

PATENT SPECIFICATION (11)

1 553 694

1 553 694

- (21) Application No. 23853/76 (22) Filed 9 June 1976 (19)
 (31) Convention Application No. 50/069 903 (32) Filed 10 June 1975 in
 (33) Japan (JP)
 (44) Complete Specification published 3 Oct. 1979
 (51) INT. CL.² E05F 15/18
 (52) Index at acceptance
 E2M 11E2 12A 12F1A 24 AX1



(54) METHOD OF AND APPARATUS FOR DRIVING THE DOOR OF A MOTORISED DOOR ASSEMBLY

(71) We, YOSHIDA KOGYO K.K., a corporation duly organized under the laws of Japan and existing at No. 1, Kanda Izumicho, Chiyoda-ku, Tokyo, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to a method of and apparatus for driving a door of a motorised door assembly, such as an automatic door assembly and more particularly, to a method of and apparatus for driving the door by a linear motor mounted within the automatic door assembly.

Automatic door assemblies having a linear motor as a prime mover are advantageous in that the linear motor can drive the door linearly without any special driving power transmission mechanism, the motor is simple and durable in construction, and it can be manufactured at low cost. However, they also have a disadvantage such that the linear motor connected with a movable door which has a relatively reduced stroke is actuated only for a period during which time the slip of the linear motor remains relatively large. Therefore, when the propulsion force of the linear motor is too small, the door is retarded and tends to stop before it reaches the end of its stroke, and when the propulsion force is too great, the door is driven so rapidly that the door frame is subjected to the full impact of the moving door. In addition, since frictional resistance and inertia acting on the door vary with the structure and extent of movement of the door when the latter travels, it is extremely difficult to determine a propulsion force for the motor which prevents the door from stopping before it comes to a stroke end or from bumping against the door frame at the stroke end. Various attempts have heretofore been made to stop the door exactly at the ends of the door stroke by retarding the door during its stroke, thereby preventing the door from striking the outer frame. One such attempt has been to reduce the speed of the door electrically by giving an

opposite propulsion force to the linear motor during a final portion of the door stroke. However, this has led to a drawback in that various intricate control devices such as a speed detecting device and a position detecting device which must be adjusted precisely are to be added to the automatic door assembly. Another such attempt has been to provide a pair of cushioning devices such as self-returning type air cylinders at the ends of stroke of the movable door or so as to dampen the door speed mechanically.

A problem with the automatic door assembly having the cushioning devices is that an additional propulsion force must be applied at the ends of the door stroke to overcome the reaction force of the cushioning devices. Furthermore, a common difficulty experienced with these prior proposals is that the door cannot be moved smoothly over its entire stroke and is subjected to stresses since the door is forcibly stopped at the ends of the stroke.

The present invention seeks to provide a method of driving a door of an automatic door assembly.

The invention further seeks to provide a method of the type described which can drive the door smoothly over its stroke and prevent it from hitting the door frame at one or more of its stroke ends.

According to the invention, there is provided a method driving a door of a motorised door assembly comprising driving the door with a propulsion force at least sufficient to overcome the frictional resistance of the door and its drive during an initial movement of the door, reducing the propulsion force to slow the door down during intermediate movement of the door and driving the door with a propulsion force at least sufficient to overcome the frictional resistance of the door and its drive during the end movement of the door.

According to a further aspect of the invention, there is provided apparatus for driving a door of a motorised door assembly comprising means for driving the door with a propulsion force at least sufficient to over-

55

60

65

70

75

80

85

90

95

100

come the frictional resistance of the door and its drive during an initial and an end movement of the door and means for reducing the propulsion force intermediate the initial and end movements for slowing the door down.

The invention will now be described in greater detail, by way of example with reference to the drawings in which:—

Figure 1 is a fragmentary front elevational view with parts cut away of an automatic door assembly driven in accordance with a method of the present invention;

Figures 2A to 2D are graphs each showing the relation between time and propulsion force of the linear motor actuated according to a method of the present invention; and

Figures 3 to 6 are circuit diagrams for controlling the linear motor in accordance with the invention.

Referring to Figure 1, an automatic door assembly 10 generally comprises an outer frame 11 to be mounted in a portal in a building and a pair of doors 12, 13, the door 12 being fixed to the frame 11 and the door 13 being horizontally movable within the frame 11 in order to open and close the portal. Each of the doors 12, 13, has an inner frame including a pair of stiles 14, 15, a top rail 16, and a glass pane 17 surrounded and held in place by the inner frame. The outer frame 11 has a pair of side jambs 18, 19 and a head 20 interconnecting the top ends of the side jambs 18, 19.

The head 20 contains therein a linear motor 21 having a reaction rod 22 extending horizontally between the side jambs 18, 19 and a movable member 23 in the form of a hollow cylinder fitted over the rod 22 with a clearance therebetween, the movable member 23 having a pair of coils for providing a shifting magnetic field. A power cable 24 extends from one of the side jambs, here the jamb 19, around the reaction rod 22 to the movable member 23 where it is connected to the windings. The head 20 also has a pair of air cushion cylinders 25, 26 of the self-returning type mounted therein and spaced apart a distance substantially equal to the stroke of the movable door 13, the cylinders 25, 26 serving to dampen the movement of the movable door 13 at its opening and closing stroke ends. The air cushion cylinders 25, 26 may however be removed under certain conditions.

Each of the air cushion cylinders 25, 26 has a piston rod 27 normally urged to its projecting position by a coil spring, not shown, in the cylinder. The movable member 23 of the linear motor 21 is provided with a downwardly extending bar 28 fixed thereto and having its bottom end connected with the top rail 16 of the movable door 13 at its central position. The piston rods 27 have

at their distal ends rubber members 29 with which the bar 28 becomes engageable when the door 13 is just about to reach its opening or closing position.

According to a method of the invention, as shown in figure 2A, a stationary propulsion force F_0 , i.e. a force at least sufficient to overcome the frictional resistance of the door and its drive from the linear motor over its opening and closing intervals, is interrupted at a central period T_2 of each of the door opening and closing intervals. The linear motor 21 is driven by the propulsion force F_0 during an initial period T_1 or T_1^1 , then by the inertia of its own and the door 13 during the period T_2 or T_2^1 , and finally by the propulsion force F_0 again during a final period T_3 or T_3^1 . The door 13 is retarded by frictional resistance of the door and the linear motor during the period T_2 or T_2^1 and accelerated again during the final period T_3 or T_3^1 . However, due to the inertia of the door and linear motor, the door 13 does not reach its full speed before arriving at the end of the stroke. The door 13 is thus prevented from bumping against the door frame 11 and is smoothly opened and closed.

In figure 2B, the propulsion force F_0 is reduced at the central periods T_2 and T_2^1 of the opening and closing intervals to a smaller propulsion force F which may range from zero to the propulsion force F_0 , thereby reducing the speed of travel of the door 13.

Since the door 13 is permitted to stop short of its fully opened position, it may be driven in accordance with patterns of figures 2C and 2D in which the propulsion force F_0 is removed or reduced on after the lapse of a suitable period in the door opening interval. More specifically, the propulsion force F_0 is cut off upon lapse of a period T_4 which is longer than the initial period T_1 , as shown in Figure 2C. In this instance, the door 13 is first driven by the linear motor 21 during the period T_4 and then, is moved by its own inertia during a remaining period T_5 .

With reference to Figure 2D, the driving force F_0 is reduced to the propulsion force F after the lapse of the initial period T_1 and held at the force F during a remaining period T_6 .

Figure 3 illustrates an electric circuit 30 provided for effecting the method according to this invention. The circuit 30 includes an autotransformer 31 connected at its end terminals to a single-phase a.c. source 32. A main switching relay 33 is connected between one of the end terminals of the autotransformer 31 and a common terminal of a pair of parallel-connected first and second coils 34, 35 mounted within the movable member 23 of the linear motor 21. There is provided a first relay 36 of the single-pole

double-throw type having a pole 37 and two contacts 38, 39, the contact 38 being connected to the other end terminal of the autotransformer 31 and the contact 39 to a tap 40 of the autotransformer 31. The first relay 36 is normally open during which time the pole 37 contacts the contact 38. A second relay 41 of the single-pole double-throw type is provided which has a pole 42 coupled with the pole 37 of the first relay 36. A contact 43 of the second relay 41 is connected to the first winding 34 and a contact 44 is connected to the second winding 35. The second relay 41 is normally open during which time the pole 42 contacts the contact 43. Connected across the contacts 43, 44 of the second relay 41 is a capacitor 45 serving as a phase-advancer for one of the windings 34, 35 which is selected by the second relay 41.

Assuming that the main relay 33 is closed and the first and second relays 36, 41 are de-energized, a full voltage of the power source 32 is applied to the winding 34 and, through the capacitor 45, the winding 35, when the door 13 is driven by the stationary propulsion force F_0 . When the first relay 36 is actuated to shift the pole 37 to the contact 39, a voltage which is produced by dropping the power supply voltage through the autotransformer 31 is applied to the winding 34 and, through the capacitor 45, the winding 35, whereupon the door 13 is driven by a propulsion force F which may range from zero to the propulsion force F_0 . The direction of movement of the movable member 23 of the linear motor 21 can be changed by shifting the pole 42 from the contact 43 to the contact 44 or vice versa, the switching of the relay 41 being the switching of direction of the shifting magnetic field formed by the windings 34, 35. The autotransformer 31 may be a variable-ratio autotransformer whereby an output voltage across the common line can be varied continuously.

With the circuit construction of Figure 3, a mode of operation of the automatic door assembly 10 according to the pattern of Figure 2B will be described below. Although not shown, there are provided four timers operatively associated with the circuit components. More specifically, a first timer serves to determine a time interval during which the door is opened. That is, when a switch under a door mat, not shown, on the floor is opened, the first timer sets a time interval after which the door starts closing. A second timer is energized when the main relay 33 is actuated and, after the lapse of a preset time interval which is slightly longer than the door opening interval, the second timer turns the main relay 33 off. A third timer is actuated at the same time as the second timer and, after the lapse of a

time interval of the initial period T_1 , energizes the first relay 36 and a fourth timer is actuated to de-energize the first relay 36 after the lapse of a preset time interval.

When a person steps on the door mat, the switch under the mat is thrown to actuate the main relay 33 and the second relay 41, the first relay 36 remaining de-energized. The door 13 starts opening and is driven by the stationary propulsion force F_0 , or otherwise a force greater than the force F_0 , during the initial period T_1 of the opening interval. After the lapse of the initial time interval T_1 , the third timer actuates the first relay 36 to apply a dropped voltage to the first and second coils 34, 35, thereby propelling the door 13 by the smaller propulsion force F . Upon lapse of a preset time interval, the first relay 36 is de-energized again by the fourth timer, so that the door 13 is driven by the stationary propulsion force F_0 , or otherwise a force greater than the force F_0 . Simultaneously with the lapse of the door opening interval, the second timer de-energizes the main relay 33 thereby completing the opening of the door 13. With the switch under the door mat open upon passage of the person through the door, the first timer is operated, after a preset time interval, to actuate the main switching relay 33 so as to initiate the door closing operation. The second relay 31 is de-energized by the first timer when the door closing operation begins. The sequence of switching of the relays 33 and 36, and operation of the second and third timers during the door closing operation is completely identical to that during the door opening operation.

Figure 4 illustrates a linear motor control circuit 10a constructed in accordance with another embodiment, wherein a variable resistor 46 is used instead of the autotransformer 31 in the circuit 30 shown in Figure 4.

According to still another embodiment shown in Figure 5, a control circuit 30b includes a single-pole double-throw type relay 47 having a pole 48 connected to one terminal of the power supply 32 and a pair of contacts 49, 50, the contact 49 being coupled to the first coil 34 and the contact 50 to the second coil 35. There is provided another relay 51 connected in series with a capacitor 52, the relay 51 and the capacitor 52 being connected in parallel with the capacitor 45. The relay 47 is used to change the direction of the shifting magnetic field formed by the windings 34, 35. The relay 51 serves to vary the strength of the propulsion force of the linear motor.

With respect to Figure 6, an electric circuit 30c finds particular utility for effecting the methods according to the patterns shown in Figures 2A and 2C. A main relay 53 is connected between the power source 32 and the

16

4

1,553,694

4

5 pole 42 of the second relay 41. When the
main relay 53 is energized, the full voltage
is applied to the windings 34, 35 of the linear
motor 21 to drive the latter by the station-
ary propulsion force F_0 . When the main
relay 53 is then de-energized, the stationary
propulsion force F_0 is interrupted to let the
door 13 be moved only by its own inertia
by which the door 13 tends to remain in
10 motion.

WHAT WE CLAIM IS:—

15 1. A method of driving a door of a
motorised door assembly comprising driv-
ing the door with a propulsion force at least
sufficient to overcome the frictional resist-
ance of the door and its drive during an ini-
tial movement of the door, reducing the
propulsion force to slow the door down dur-
20 ing intermediate movement of the door and
driving the door with a propulsion force at
least sufficient to overcome the frictional re-
sistance of the door and its drive during the
end movement of the door.

25 2. A method according to claim 1, in
which the door is driven by a linear motor.

30 3. Apparatus for driving a door of a
motorised door assembly comprising means
for driving the door with a propulsion force
at least sufficient to overcome the frictional
resistance of the door and its drive during
an initial and an end movement of the door
and means for reducing the propulsion force
intermediate the initial and end movements
35 for slowing the door down.

4. A method substantially as herein de-
scribed with reference to and as illustrated
in the accompanying drawings.

40 5. Apparatus for driving a door of a
motorised door assembly substantially as
described herein with reference to the draw-
ings.

For the Applicants:
J. F. WILLIAMS & CO.,
Chartered Patent Agents,
34 Tavistock Street,
London, W.C.2.



(16)

4 pole 42 of the second relay 41. When the main relay 53 is energized, the full voltage is applied to the windings 34, 35 of the linear motor 21 to drive the latter by the stationary propulsion force F_0 . When the main relay 53 is then de-energized, the stationary propulsion force F_0 is interrupted to let the door 13 be moved only by its own inertia by which the door 13 tends to remain in motion.

WHAT WE CLAIM IS:—

1. A method of driving a door of a motorised door assembly comprising driving the door with a propulsion force at least sufficient to overcome the frictional resistance of the door and its drive during an initial movement of the door, reducing the propulsion force to slow the door down during intermediate movement of the door and driving the door with a propulsion force at least sufficient to overcome the frictional resistance of the door and its drive during the end movement of the door.

2. A method according to claim 1; in which the door is driven by a linear motor.

3. Apparatus for driving a door of a motorised door assembly comprising means for driving the door with a propulsion force at least sufficient to overcome the frictional resistance of the door and its drive during an initial and an end movement of the door and means for reducing the propulsion force intermediate the initial and end movements for slowing the door down.

4. A method substantially as herein described with reference to and as illustrated in the accompanying drawings.

5. Apparatus for driving a door of a motorised door assembly substantially as described herein with reference to the drawings.

For the Applicants:
J. F. WILLIAMS & CO.,
Chartered Patent Agents,
34 Tavistock Street,
London, W.C.2.