



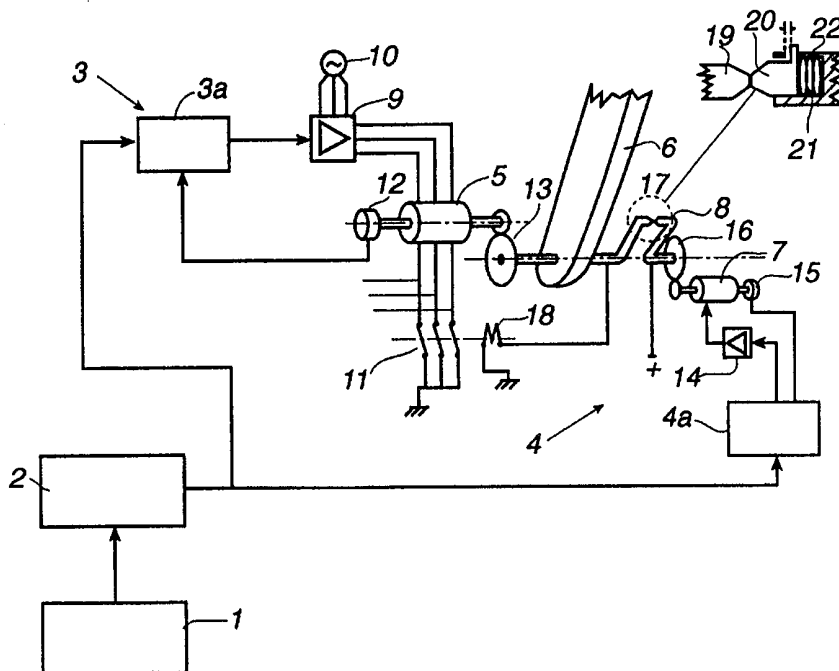
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(54) Title: DEVICE FOR CONTROLLING THE OPERATION OF A DRIVING APPARATUS

(57) Abstract

A device for monitoring the operation of a driving arrangement comprising at least a servo-mechanism (3), which includes a regulator (3a), a driving motor (5) controlled by this regulator and an element (6) which can be set in motion by the driving motor, a detection arrangement (19-22, 23) for detecting deviations between intended and actual movement positions of the element (6) and an operation inhibiting and/or alarming arrangement (23, 36, 37, 38) for inhibiting the operation of the driving arrangement and/or starting an alarm when impermissible deviations have been established by means of the detection arrangement. The device comprises a redundant driving arrangement, which comprises at least one auxiliary servomechanism (4) including a redundant regulator (4a), a redundant driving motor (7) controlled by this regulator and a redundant element (8) which can be set in motion by this driving motor, that the regulator (3a) and the redundant regulator (4a) are connected to an arrangement (2) delivering control information or imparting to the element and the redundant element movements being the same or having a predetermined relation to each other, and that the detection arrangement is arranged to detect the deviations concerning the relative position or movements of the element (6), or an object (17) connected thereto, and the redundant element (8).



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Device for controlling the operation of a driving apparatus

10 FIELD OF THE INVENTION

The present invention relates to a device for monitoring the operation of a driving arrangement according to the preamble of the subsequent claim 1. As will be more closely described
15 hereinbelow, it is preferred that the driving arrangement forms part of a manipulator, in particular an industrial robot, so that the element which can be set in motion by the driving motor forms a manipulator element of the manipulator.

20 PRIOR ART

The safety systems of the industrial robots of today are not sufficient for allowing people to work within the operating range of an industrial robot when the robot executes its programs. This is
25 due to the fact that there is a large likelihood that an error in the electromechanics of the robot can cause robot movements that can injure or kill people in the vicinity of the arm system of the robot. The accidents, which can ensue, are due to the fact that the robot makes unexpected programmed movements or that the
30 robot rushes owing to measuring or driving system errors. The injuries which can ensue in that connection are either that the robot gives the person in the operating range a strong blow or injuries caused by clamping. The cases when the head it subjected to these injuries are of course particularly serious.

35

Today it is presupposed that people are not allowed to be within the operating range of industrial robots when the robots execute production programs at full speed, and therefore the safety systems are today only aimed at minimizing the damages to the robot, surrounding equipment and work objects. Consequently, model based monitoring is used in order to continuously compare motor moments and motor position of the robot axles with moments and positions of a model of the robot. A more simple type of monitoring uses the control errors in the servos which are controlling the position and the velocity of the axles, and the magnitude of the moment references generated by the regulator or the current controlling devices of the motors. Furthermore, the motor currents and the motor temperature are often monitored.

When the monitoring in the robot systems of today indicate an error during the axle manoeuvre, a digital output signal is generated from a computer card to a relay, which is connected to a breaker, which disconnects the current to the motors of the robot and makes sure that the brakes of the robot are activated. The reason why these safety concepts are not sufficient is that many functions must work simultaneously in order for the motors of the robot to, with sufficiently large likelihood, always become immediately currentless in connection with a frightful situation. For instance, the software and hardware have to work in the processor which detects the condition of error. Thereupon, the software and hardware for the processor which signals the condition of error to a digital safety output also have to work, as well as the relays and breakers which are to make sure that the motor currents disappear as soon as possible.

If the error is due to the fact that the computer, which is to indicate the error, or the interface towards driving devices and measuring systems of this computer is not working, there is the risk that the error situation will not at all be detected and the driving system can make the robot rush without any control. If

the error is due to the fact that a person has been clamped up between the robot and the surrounding equipment of the robot, there is the risk that the monitoring with subsequent software and hardware signalling and relay handling will take so long time
5 that too high clamping forces have time to develop before the motors are cut off. In the same way, there is a great risk that too strong forces have time to develop between the robot and the person in case of a collision at the normal programmed robot velocity. Even though an advanced model-based collision
10 detection is used, there is a risk that the direction of the motors will reverse too late or that some error in the software or hardware will make that the robot will not stop at all.

PURPOSE OF THE INVENTION

15 The purpose of the present invention is to achieve a monitoring device, by means of which a substantially improved safety in the monitoring is to be attained.

20 Preferably, it is intended that the risk of injuries when someone is within the range of the driving arrangement, in particular a manipulator, will be so small that it can be generally accepted to work together with a manipulator or an industrial robot.

25 BRIEF DESCRIPTION OF THE INVENTION

According to the present invention, a very safe monitoring device is achieved as a consequence of the redundant driving arrangement in accordance with the subsequent characterizing
30 part of claim 1, the high safety being attained in that the detection arrangement is designed to detect the deviations concerning the relative positions or movements between the driven element and the redundant element.

35 Manipulators or robots having this safety system will be able to work together with human beings, for instance during assem-

blage of different work shop technical products and disassembly of corresponding products for material recycling. With the invention-
tional monitoring device, manipulators, in particular robots, can
be introduced on different places in an assembly line for motor
5 cars without having to be surrounded by fences obstructing the
motor car assemblers in the operating range of the manipulators
or robots. This opens up new possibilities for automatization of
the assembly of private cars, lorries and busses, which today is
almost entirely manual. This gives a great flexibility and the
10 possibility to robotize afterwards an existing manual assembly
line.

Further features and embodiments of the invention device are
related to in the dependent claims.

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BRIEF DESCRIPTION OF THE DRAWINGS

With reference to the subsequent drawings, a closer description
of embodiments of the invention given as examples will follow
20 below.

In the drawings:

Fig 1 is a schematic view illustrating a first embodiment of the
25 invention monitoring device,

Fig 2 is an enlarged detail view illustrating a possible embodi-
ment of a safety contact,

30 Fig 3 is a detail view illustrating an alternative embodiment of
the invention with non-contact measuring,

Fig 4 is a detail view illustrating an embodiment of the detection
arrangement,

35

Fig 5 is a detail view illustrating a brake arrangement for the driven element 6,

5 Fig 6 is a detail view illustrating an alternative embodiment of the driven auxiliary element and the detection arrangement,

10 Fig 7 is a view illustrating an alternative detection arrangement based on a belt transmission between the driven element and the auxiliary element,

Fig 8 shows a further alternative of a detection arrangement comprising a gear unit,

15 Fig 9 is a detection arrangement illustrating that objects following each other can have very different designs,

Fig 10 is a view illustrating a detection arrangement with series connected contact points,

20 Fig 11 is a view illustrating a detection arrangement with pneumatic realization of contact points,

25 Fig 12 is a view of a detection arrangement illustrating change of contact points during movement of the driven element and the redundant element,

Fig 13 is a view of a detection arrangement based on moiré-technique for error detection,

30 Fig 14 is a view of a detection arrangement comprising a linkage system for error detection, and

Fig 15 is a view of a monitoring device, where the safety system is implemented with simulated contact point.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Fig 1 shows a possible embodiment of the safety system embraced by this invention. The program executor 1 generates
5 programmed path positions to the path generator 2, which carries out interpolation between these path positions and generates references in the form of motor angles to be used by the servo of the control system. According to Fig 1, the servo frequencies generated by the path generator 2 are sent to two
10 separate servomechanisms 3 and 4, namely the regulators 3a and 4a, respectively, of the servomechanisms. The regulator 3a is the one which controls the motor 5 that is driving the associated element 6, which here is formed as a revolving robot arm, whereas the regulator 4a is a redundant regulator controlling the
15 redundant motor 7, which in this embodiment is driving a redundant element 8, here an arm. The motor 5 is controlled by the regulators via the driving device 9, and are connected to a three-phase voltage source 10 via the contactor 11. On the axle to the motor 5, there is an angle sensor 12, which is measuring
20 the motor angle for feedback to the regulator 3. Between the motor 5 and the arm 6 there is a gear unit 13. The motor 7, which only needs to generate a fraction of the moment generated by the motor 5, is driven by the driving device 14, has the angle sensor 15 and the gear unit 16. The arm 8 is in mechanical
25 contact with an arm 17, which is mounted on the arm 6. The contact between the arms 17 and 8 are obtained via two points 19 and 20, where the point 20 is pressed against the point 19 by a spring 21, which is located in a sleeve 22 of the arm 8.

30 During normal operation of the robot, the servomechanisms 3 and 4 will position the points 19 and 20, respectively, in such a way that these will stand directly in front of each other and the breaker coil 18 will hold the breaker 11 drawn so that the motor 5 can operate. However, if the arm 17 is not moving in exactly
35 the same way as the arm 8, the contact between the points 19 and 20 will be broken and the breaker 11 will immediately make

the motor 5 currentless. In that connection, there is relay logic (not shown in the figure), which entails that all the motors of the robot will become currentless, that the brakes will be actuated and that the robot will not restart without an operator controlled
5 restart.

With the safety system according to Fig 1, all the errors in the servo 3, driving device 9, motor 5, gear unit 13, supply voltage 10, measuring sensor 12, cabling, hardware and software will
10 immediately result in that the points 19 and 20 will be separated, which entails that the current is disconnected from all the motors without any risk that hardware and software will fail to detect and signal the error via digital outputs and relay connections to the breaker 11. The safety system also entails that the points 19
15 and 20 will be separated if the movement of the arm 6 is obstructed during its programmed movement, which results in that the robot motors immediately will be disengaged and will become currentless.

20 The only possibility of missing a condition of error would be if two errors occur simultaneously, one error in the servo 3 with associated electronics and one error in the servo 4 with associated electronics, and that these errors would make the points 19 and 20 move with the same velocity in the same direction. The
25 likelihood that two such errors should occur is non-existent, since the mass inertia of the real arm 6 is much larger than the mass inertia of the redundant arm 8. This results in that, in case of errors in the servo 3 as well as the servo 4, the arm 8 will react with a shorter time constant than the arm 6 and the points 19
30 and 20 will separate during the transient movements which immediately are obtained due to both errors.

In order to further reduce the forces which can develop at the collision between robot and human being or when a human being
35 is clamped between the robot and its surroundings, the servo 3 can be model-controlled and trimmed for low stiffness,

which results in that external forces on the arm 6 rapidly cause angular misalignments of the arm and thereby that the points 19 and 20 will be separated. In order to further increase the safety in this case, the weakness in the servo can be supplemented
5 with or replaced by a mechanical weakness, e.g. in the form of a torsion spring, between the motor 5 and the arm 6.

Furthermore, it has to be pointed out that the robot should be designed for a minimal movable arm mass and that the maximal
10 angular velocity is fixed with regard to the maximal allowable collision forces at collision robot-human being. The maximal angular velocity is defined for the servo 3 as well as the servo 4, whereby the risk of overspeed will be non-existent.

15 ALTERNATIVE EMBODIMENTS

The safety concept according to Fig 1 can be implemented in several ways depending on the desired safety level, cost and adaption to robot construction. What can be varied is the
20 detection principle for deviation between the real arm 6 and the redundant arm 8, the design of the mechanics which connects the redundant arm 8 to the real arm 6, and the location of the redundant arm 8 in the transmission from the motor axle (of the motor 5) and the arm 6.

25 When it comes to the detection principle, two contact points according to Fig 1 constitute one of the most simple and most direct methods for determining if the arm 6 and the redundant arm 8 are moving synchronously. If only a mechanical contact is
30 used between the real and the redundant arm, there are then many possibilities to connect a movement of one or both of the points in Fig 1 to a separate electromechanical contact. An example of this is shown in Fig 2, where the point 20 via the pin 24 is mechanically connected to a spring loaded contact 23, which
35 is connected to the coil 18 of the breaker 11. The contact 23 in Fig 2 is in principle a binary position sensor, and such a sensor

can of course be implemented in many different ways, e.g. by use of an electro-optical read fork, a capacitive sensor, an inductive sensor or an ultrasonic sensor. In those cases where the sensor is of non-contact type, this can of course be used directly for detecting deviations between the real arm and the redundant arm. Consequently, Fig 3 shows an example of how a non-contact sensor 25 can be used for measuring the position of the redundant arm 8 in relation to the position of the real arm 6.

10 The sensor 25 is measuring against a target 27 on the real arm 6, but the sensor and the target can of course change places. From the measuring transducer 26 a signal S is obtained, which signal depends on the deviation between the arms 6 and 8. In the comparator 29 S is compared with $S_{ref} + \Delta S$ and $S_{ref} - \Delta S$ and as long as the signal S is within the interval $[S_{ref} - \Delta S, S_{ref} + \Delta S]$ the output of the comparator is high and the driving circuit 30 gives a high signal, which implies that the coil 18 of the breaker 11 is holding the breaker closed. However, if S leaves the allowed signal interval the motor currents are immediately broken and the brakes will be activated. However, there is now a risk that the sensor 25, measuring transducer 29 or driving circuit 30 will receive such an error that the breaker 18 will remain closed despite the arms 6 and 8 deviating in an angle in relation to each other. In order to decrease this risk, a high-frequency test signal s_t is introduced from the oscillator 28. This signal is added to the position frequency of the servo 4 and entails that the signal S is going to have a high-frequency component. The comparator 29 and the driving circuit 30 are constructed in such a way that the high-frequency signal reaches the breaker circuit with the coil 18. Here the high-frequency signal is detected by means of a phase-sensitive demodulator 32, the output of which is supplied to a further comparator 33, which is also connected to the coil 18. If any error will now occur in the servo 4, motor 7, sensor 15, driving circuit 14, sensor 25, measuring transducer 26, comparator 29 or driving circuit 30, the signal filtered by the band pass filter 31 will immediately change and the comparator

33 will make sure that the breaker 11 will open and that the motors will become currentless.

As can be seen, the safety system with a sensor according to
5 Fig 3 will be more complicated and also less safe than a system
with a direct electrical contact member according to Fig 1. The
contact member in Fig 1 has been accomplished as points 19
and 20, which is not necessary. It is also possible to use e.g. a
10 point against a conductive electrode surrounded by insulating
areas according to Fig 4. Furthermore, in Fig 4 the possible
risks that a breaker can get stuck in closed position have been
eliminated by making the contacts in the redundant arm conduct
the motor current directly, as well as the current to the holding
15 circuit 35 of the brake 36. Consequently, the three phases from
the motor 5 pass three of the electrodes 19 and the points 20 on
the way to a common ground. The brake coil 35 is in the same
way connected to ground and a total of four electrodes 19 is
obtained in the insulator 17 connected to the real arm and four
20 points in the redundant arm 8, which is partly made of insulating
material.

The electrodes 19 and the points 20 can of course change
places and there are many ways of connecting the contact pairs
19/20 in the motor circuit. If strong brakes are provided, there is
25 also the possibility of activating the brakes only with the re-
dundant servo 7 and making the motor monitoring see that the
motors are made currentless.

In Fig 5 it is shown that it is also possible to activate the brakes
30 without any electrical holding circuit being connected to contact
pairs between the real and redundant arm. Instead, a completely
mechanical holding of the spring loaded brake disc 37 is used.
This brake disc is located in the brake mechanism 39, which
holds the brake disc 37 and the preloading spring 40. When the
35 redundant arm 8 deviates from the position of the real arm 6, the
beam 20 in the yoke 19 will turn the arm 17 around its attach-

ment point 41, which is journalled in bearings, and the brake disc 37 will be released and be pressed against brake blocks 38, whereby the real arm is locked. The mechanical method for holding the brake can of course be carried out in many different ways and instead of a brake some type of lever can be used, which is pushed into a fixed mechanical stop when the redundant arm 8 deviates from the real arm 6.

In Figs 1, 3 and 5, the contact point 19, 20 and 25, 27 is positioned between the redundant and the real servo by means of arms 8 and 17. The function of these arms can of course be carried out by other mechanical solutions. For instance, Fig 6 shows a construction suitable of being mounted on e.g. the wrist axles of a robot. The wrist mechanism is for the axle in Fig 5 carried out in such a way that the pipe 46 is turned in relation to the pipe 45 when the corresponding motor is operating. A carbon rod holder 47 with two spring-loaded carbon rods 44 is mounted on the pipe 45, the carbon rods being connected to the relay coil 18 of the motor breaker. On the pipe 46 a ring is journalled in bearings. This ring can be rotated around the pipe 46 by the redundant motor via the gear wheel 4. The motor 7 is mounted on the pipe 46. The ring 42 is made of insulator material, at least on the surface against which the carbon rods 44 are pressed. On the electrically insulated surface of the ring 42 there is a narrow electrically conducting rectangular surface, which short-circuits the carbon rods 44. When the axle 46 is turned in relation to the axle 45, the redundant motor 7 will turn the ring in the opposite direction, so that the conducting surface 43 holds the rods 44 short-circuited and thereby the motor breaker closed.

The redundant arm does not have to meet directly against the real arm, on the contrary, in constructions with lack of space, the movements of the real arm can be transferred to an extra axle via e.g. a belt transmission according to Fig 7. Here the real arm 6 is turned by the axle 45, on which a drum 52 for the

belt 51 is fixed. The belt transfers the turning of the axle 45 to the belt wheel 50, which is journalled in bearings in the housing 49. The belt wheel 50 is electrically insulating, at least on the surface facing the motor 7. On the insulated surface there is a small electrically conducting surface 43, which is in contact with the bearing housing 49. The redundant motor 7 has its centre of rotation coinciding with the centre of rotation of the belt wheel 50, and the motor positions the contact wheel 48 by means of the arm 8 so that the contact wheel keeps electrical contact with the conducting surface 43. The breaker coil 18 will thereby receive its holding current via motor bearings, motor axle, the redundant arm 8, the contact wheel 48, the axle of the belt wheel and the bearing housing 49.

The contact point for current breaking to the coil 18 can be connected to different components in the transmission between the motor 5 and the arms 6. For instance, the redundant motor 7 can turn the arm 8 in relation to a contact point being directly turned by the motor 5. In Fig 8 another variant is shown, where the redundant motor is integrated with the gear unit. An extra gear wheel 53 is connected to the gear wheel 13 in the gear unit, which extra gear wheel turns a plate 54, on which contact points are provided. The redundant motor 7 turns the axle 61, on which the redundant arm 8 is mounted. On the redundant arm 8 there are two spring-loaded electrodes 56 and 57, which are connected to the coil 58. A core 59 of iron or ferrite is magnetically connected to the coil 58 via air gaps and the axle 61 made of magnetic material. The core 59 is provided with a coil 60, which functions as a primary coil to the air gap transformer with the secondary coil 58. The primary coil 60 is connected to the breaker coil 18 and controls the alternating current depending on whether the secondary coil is short-circuited or open. During normal operation, the secondary coil is short-circuited via the metal surface 55 on the plate 54, the remaining part of which is insulating.

Besides the contact point carrying out circular motions, it is also possible to use a construction where the redundant arm carries out scanning motions in a predetermined pattern. An example of this is shown in Fig 9. During rotation of the axle in question, the pipe 46 will in the same way as in Fig 6 move in relation to the pipe 45. On the pipe 46 a collar 62, e.g. of metal, is rigidly mounted, which collar has a sawblade-like profile. The redundant motor turns the redundant arm 8 with the non-contact sensor 25 to and fro so that the sensor describes a path corresponding to the sawtooth pattern when the pipe 46 turns in relation to the pipe 45. The higher the velocity of the pipes in relation to each other, the higher frequency in turning the arm 8 to and fro is required by the motor 7. In case of a difference between the programmed movement of the real arm and the corresponding movement, converted into scanning, of the redundant arm 8, the sensor 24 immediately detects an error and the motors are made currentless according to the schedule in Fig 3.

The described concept for high safety robot control can of course be implemented in many different ways. A stepping motor can e.g. be used for the redundant motor, in which case the servo will be of another type. If a linear movement is to be monitored, the contact point has to be moved with a translational movement, e.g. with means of a worm transmission or a belt transmission. In order to obtain the same dynamics in the transfer function between the servo reference and movement of the redundant arm and between servo reference and movement of the real axle, model-based variable filters can be used in the redundant servo. If it desired to increase the sensibility of the monitoring, e.g. at lower velocity, the redundant motor can be controlled with a variable reference offset signal in position so that the redundant arm drives e.g. the point electrodes 56 and 57 in Fig 8 closer to the edge of the metal surface.

So far only 1 contact point has been used for each electrical circuit. However, several contact points can be used, either series

of parallel connected. By series connection of the contact points according to the example in Fig 10, the circuit breaking function of the contact points will be even safer. According to Fig 10 the redundant motor 7 drives two redundant arms 8A and 8B via the
5 axle 61. In the end of these arms, there is a conducting surface, 55A and 55B, respectively, against which the electrodes 56A and 56B are pressed. These electrodes are located on the pipe 46, which is turned by the real motor. Between the conducting surfaces 55A and 55B there is a conductor 64, which makes that
10 current supply is obtained to the breaker coil 18 when the redundant arms 8A and 8B move synchronously with the pipe 46. When an error occurs, the electrodes 56A and 56B will get outside the surfaces 55A and 55B, respectively, where the redundant arms are electrically insulating. Through the slits 62A and
15 62B the redundant arms 8A and 8B will strike the pipe 46 before the electrodes 55A and 55B get outside the insulating surface of the redundant arms around the conducting contact point.

Instead of using an electric circuit for manoeuvring breakers and
20 brakes, a pneumatic circuit can be used. In that case, with the arrangement in Fig 10, the electrodes 56A and 56B and the conducting surfaces 55A and 55B can be replaced by pneumatic pipe couplings 65A and 65B and the conductor 64 by a tube or a pipe 66, see Fig 11.

25 Of course, more than two contact points can also be used and it is also possible to change contact points when the real arm is moving, which is illustrated in Fig 12. The pipe 46 is here seen in cross-section and there is a number of contact surfaces 55 on
30 the periphery thereof, which contact surfaces have an insulating surrounding in the form of an insulating soft layer 67. The contact surfaces 55 are electrically connected to the breaker coil 18 via the conductors 68, 69 and 70. To the left of the pipe 46 there is a pipe 61, which is driven in rotation by the redundant motor
35 (not shown). On the periphery of this pipe 61, there are a number of electrodes 56 with the same mutual distance as the dis-

tance between the contact surfaces 55 on the pipe 46. All of the electrodes 56 are electrically connected to the current supply of the breaker coil by the conductors 71 and the conductor 72. When the pipes 61 and 46 are synchronously driven in rotation,
5 at least one electrode 56 will always be in contact with a contact surface 55, so that the breaker coil receives its current supply. If any error occurs, the electrode 56 which is in contact position will slide out into the insulating material 67 and the breaker will cut of the motor.

10 If a large number of contact points are used a moiré-like technique is obtained. In Fig 13 it is shown how this can be used. The real motor turns the axle 46, whereas the redundant motor turns the axle 61. The disc 73 with one of the moiré-patterns is
15 provided on the axle 61 and the disc 74 with the other moiré-pattern is provided on the axle 46. The simplest way to carry out moiré-patterns is to let them be identical, which causes fade-out at a relative turning of half a pattern partition. For detection of the moiré-pattern, one or several light sources 75 and one or
20 several photodetectors 76 are used.

For the sake of completeness, it is shown in Fig 14 that it is also possible to use a linkage system for obtaining contact points between the real robot arm and the redundant arm.
25 Consequently, Fig 14 shows how the real robot axle 46 is connected with a linkage system to the redundant axle 61. The axle 46 drives a wheel 94 via the belt 96, which wheel is journalled in bearings in the beam 93. The wheel 94 rotates two rods 89 and 90, which are mounted on each side of the wheel 94 and connected to the linkage arms 85 and 86 via the hinges 91
30 and 92. In a corresponding way, the redundant axle 61 drives the linkage arms 83 and 84 via the belt 78, the wheel 95, the rods 79 and 80 and the hinges 81 and 82. The linkage arms 83 and 85 are coupled together by the bearings 87A, which make
35 that the two linkage arms can move longitudinally in relation to each other. In the same way, the bearings 87B couple together

the linkage arms 84 and 86. When the axles 46 and 61 are rotating synchronously, the distances between the bearings 81 and 91 and 82 and 92, respectively, will be constant owing to that the length of the rod 79 is the same as the length of the rod 89, and the length of the rod 80 the same as the length of the rod 90. If a deviation from synchronism occurs, at least one of the distances mentioned above will however change, which results in that at least one of the contact points 55A/56A and 55B/56B, respectively, will be broken. The angle between the rods 89 and 90 has to be the same as the angle between 79 and 80, and preferably in the vicinity of 90°, since this results in that at least one of the linkages will have to change its length when the synchronism is lost.

Finally, the possibility of using a simulated contact point is shown in Fig 15. The upper part of the figure is the same as in Fig 1, but instead of a physical contact point 19/20 between the real arm 6 and the redundant arm 8, a simulated contact point 97 is used. In this contact point 97 the position of the real arm is obtained from the angle sensor 96, and the position of the redundant arm from a simulated redundant arm with associated motor and driving electronics in the module 98. In order to obtain, in the normal case, the same transfer function between path generator and real arm movement as between path generator and movement of simulated redundant arm, the simulated redundant arm module 98 is given essentially the same dynamic characteristics as the real arm. The output signal from the contact point simulator 97 is supplied to an absolute value function 99, the output of which is compared with the value ΔS in the comparator 100. ΔS simulates half the width of the contact surface in the physical contact point. When the output from 99 exceeds the value ΔS , the comparator will break the current supply to the coil 18 via the driving circuit 101 and the motor 5 will be made currentless. In order to increase the safety in the system, the function generator 102 generates a monitor signal, at one or several frequencies, with a repetitive wave form shape.

This signal is supplied to the input of the servo 3 via the sum-
mator 103 and the input of the servo 4 via the subtractor 104.
The frequency of the monitor signal can be varied so that it will
not come at a frequency where the arm dynamics has a low
transmission, e.g. at zero position frequencies. By supplying
5 monitor signals to servo 3 and 4 with different phase, the trans-
mitted monitor signals on the input of the subtractor 97 will have
different phase, and a monitor signal component will also be
obtained on the output of the subtractor 97. The circuits 99-101
10 are then constructed in such a way that they let through the
monitor signal when they are working, and the monitor signal
will function as a test signal for these circuits. On the output
from the driving circuit 101, the monitor signal is detected by the
phase-sensitive detector 105, which generates an output signal
15 proportional to the amplitude of the monitor signal on the output
of the circuit 101. The output signal from the detector 105 is
supplied to a comparator 106, and if the level is higher than a
threshold level t_r the driving circuit 107 will hold the relay 108
drawn. If, however, an error occurs in the real system as well as
20 the redundant system, or if an error occurs in any of the circuits
97, 99, 100 or 101, the relay 108 will be opened.

It is pointed out that all the electronic functions can be doubled
or trebled, the later in order to make decisions of the type 2 out
25 of 3. In order to obtain the highest possible safety, different
functions or the same functions can be implemented in different
hardwares, battery backup can be used etc.

Claims

1. A device for monitoring the operation of a driving arrangement comprising at least one servo mechanism (3), which includes a regulator (3a), a driving motor (5) controlled by this regulator and an element (6) which can be set in motion by the driving motor, a detection arrangement (19-22, 25-27, 19-21, 23, 43, 44, 48, 55-57, 25, 62, 65-66, 73-76, 88, 97-100) for detecting deviations between intended and actual movement positions of the element (6) and an operation inhibiting and/or alarming arrangement (18, 23, 36, 37, 38) for inhibiting the operation of the driving arrangement and/or starting an alarm when impermissible deviations have been established by means of the detection arrangement, **characterized** in that it comprises a redundant driving arrangement, which comprises at least one redundant servomechanism (4), including a redundant regulator (4a), a redundant driving motor (7) controlled by this regulator and a redundant element (8) which can be set in motion by this driving motor, that the regulator (3a) and the redundant regulator (4a) are connected to an arrangement (2) delivering control information for imparting to the element and the redundant element movements being the same or having a predetermined relation to each other, and that the detection arrangement is arranged to detect the deviations concerning the relative position or movements of the element (6), or an object (17) connected thereto, and the redundant element (8).
2. A device according to claim 1, **characterized** in that the detection arrangement comprises contact members (19, 20; 25, 27; 43, 44; 43, 48; 55, 57; 25, 62; 55, 56; 65, 66) being in contact with each other in a contact point (19, 20; 25, 27; 43, 44; 43, 48; 55, 57; 25, 62; 55, 56; 65, 66), which contact members detect deviations between the element (6) which

can be set in motion by the driving motor and the redundant element (8).

- 5 3. A device according to claim 2, **characterized** in that the detection arrangement comprises electronic circuits or a computer for obtaining a contact point by comparison between the output signal from an angle or position sensor (96), connected to the element (6) to be monitored, and the output signal from members (98), comprised in the detection arrangement, being arranged to emit an output signal corresponding to the position of the redundant element (8).
- 10 4. A device according to claim 3, **characterized** in that the output signal from the detection arrangement represents a simulation (98) of the redundant driving motor (7) and the redundant element (8) driven by said motor, which simulation has been obtained by electronic circuits or one or several computers.
- 15 5. A device according to claim 3, **characterized** in that the simulation (98) of the redundant driving motor (7) is dimensioned for obtaining the same dynamic characteristics as the driving motor (5) with associated elements (6) which can be set in motion by said motor.
- 20 6. A device according to claim 3, **characterized** in that the detection arrangement comprises detection members in the form of angle or position sensors associated with the element (6) and the redundant element (8), respectively, and a difference former (97) connected to these sensors, and that the output signal from this difference former (97) is supplied to a comparator (100), the comparing signal (ΔS) of which simulates the half of a permitted relative movement or position differential between the element (6) and the redundant element (8) or objects (17) connected to these.
- 25 30 35

7. A device according to claim 2, **characterized** in that the members (19, 20) being in contact with each other in the contact point consist of electrically conducting members (55, 56), one member of which, directly or via transmissions, follows the movements of the element (6), and a second member of which, directly or via transmissions, follows the movements of the redundant element (8).
8. A device according to claim 7, **characterized** in that at least one of said electrically conducting members (55, 56) is surrounded by a medium (54), being insulating to electric current, in such a way that a deviation in movements between the element (6, 17) and the redundant element (8) results in that the electrical contact in the contact point is interrupted and that the driving motor (5) is disengaged and/or is braked by means of the operation inhibiting arrangement.
9. A device according to claim 7, **characterized** in that one of the electrically conducting members consists of a conducting surface (55) surrounded by an insulating surface (54), and that two other conducting members (56, 57), connected in series, are pressed against the conducting surface (55) so as to close an electric circuit, in which circuit a breaker (11) for the driving motor (5) is included.
10. A device according to claim 7, **characterized** in that electrically conducting members in to or more contact points (55A/56A, 55B/56B) are connected in series.
11. A device according to claim 2, **characterized** in that several contact points (fig 12) are provided and that the arrangement is such that a successive change of contact points takes place during relative movements of the driven element (6, 46) and the redundant element (8, 61).

12. A device according to claim 2, **characterized** in that at least one contact point is located on a linkage system between the driven element (6, 46) and the redundant element (8, 61).
- 5 13. A device according to claim 2, **characterized** in that the contact point (19/20) is mechanically connected to an electric contact (23).
- 10 14. A device according to claim 2, **characterized** in that the contact point is mechanically connected to a holding mechanism (41, 17) for a brake or an electric breaker included in the operation inhibiting arrangement.
- 15 15. A device according to claim 2, **characterized** in that said contact point is formed of a pneumatic coupling (65A, 65B).
- 20 16. A device according to claim 2, **characterized** in that said contact point is formed between a sensor (25) and a sensor target (27) and that the detection arrangement comprises a non-contact measuring system (25, 27).
- 25 17. A device according to claim 16, **characterized** in that the measuring system utilises inductive, capacitive, optical or ultrasonically based sensors.
- 30 18. A device according to claim 16, **characterized** in that the auxiliary driving arrangement is arranged to make the redundant element oscillate or that a sensor for the redundant element is arranged to be electrically modulated at at least one frequency, and that the detection arrangement is arranged to use the signal/signals, thus obtained, as monitor signal/signals for testing the monitoring device
- 35 19. A device according to claim 17, **characterized** in several measuring points and moirè-technique for measuring devia-

tions between the movements of the driven element and the redundant element.

- 5 20. A device according to claim 16, **characterized** in that the measuring point is moveable and is defined by a pattern arranged to move connected to the movements of either the driven element or the redundant element.
- 10 21. A device according to claim 20, **characterized** in that a sensor in the redundant element is arranged to be moved in a path corresponding to said pattern (62) when the movements of the driven element and the redundant element are synchronised.
- 15 22. A device according to claim 2, **characterized** in that a signal generator (102) is arranged to generate a monitor signal to the regulator in the servomechanism (3) for the driven element (6) and to the regulator of the redundant servomechanism for the redundant element (8), and that the
- 20 monitor signal, transmitted in two ways, is used for monitoring if errors ensue simultaneously as concerns the driving of the driven element (6) and the redundant element (8).
- 25 23. A device according to claim 6, **characterized** in that a signal generator (102) is arranged to generate a monitor signal to the regulator (3a) in the servomechanism for the driven element (6) and to supply said monitor signal offset in phase to the regulator (4a) in the servomechanism (4) for the simulated redundant element (98), and that the detection arrangement is arranged to use this monitor signal for
- 30 securing that no errors will ensue simultaneously as concerns the driving of the driven element (6) as well as the simulated redundant element and that no errors will ensue in the driving circuits (101) included in the difference former
- 35 (97), the comparator (100) and the detection arrangement.

24. A device according to claim 2, **characterized** in that the contact point (56, 55, 57) is electromagnetically connected to driving circuits for the driving motor (7) of the driven element and/or a brake (36) for said motor.

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25. A device according to any preceding claim, **characterized** in that the driving arrangement forms part of a manipulator, particularly an industrial robot, and that the element (6) which can be set in motion by the motor consists of an arm of the manipulator.

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Fig.5

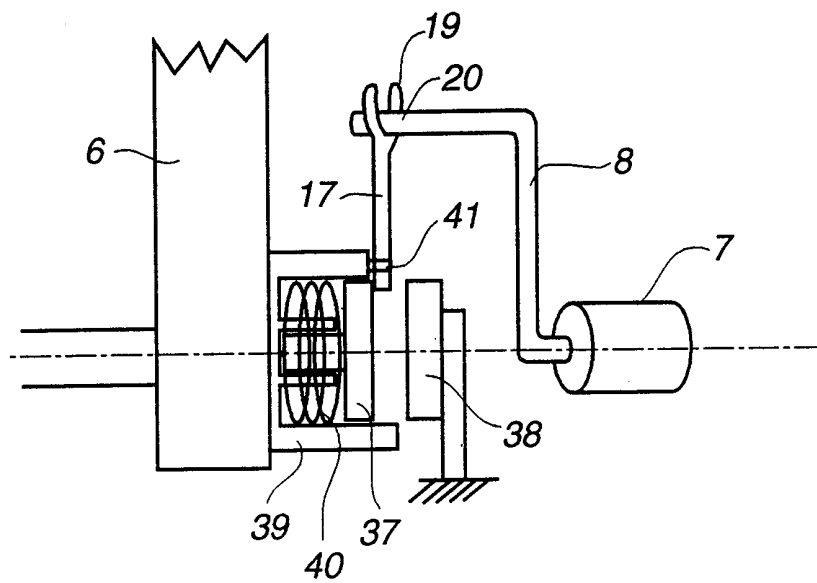
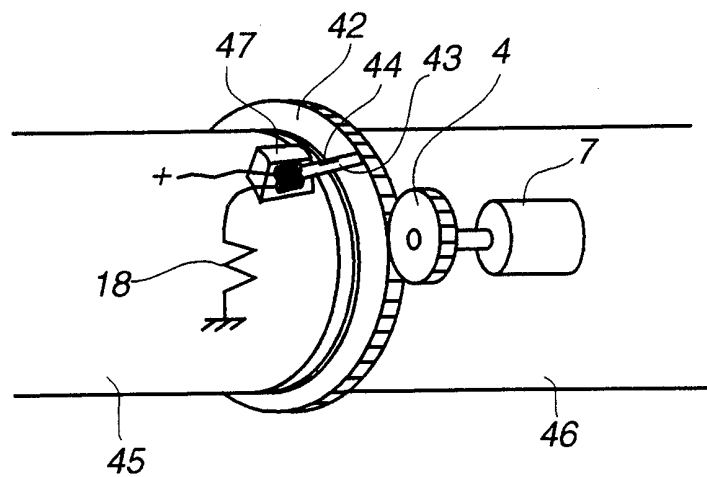


Fig.6



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Fig.7

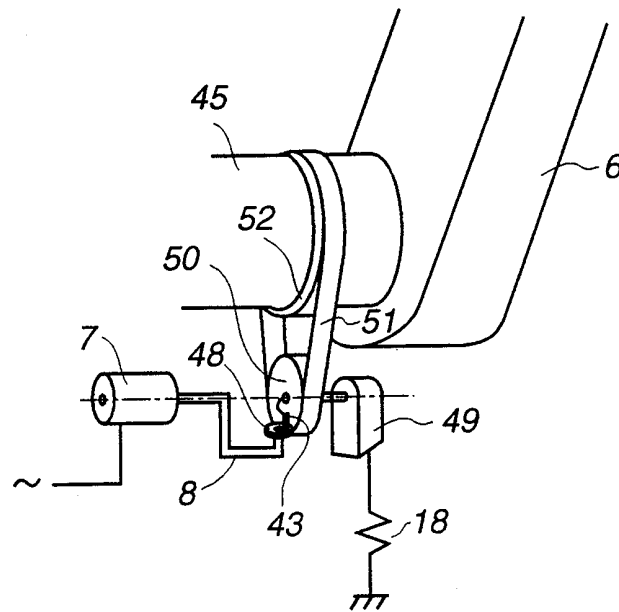


Fig.8

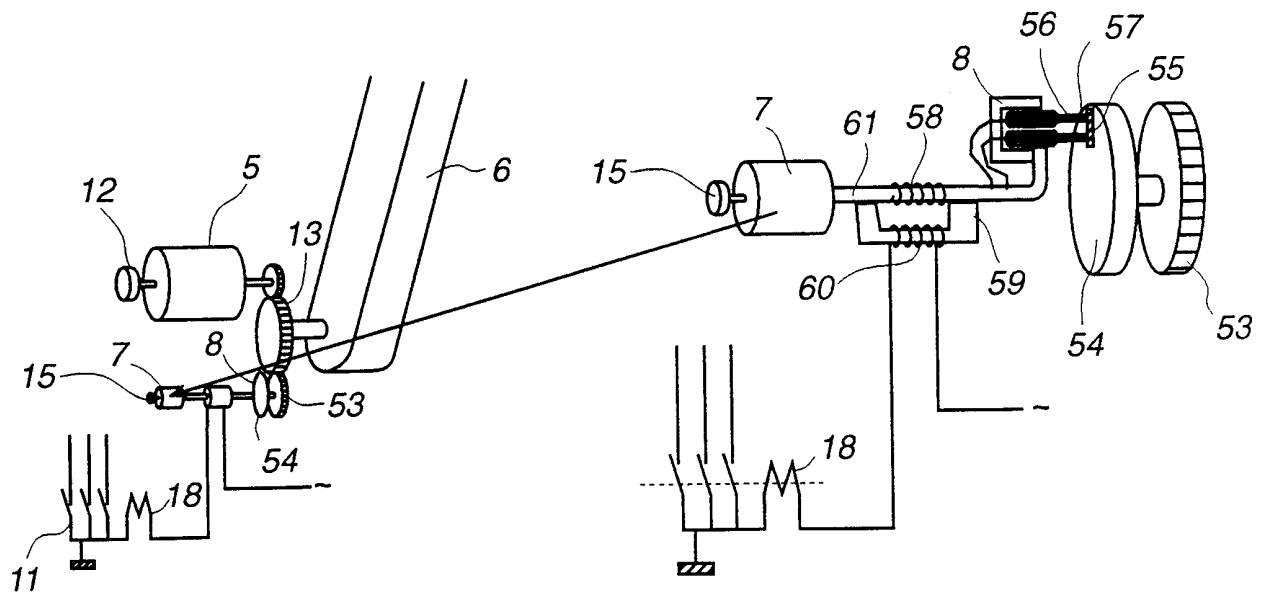
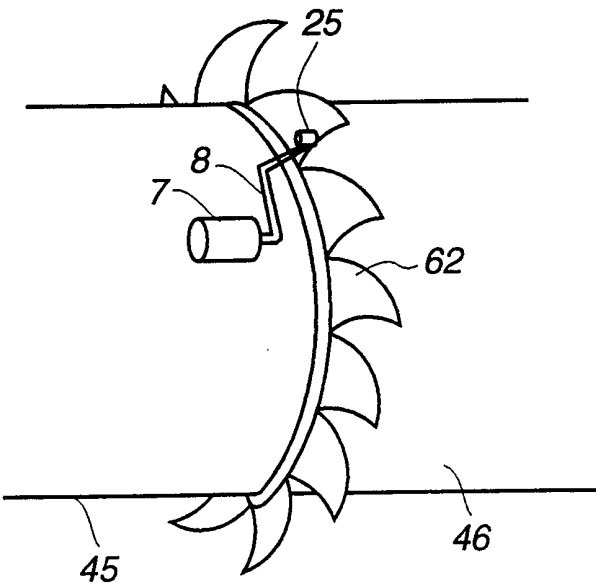


Fig.9



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Fig.10

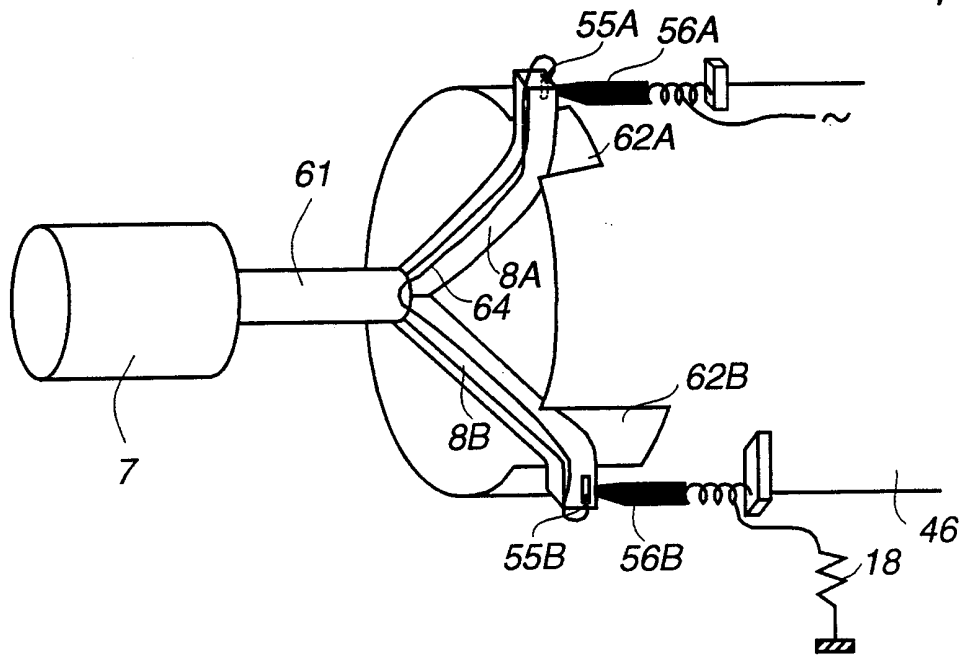
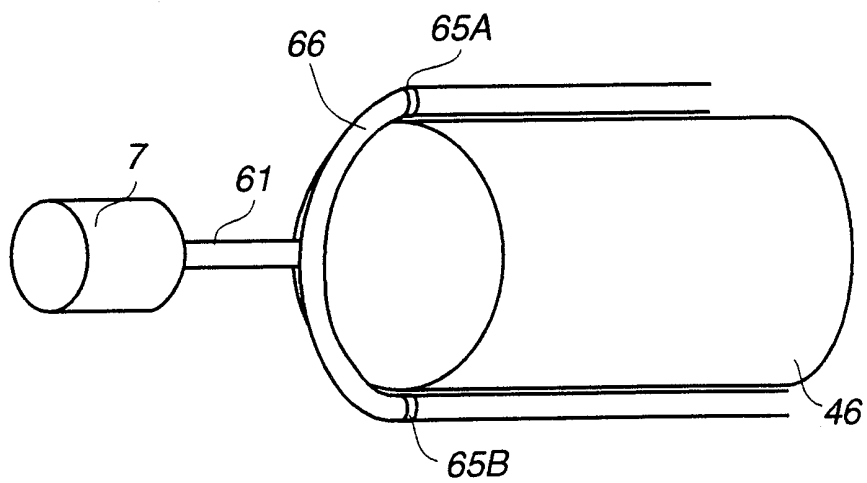


Fig.11



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Fig.12

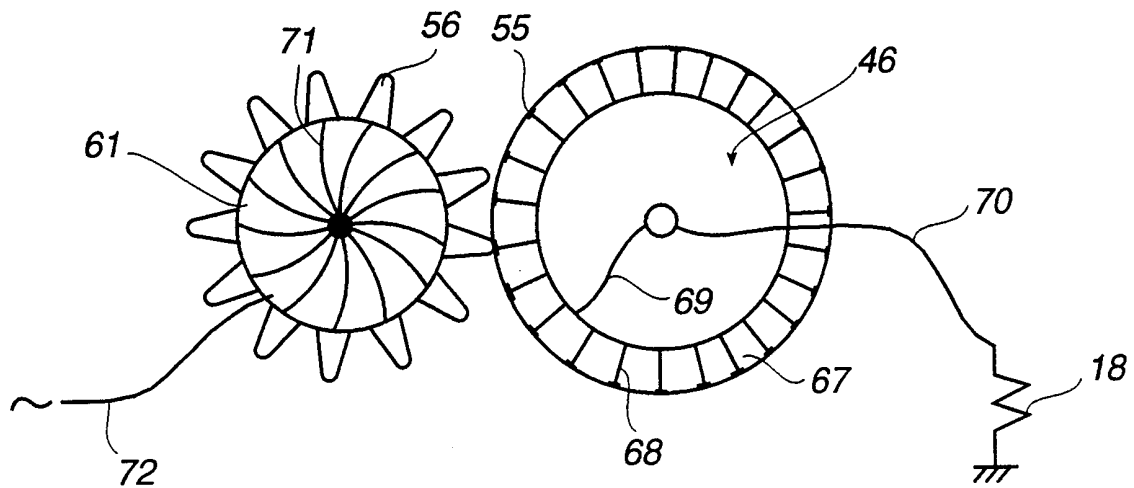
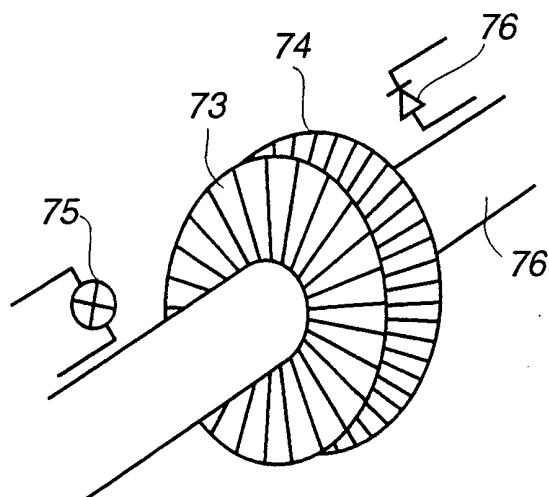
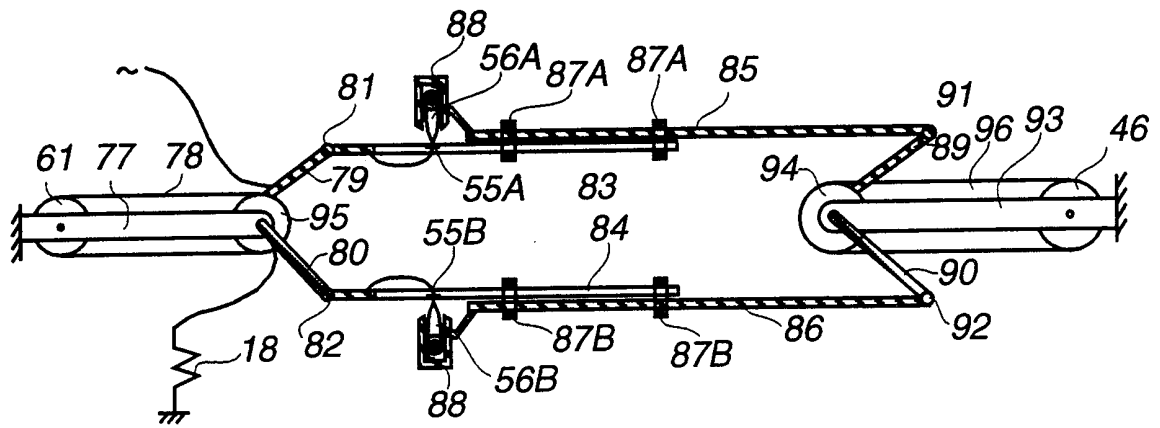


Fig.13



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Fig.14



INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 00/00090

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: B25J 19/06, B25J 9/16

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: B25J, G05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,A	EP 0927612 A1 (FANUC LTD), 7 July 1999 (07.07.99) --	1,4
P,A	JP 11077580 A (YASKAWA ELECTRONIC CORP) 1999-03-23 (abstract) World Patents Index (online). London, UK. Derwent Publications, Ltd. (retrieved on 2000-05-03) . Retrieved from: EPO WPI Database. DW199922, Accession No. 1999-259275. JP 11077580 A (YASKAWA ELECTRONIC CORP) 1999-03-23 (abstract). (online)(retridved on 2000-05-03). Retrieved from EPO PAJ Database; JP 11-77580 A (YASKAWA ELECTRONIC CORP) 23 marsh 1999. --	1,4



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"&" document member of the same patent family

Date of the actual completion of the international search

4 May 2000

Date of mailing of the international search report

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Name and mailing address of the ISA

Swedish Patent Office

Box 5055, S-102 42 STOCKHOLM

Facsimile No. +46 8 666 02 86

Authorized officer

Mariana Eddin/AB

Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 00/00090

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,A	JP 11282540 A (MATSUSHITA DENKI SANGYO KK)1999-10-15 (abstract) World Patents Index (online). London, UK. Derwent Publications, Ltd. (retrieved on 2000-05-03) Retrieved from: EPO WPI Database. DW 200001, Accession No. 2000-003989. JP 11282540 A (MATSUSHITA DENKI SANGYO KK)1999-10-15 (abstract).(online)(retrieved on 2000-05-03). Retrieved from: EPO PAJ Database: JP 11-282540 A (MATSUSHITA DENKI SANGYO KK) 15 OKT 1999. --	1,4
A	EP 0889383 A1 (FANUC LTD), 7 January 1999 (07.01.99), abstract --	1
A	JP 2059291 A (MATSUSHITA ELECTRIC IND CO LTD) 1990-02-28 (abstract).(online)(retrieved on 2000- 05-03). Retrieved from EPO PAJ Database. JP 2-59291 A (MATSUSHITA ELECTRIC IND CO LTD) 28 fed 1990. --	1
A	US 5697480 A (HERBERMANN ET AL.), 16 December 1997 (16.12.97), figures 1-9, abstract -- -----	1

INTERNATIONAL SEARCH REPORT

Information on patent family members

02/12/99

International application No.

PCT/SE 00/00090

Patent document cited in search report			Publication date	Patent family member(s)		Publication date
EP	0927612	A1	07/07/99	JP 10264080 A		06/10/98
				WO 9842483 A		01/10/98
EP	0889383	A1	07/01/99	WO 9824011 A		04/06/98
US	5697480	A	16/12/97	NONE		