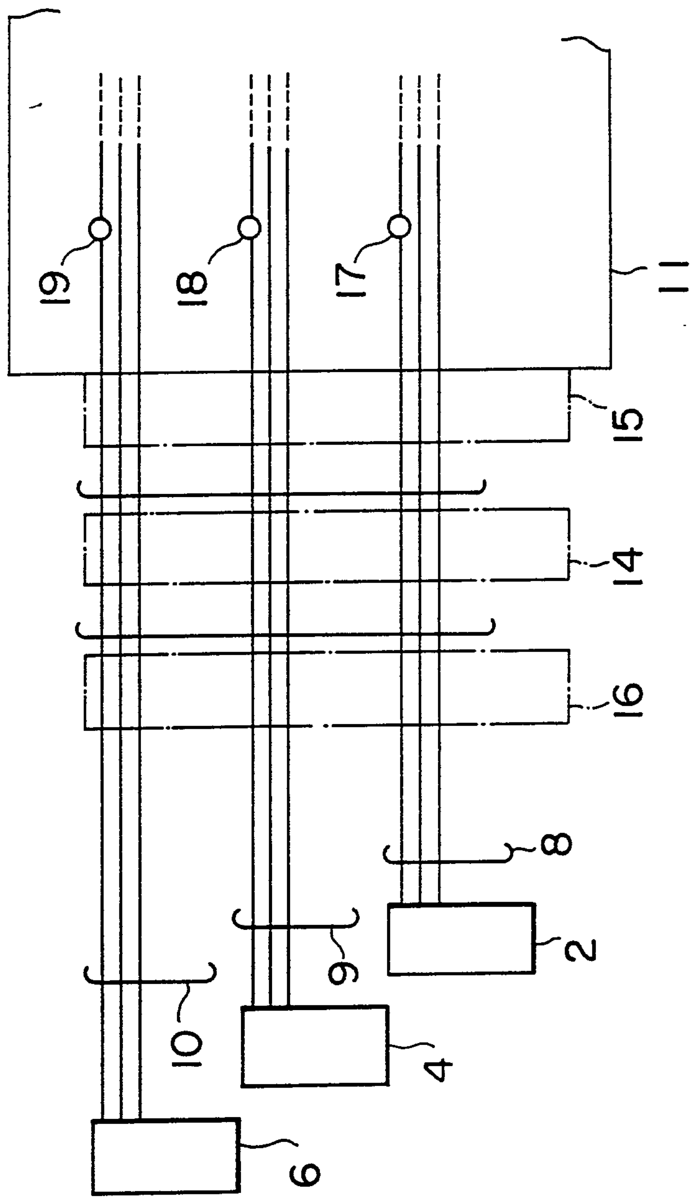
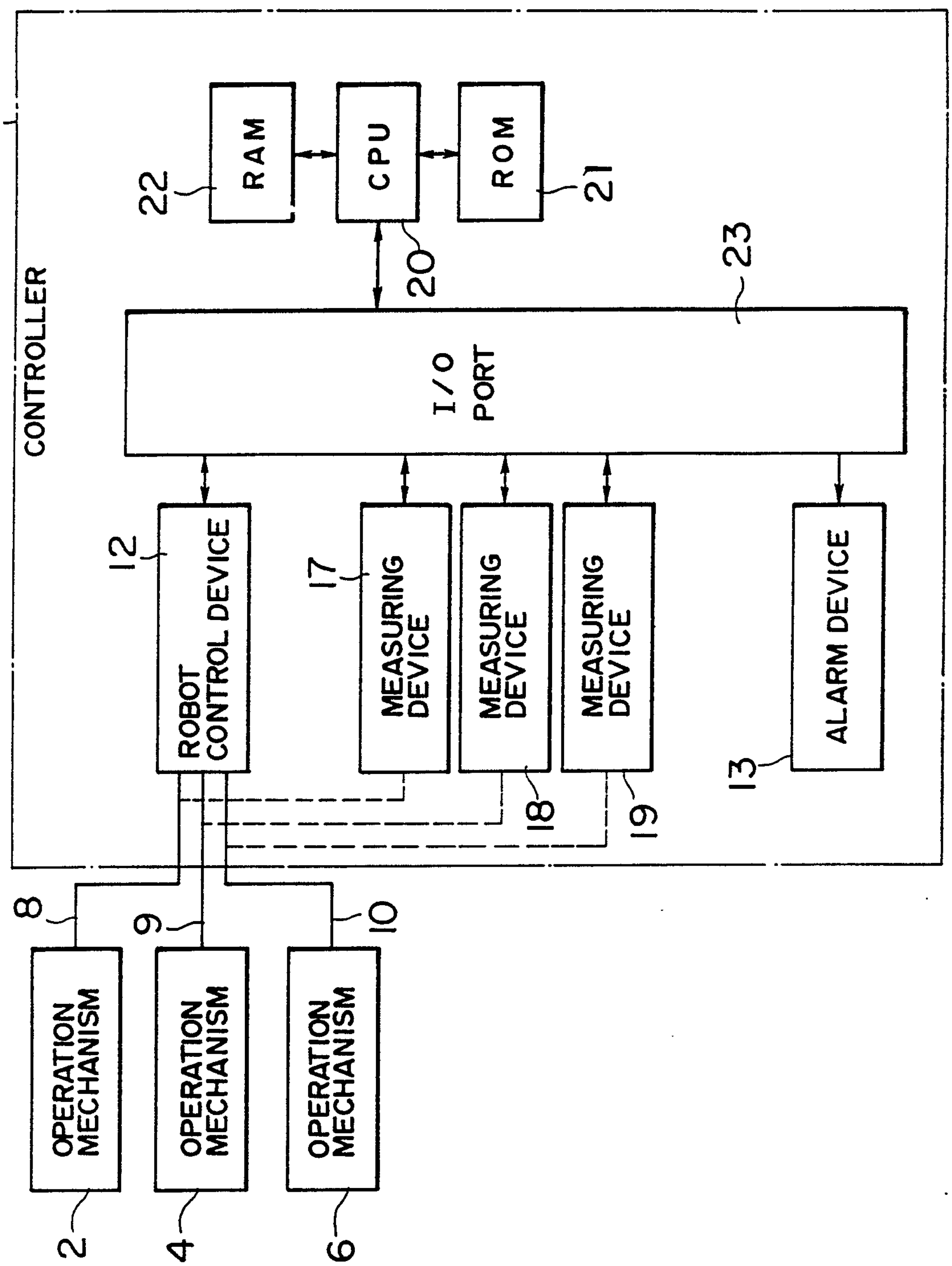


FIG. 2



F I G. 3



CONTROLLER
11
RAM
CPU
ROM
22
20
21
I/O PORT
23
ROBOT CONTROL DEVICE
12
MEASURING DEVICE
17
MEASURING DEVICE
18
MEASURING DEVICE
19
ALARM DEVICE
13
8
9
10
OPERATION MECHANISM
2
OPERATION MECHANISM
4
OPERATION MECHANISM
6

FIG. 4

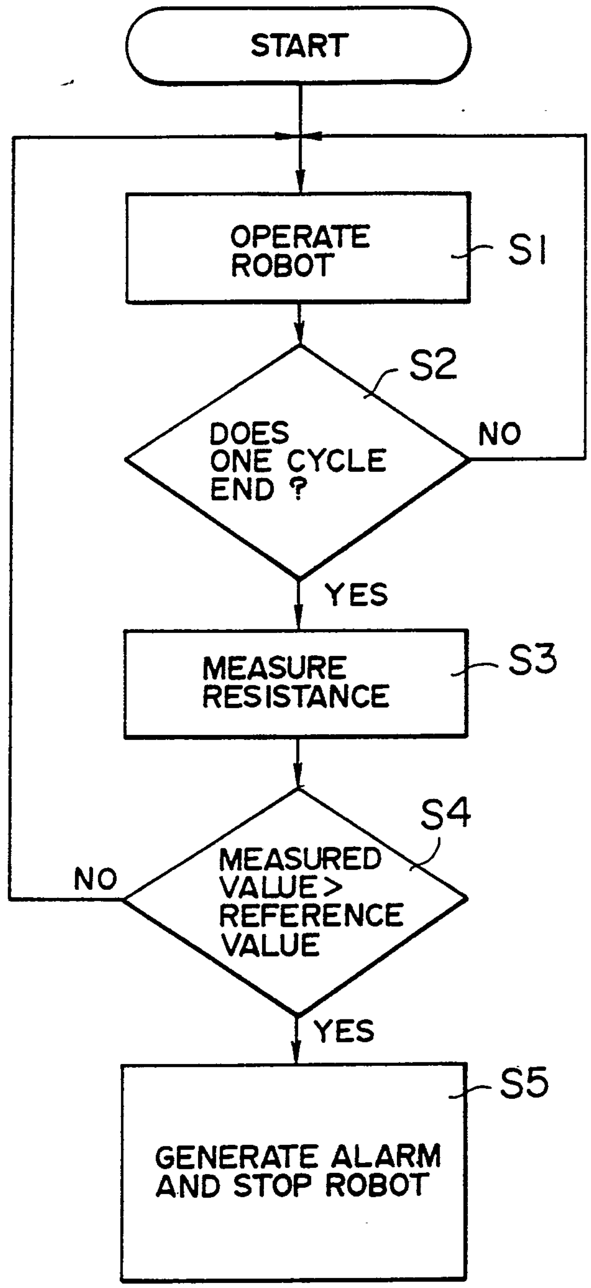

START
OPERATE ROBOT
S1
S2
DOES ONE CYCLE END ?
NO
YES
MEASURE RESISTANCE
S3
S4
MEASURED VALUE > REFERENCE VALUE
NO
YES
S5
GENERATE ALARM AND STOP ROBOT

FIG. 5

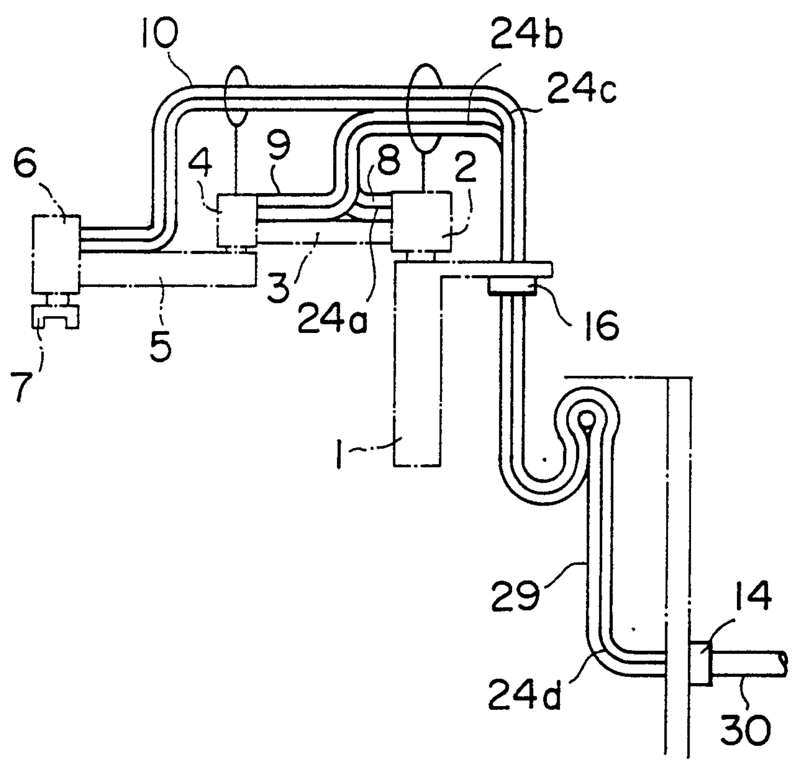


FIG. 6

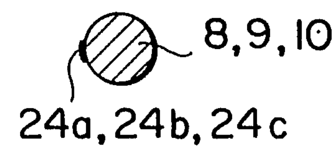

8,9,10
24a,24b,24c

FIG. 7

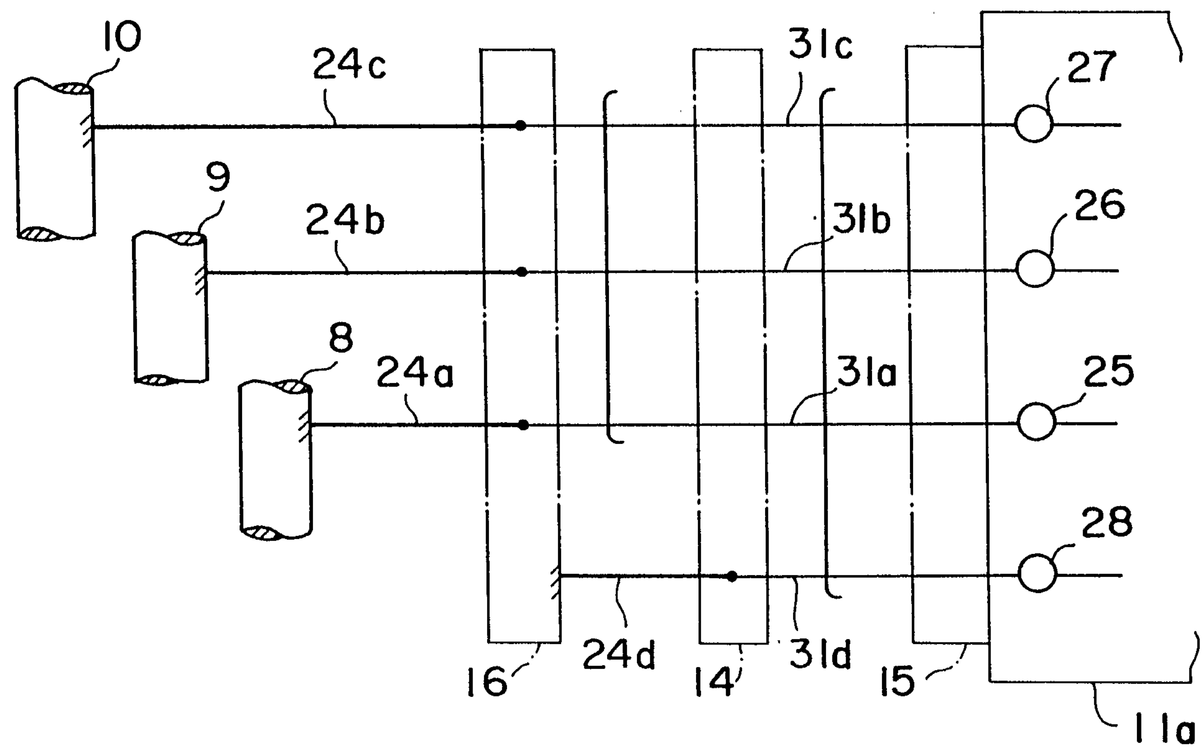

10
9
8
24c
24b
24a
24d
31c
31b
31a
31d
27
26
25
28
16
14
15
11a

FIG. 8

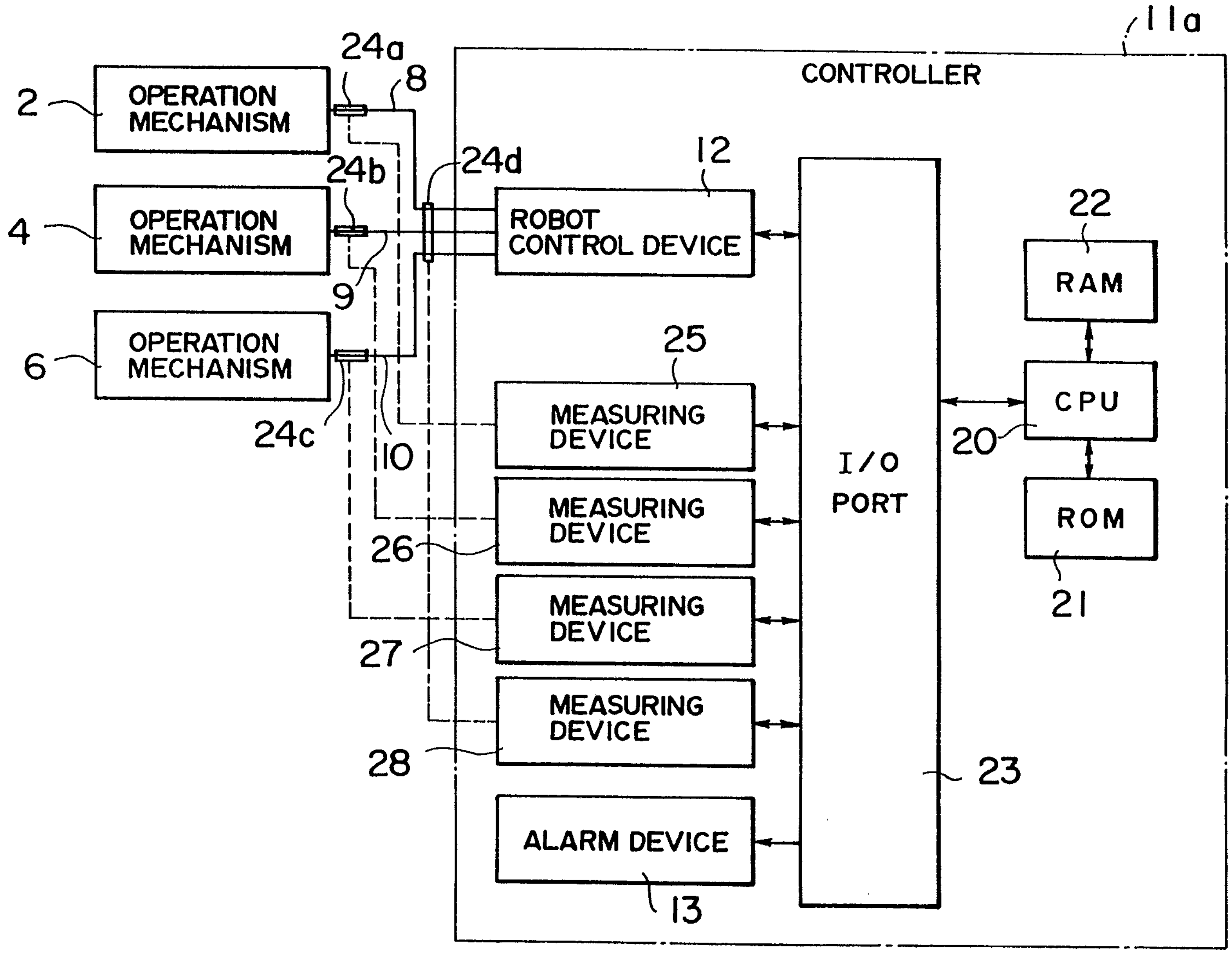

11a
CONTROLLER
2
OPERATION MECHANISM
4
OPERATION MECHANISM
6
OPERATION MECHANISM
24a
8
24b
9
24c
10
24d
12
ROBOT CONTROL DEVICE
25
MEASURING DEVICE
26
MEASURING DEVICE
27
MEASURING DEVICE
28
MEASURING DEVICE
ALARM DEVICE
13
I/O PORT
23
22
RAM
CPU
20
ROM
21

FIG. 9

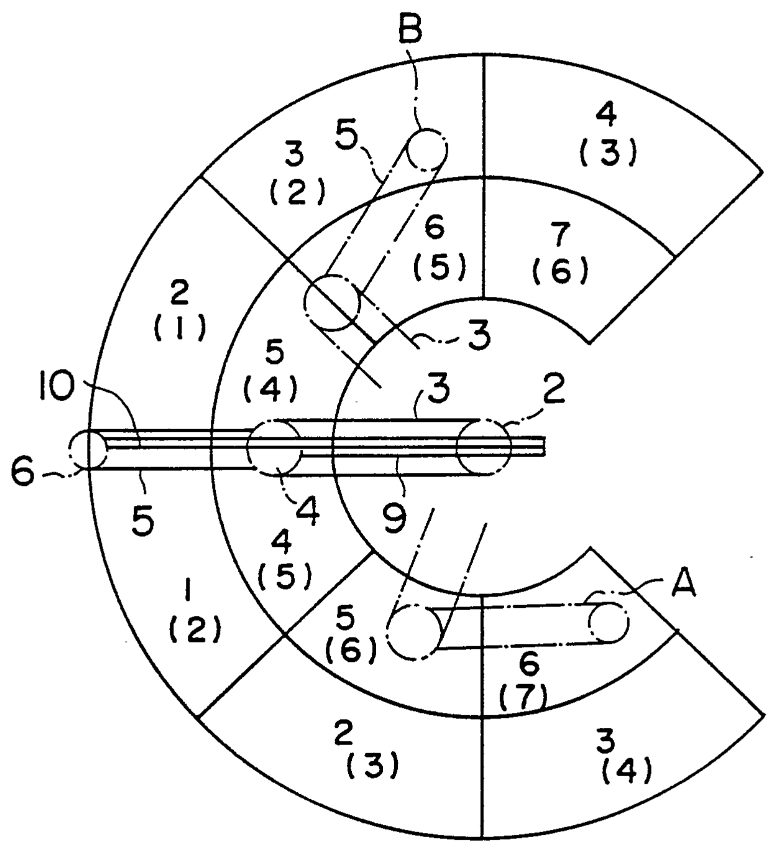


FIG. 10

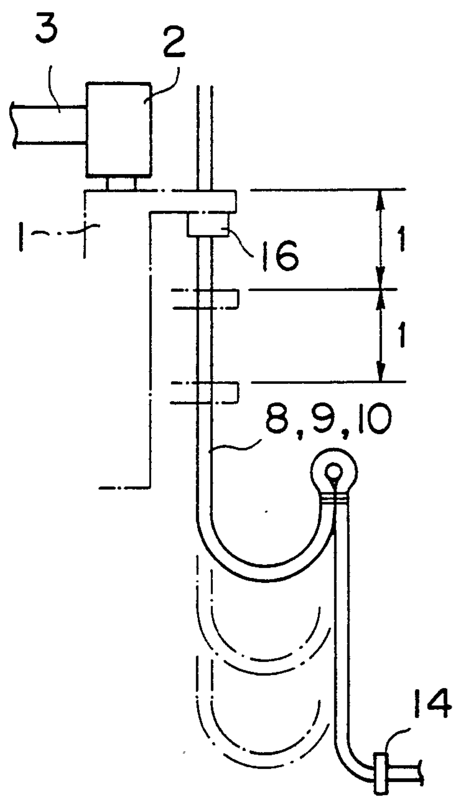
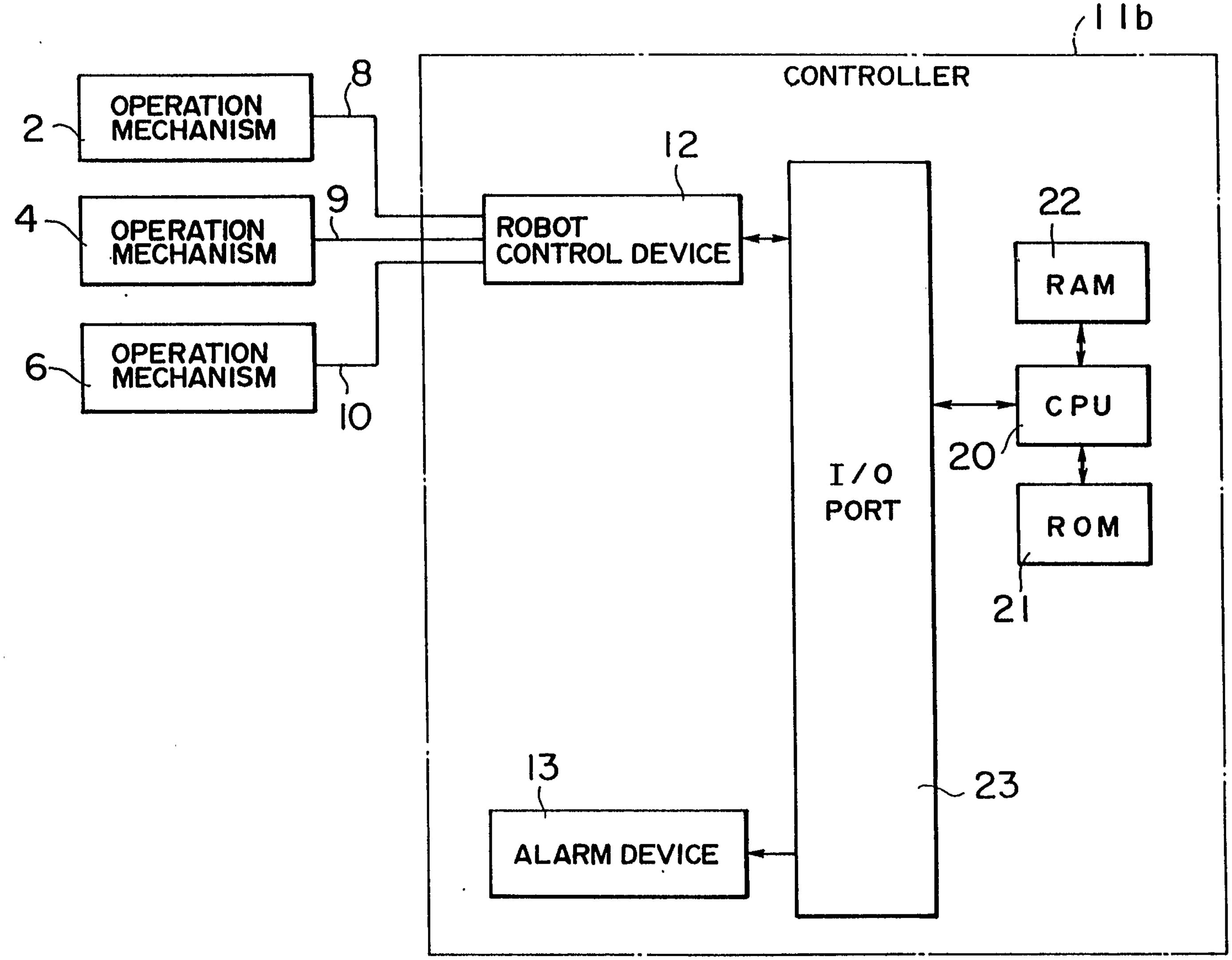


FIG. 11


11b
CONTROLLER
OPERATION MECHANISM
OPERATION MECHANISM
OPERATION MECHANISM
2
4
6
8
9
10
12
ROBOT CONTROL DEVICE
I/O PORT
23
RAM
22
CPU
20
ROM
21
13
ALARM DEVICE

APPARATUS FOR PREDICTING THE LIFETIME OF CABLE FOR MOVABLE PORTION OF INDUSTRIAL ROBOT

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to an apparatus for predicting the lifetime of cables arranged in movable portions such as arm portions of an industrial robot.

Description of the Related art

Cables for movable portions are arranged in the arm portions of an industrial robot so that the arm portions can be moved. Since each of the cables for the movable portions of the type described above is given bending stress and torsional stress when the arm portions move, the cables for the movable portions suffer from a problem in terms of their short lifetime.

If an industrial robot in which a strand constituting the cable has been broken due to the expiration of the lifetime were continued to be used, the operation of the industrial robot is stopped, causing the production line using the same to be also stopped. Alternatively, an error taken place during the operation of the robot can damages the outer equipments, causing an accident resulting in injury or death in the worst case.

Hitherto, a variety of apparatuses capable of detection of the breaking of the cable has been disclosed. For example, there has been an apparatus disclosed in Japanese Patent Laid-Open No. 62-165158, the apparatus being capable of detecting the breaking of an output cable of a rotary encoder which is provided for the purpose of detecting the angle or the position of the arm or the like of an industrial robot. Another apparatus capable of detecting the breaking of the cable arranged in a resistance welding machine has been disclosed in Japanese Patent Laid-Open No. 62-245162.

However, since the above-disclosed conventional apparatuses for detecting the breaking of a cable are arranged simply to detect the breaking of the cable, they cannot predict the breaking of the cable depending upon the result of the detection of the lifetime of a cable, that is, the state of the fatigue of the cable.

SUMMARY OF THE INVENTION

In order to overcome the above-described conventional problems, an object of the present invention is to provide an apparatus for predicting the lifetime of cables in the movable portions of an industrial robot, the apparatus being capable of predicting the lifetime of the cables for the movable portions prior to the breaking of the same.

According to the present invention, there is provided an apparatus for determining the lifetime of a cable connected to a movable element and subjected to repeated flexing in operation, for example to a movable portion of an industrial robot, said apparatus comprising: means connected to said cable for measuring electric characteristics of said cable; and determining means for making comparisons between results of measurements obtained by said measuring means and a predetermined reference value to determine that the useful lifetime of the said cable has expired if said results of said measurements exceed said predetermined reference value.

Another aspect of the present invention lies in an apparatus for determining the lifetime of a cable connected to a movable element and subjected to repeated flexing in operation, for example to a movable portion of an industrial robot, said apparatus comprising: a conductive member formed in the lengthwise direction of the surface of said cable; measuring means connected to said conductive member for measuring electric characteristics of said conductive member; and determining means for making comparisons between results of measurements obtained by said measuring means and a predetermined reference value to determine that the useful lifetime of said cable has expired if said results of said measurements exceed said predetermined reference value.

A still further aspect of the present invention lies in an apparatus for determining the lifetime of a cable connected to a movable arm and subjected to repeated flexing in operation, said apparatus comprising: storage means for storing predetermined degrees of the amount of bending and torsion of said cable, said predetermined degrees of amount of bending and torsion being determined for each of a plurality of regions formed by dividing an operating region of the said arm into a plurality of sections; arithmetic means for reading out said degree which corresponds to the position of said arm from said storage means whenever said arm stops and for adding said degrees; and determining means for making comparisons between results of additions obtained by said arithmetic means and a predetermined reference value to determine that the useful lifetime of said cable has expired if said results of said addition exceed said predetermined reference value.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a side-elevational view which illustrates an industrial robot equipped with a lifetime predicting apparatus according to a first embodiment of the present invention:

Fig. 2 is a schematic view which illustrates an essential portion of the first embodiment;

Fig. 3 is a block diagram which illustrates the first embodiment;

Fig. 4 is a flow chart which illustrates the operation of the first embodiment;

Fig. 5 is a view which illustrates a portion of an industrial robot equipped with the lifetime predicting apparatus according to a second embodiment;

Fig. 6 is a cross-sectional view which illustrates the cable shown in Fig. 5;

Fig. 7 is a schematic view which illustrates an essential portion of the second embodiment:

Fig. 8 is a block diagram which illustrates the second embodiment;

Figs. 9 and 10 are views each of which illustrates an operating region of the arm and the elevation shaft of the industrial robot in a third embodiment; and

Fig. 11 is a block diagram which illustrates the third embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Embodiments of the present invention will now be described with reference to the accompanying drawings.

First, a lifetime predicting apparatus according to a first embodiment will be described with reference to Figs.

1 to 4. An industrial robot comprises, as shown in Fig. 1, an elevation shaft 1. A first articulation operation mechanism 2 is secured to the upper end portion of the elevation shaft 1. A second articulation operation mechanism 4 is connected to the first articulation operation mechanism 2 via a first arm 3. A third articulation operation mechanism 6 is connected to the second articulation operation mechanism 4 via a second arm 5. A hand 7 is connected to the third articulation operation mechanism 6. The first, the second, and the third articulation operation mechanisms 2, 4 and 6 are connected to a controller 11 via cables 8, 9 and 10, respectively, which are arranged in movable portions. The cables 8, 9 and 10 are collectively bound and divided into three sections in terms of the length thereof so as to be connected by connectors 16, 14 and 15 before being connected to the controller 11.

As shown in Fig. 2, in the controller 11, the cables 8, 9 and 10 are provided with corresponding measuring devices 17, 18 and 19 for the purpose of measuring each of the resistance of the cables 8, 9 and 10. The measuring devices 17, 18 and 19 are connected to a CPU 20 via an I/O port 23 as shown in Fig.3. The cables 8, 9 and 10 are connected to a robot control device 12 which is capable of controlling the action of the robot, this robot control device 12 being connected to the CPU 20 via the I/O port 23. A ROM 21 and a RAM 22 are connected to the CPU 20, and an alarm device 13 is also connected to the CPU 20 via the I/O port 23. A program capable of operating the CPU 20 is previously stored in the ROM 21, while a reference level of the resistance for each of the cables 8, 9 and 10 is previously stored in the RAM 22.

Then, the operation of the first embodiment will be described with reference to a flow chart shown in Fig. 4. First, the robot control device 12 is operated in response to a command issued from the CPU 20. As a result, the operation mechanisms 2, 4 and 6 cause the first arm 3, the second arm 5 and the hand 7 to be operated so that the industrial robot is operated (step S1). The CPU 20 determines whether or not the operation for one cycle has been completed in response to a signal supplied from the robot control device 12 (step S2). If it is determined that one cycle of the operation has been completed, the CPU 20 supplies commands to the measuring devices 17, 18 and 19 to measure the resistance of each of the cables 8, 9 and 10 so that the measurement of the resistance is conducted (step S3).

The CPU 20 receives the thus measured results obtained from the measuring devices 17, 18 and 19, and then makes comparisons between the received results and the reference values which have been stored in the RAM 22 (step S4). If all of the results of the measurements are below the reference levels respectively, it is determined that each of the cables 8, 9 and 10 is normal, and the flow returns to step S1. On the other hand, if at least any of the results of the measurements exceeds the corresponding reference level in step S4, the CPU 20 determines that the cable almost expires its lifetime, issues a command to the robot control device 12 to stop the operation of the robot, and causes the alarm device 13 to generate an alarm (step S5).

Although the normal resistance of each of the cables 8, 9 and 10 for movable portions is smaller than, for example, 1 Ω, it becomes several to several tens Ω in a semi-disconnection state in which a portion of the strands constituting the cable is broken. The resistance becomes infinite in a complete-disconnection state in which all of the strands are broken. Therefore, the reference level may be determined to be 1 Ω for the purpose of predicting the fact that the cable almost expires its lifetime if the results of the measurements of the resistances obtained by the measuring devices 17, 18 and 19 exceed 1 Ω.

Therefore, according to this embodiment, the lifetime of the cables 8, 9 and 10 for movable portions can be predicted prior to the complete breaking of these cables.

As a result, the safety and the reliability of the industrial robot can be improved and any trouble deteriorating the production schedule can be prevented.

Although the resistance are measured by the measuring devices 17, 18 and 19 according to the above-described embodiment, the structure may be constituted in such a manner that each of electric currents passing through the cables 8, 9 and 10 is measured. In this case, the structure may be arranged in such a manner that the current level when the resistance becomes 1 Ω is arranged to be the reference level so that prediction that the lifetime of cable is almost expired can be made when the result of the measurement is smaller than the thus arranged reference level.

As an alternative to the alarm device 13, another alarm device utilizing light can be employed.

Then, the lifetime predicting apparatus according to a second embodiment will be described with reference to Figs. 5 and 8. According to the second embodiment, conductive members 24a to 24c are adhered to the surface of the corresponding cables 8 to 10 in the lengthwise directions. Referring to Figs. 5 and 6, the conductive members 24a to 24c are connected to connection cables by the connector 16 before being collectively bound into a cable 29 together with the cables 8, 9 and 10. Another conductive member 24d is adhered to the surface of the cable 29 which establishes the connection between the connector 16 and the connector 14, the conductive member 24d being connected to a connection cable at the connector 14 before being bound into a cable 30 together with the cables 8 to 10 and each of the connection cables connected to the conductive members 24a to 24c.

As shown in Fig. 7, connection cables 31a to 31d connected to the conductive members 24a to 24d are respectively connected to the measuring devices 25 to 28 which are capable of measuring the resistance of each of the conductive members 24a to 24d. The measuring devices 25 to 28 are connected to the CPU 20 via the I/O port 23 as shown in Fig. 8. The RAM 22 has previously stored the reference level of the resistance of each of the conductive members 24a to 24d.

The operation of the apparatus according to the second embodiment is, similarly to the apparatus according to the first embodiment shown in Fig. 4, conducted in such a manner that whenever the robot completes one cycle of its operation, the resistances of the conductive members 24a to 24d are measured by the measuring devices 25 to 28 so as to be subjected to comparisons with the corresponding reference levels. That is, as an alternative to the direct measuring of the electric characteristic of each of the cables 8 to 10, the states of fatigue of the cables 8, 9 and 10 arranged between each of the operation mechanisms 2, 4 and 6 and the connector 16 are determined depending upon the resistance level of each of the conductive members 24a to 24c adhered to the corresponding cables 8 to 10. Furthermore, the states of fatigue of the same arranged between the connectors 16 and 14 are determined depending upon the resistance level of the conductive member 24d adhered to the cable 29. Since the conductive members 24a to 24d adhered to the surfaces of the cables 8 to 10 and 29 are given the similar levels of the bending stress and torsional stress which are given to each of the cables 8 to 10 and 29, the lifetime of each of the cables 8 to 10 can be predicted by measuring the resistance of each of the conductive members 24a to 24d.

The conductive members 24a to 24d are formed by applying conductive tapes or printing conductive materials. As the conductive tape, a metal foil made of, for example, copper, or aluminum can be used. A required resistance level can be achieved by properly determining the thickness, the width, and the like of the tape. On the other hand, the printing of the conductive material can be conducted by applying a binder which contains metal powder such as copper, aluminum, or the like to the surface of the cable.

Although the resistance of each of the conductive members 24a to 24d is measured according to the second embodiment, the current level may be measured.

Then, the life predicting apparatus according to a third embodiment will be described with reference to Figs. 9 to 11. According to the third embodiment, the working region of the first arm 3 and that of the second arm 5 are divided into a plurality of sections and a degree corresponding to the amount of the bending and the torsion of the cables 8, 9 and 10 for movable portions is respectively determined previously for each of the sections. Referring to Fig. 9, the degrees corresponding to the operation conducted by the right hand system as designated by an alternate long and short dash line A are indicated by numbers in parentheses, while the degrees corresponding to the operation conducted by the left hand system as designated by an alternate long and short dash line B are indicated by numbers without the parentheses. The greater the number is, the greater the amount of the bending and torsion is.

As shown in Fig. 10, as for the cables 8, 9 and 10 arranged between the connectors 16 and 14, it is determined to be 1-degree when the elevation shaft 1 moves in any of the vertical directions with respect to the intermediate position of the movement of the elevation shaft 1 serving as the reference position.

Referring to Fig. 11, the RAM 22 in the controller 11b has previously stored the degrees corresponding to the regions shown in Figs. 9 and 10. The CPU 20 causes the robot control device 12 to operate. As a result, the industrial robot is operated. In synchronization with the operation of the robot, the CPU 20 receives positional information about the third operation mechanism 6 via the robot control device 12 whenever the third operation mechanism 6 stops, and the CPU 20 reads the degree corresponding to the region in which the third operation mechanism 6 is positioned from the RAM 22 so as to add the thus read degree. Similarly, whenever the elevation shaft 1 stops, the CPU 20 receives positional information about the elevation shaft 1 via the robot control device 12, and the CPU 20 reads the degree corresponding to the position of the same from the RAM 22 so as to add the thus read degree. If the results of the additions above exceed a predetermined level, the lifetime of the cables 8 to 10 arranged between the operation mechanisms 2, 4 and 6 and the connector 16, and the lifetime of the cables 8 to 10 arranged between the connectors 16 and 14 are predicted. As a result, the CPU 20 stops the operation of the robot, and causes the alarm device 13 to generate an alarm.

Also according to the third embodiments, the lifetime of the cables 8 to 10 can be predicted similarly to the first and second embodiments prior to the complete breaking of the same for movable portions.

The degrees described in Figs. 9 and 10 serve as only one example. Therefore, the degrees corresponding to the industrial robot to be used may be previously determined.

CLAIMS

1. An apparatus for determining the lifetime of a cable connected to a movable element and subjected to repeated flexing in operation, for example to a movable portion of an industrial robot, said apparatus comprising:

measuring means connected to said cable for measuring electric characteristics of said cable; and

determining means for making comparisons between results of measurements obtained by said measuring means and a predetermined reference value to determine that the useful lifetime of the said cable has expired if said results of said measurements exceed said predetermined reference value.

2. An apparatus according to Claim 1, wherein said measuring means measures the resistance of said cable.

3. An apparatus according to Claim 1, wherein said measuring means measures electric current passing through said cable.

4. An apparatus for determining the lifetime of a cable connected to a movable element and subjected to repeated flexing in operation, for example to a movable portion of an industrial robot, said apparatus comprising:

a conductive member formed in the lengthwise direction of the surface of said cable;

measuring means connected to said conductive member for measuring electric characteristics of said conductive member; and

determining means for making comparisons between results of measurements obtained by said measuring means and a predetermined reference value to determine that the useful lifetime of said cable has expired if said results of said measurements exceed said predetermined reference value.

5. An apparatus according to Claim 4, wherein said measuring means measures the resistance of said conductive member.

6. An apparatus according to Claim 4, wherein said measuring means measures electric current passing through said conductive member.

7. An apparatus according to Claim 4, 5 or 6, wherein said conductive member is a conductive tape applied to the surface of said cable.

8. An apparatus according to Claim 4, 5 or 6, wherein said conductive member consists of conductive material printed on the surface of said cable.

9. An apparatus for determining the lifetime of a cable connected to a movable arm and subjected to repeated flexing in operation, said apparatus comprising:

storage means for storing predetermined degrees of the amount of bending and torsion of said cable, said predetermined degrees of amount of bending and torsion being determined for each of a plurality of regions formed by dividing an operating region of the said arm into a plurality of sections;

arithmetic means for reading out said degree which corresponds to the position of said arm from said storage means whenever said arm stops and for adding said degrees; and

determining means for making comparisons between results of additions obtained by said arithmetic means and a predetermined reference value to determine that the useful lifetime of said cable has expired if said results of said addition exceed said predetermined reference value.

10. An apparatus according to any preceding Claim further comprising an alarm device for issuing an alarm when said determining means determines that said cable lifetime has expired.

11. Apparatus for determining the lifetime of a cable subjected to repeated flexing in operation, substantially as described with reference to Figures 1 to 4, Figures 5 to 8, or Figures 9 to 11 of the accompanying drawings.

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