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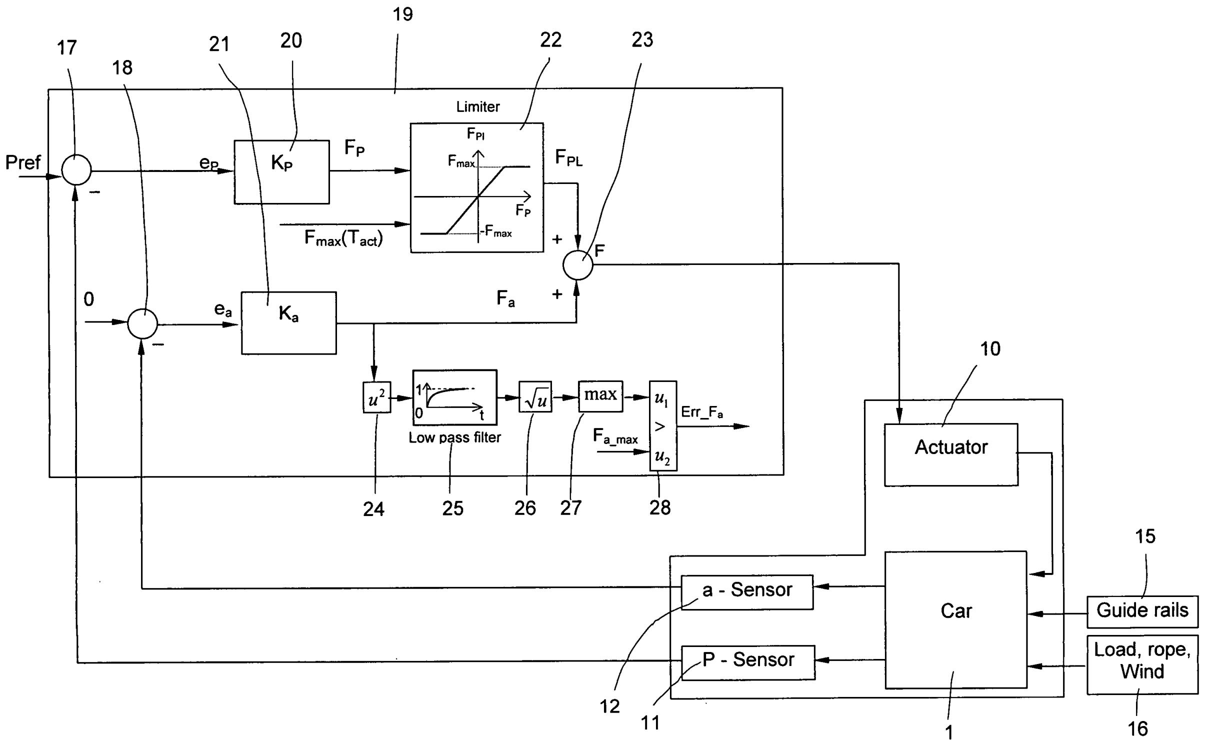
(54) Controller supervision for active vibration damping of elevator cars

(57) The present invention automatically detects the onset of instability of the active ride control system and activates to system shutdown if this happens. As an elevator car (1) is guided along rails (15) by guide elements (6), a plurality of sensors (11,12) mounted on the car (1) measure vibration transverse to a direction of travel. The signals from the sensors (11,12) are input to a controller (19) which in turn produces a controller output signal (F). This signal (F) is used to energise an actuator (10) positioned between the car (1) and the guide elements (6) and thereby dampen the vibrations acting on the car (1). As instability sets in, a controller signal (F_a) increases. This controller signal (F_a) is monitored by a comparator (28) such that the actuator (10) is deactivated if the controller signal (F_a) becomes greater than a predetermined value ($F_{a\,max}$)

Fig. 2



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Description

[0001] The present invention relates to a method and apparatus for detecting instability of a controller used to actively dampen vibrations on an elevator car in an elevator installation.

[0002] EP-B-0731051 describes an elevator installation in which the ride quality is actively controlled using a plurality of electromagnetic linear actuators. Such a system in commonly referred to as an active ride control system. As an elevator car travels along guide rails provided in a hoistway, sensors mounted on the car measure the vibrations occurring transverse to the direction of travel. Signals from the sensors are input to a controller which computes the activation current required to suppress the sensed vibrations for each linear actuator. These activation currents are supplied to the linear actuators which actively dampen the vibrations and thereby the ride quality for passengers traveling within the car is enhanced.

[0003] The controller comprises a position controller with position feedback and an acceleration controller with acceleration feedback. The position controller is rather slow and its output is limited to a level so as not to cause overheating of the actuators. This procedure is described further in our co-pending Application entitled "Thermal Protection of Electromagnetic Motors". The output from the acceleration controller, however, is not restricted and can produce large amplitude, resonance forces at the actuators.

[0004] All closed loop controllers can become unstable if feedback gain is too high. Indeed, the acceleration controller can become unstable very easily since the feedback gain margin that leads to stability can be as low as a factor of two. Hence, simple hardware failures or software errors can easily cause instability of the acceleration controller. An unstable situation would not necessarily harm the safety of any passengers traveling in the elevator car, but undoubtedly causes a considerable amount of discomfort for them. Since the active ride control system is solely designed to improve passenger comfort, an unstable and vibrating system would therefore defeat the purpose of, and completely undermine user confidence in, the active ride control system.

[0005] Accordingly, the objective of the present invention is to detect instability of the active ride control system and to shut the system down if this happens. Although the vibration level will rise, it will not approach the level inherent in the unstable active ride control system. The objective is met by providing an apparatus and method according to the appended claims.

[0006] By way of example only, a preferred embodiment of the present invention will be described in detail with reference to the accompanying drawings, of which:

FIG. 1 is a schematic representation of an elevator car traveling along guide rails, the car incorporating linear actuators to suppress vibration of the car; and

FIG. 2 shows a signal flow scheme of the active ride control system for the elevator installation of FIG. 1 incorporating instability detection according to the present invention.

[0007] FIG. 1 is a schematic illustration of an elevator installation incorporating an active ride control system according to the EP-B-0731051. An elevator car 1 is guided by roller guide assemblies 5 along rails 15 mounted in a shaft (not shown). Car 1 is suspended elastically in a car frame 3 for passive oscillation damping. The passive oscillation damping is performed by several rubber springs 4, which are designed to be relatively stiff in order to isolate sound or vibrations having a frequency higher than 50Hz.

[0008] The roller guide assemblies 5 are laterally mounted above and below car frame 3. Each assembly 5 includes a mounting bracket and three rollers 6 carried on levers 7 which are pivotally connected to the bracket. Two of the rollers 6 are arranged laterally to engage opposing sides of the guide rail 15. The levers 7 carrying these two lateral rollers 6 are interconnected by a linkage 9 to ensure synchronous movement. The remaining, middle roller 6 is arranged to engage with a distal end of the guide rail 15. Each of the levers 7 is biased by a contact pressure spring 8 towards the guide rail 15. This spring biasing of the levers 7, and thereby the respective rollers 6, is a conventional method of passively dampening vibrations.

[0009] Each roller guide assembly 5 further includes two electrical actuators 10 disposed to actively move the middle lever 7 in the y direction and the two interconnected, lateral levers 7 in the x direction, respectively.

[0010] Unevenness in rails 15, lateral components of traction forces originated from the traction cables, positional changes of the load during travel and aerodynamic forces cause oscillations of car frame 3 and car 1, and thus impair travel comfort. Such oscillations of the car 1 are to be reduced. Two position sensors 11 per roller guide assembly 5 continually monitor the position of the middle lever 7 and the position of the interconnected lateral levers 7, respectively. Furthermore, accelerometers 12 measure transverse oscillations or accelerations acting on car frame 3.

[0011] The signals derived from the positions sensors 11 and accelerometers 12 are fed into a controller box 14 mounted on top of the car 1. The controller box 14 contains the power electronics necessary to drive the actuators 10 and the closed loop feedback controller 19 processing the signals from the sensors 11 and 12 to operate the actuators 10 in directions such to oppose the sensed oscillations. Thereby, damping of the oscillations acting on frame 3 and car 1 is achieved. Oscillations are reduced to the extent that they are imperceptible to the elevator passenger.

[0012] FIG. 2 shows a signal flow diagram of the active ride control system for the elevator installation of FIG. 1 incorporating instability detection according to the present invention. External disturbances act of the car 1 and frame 3 as they travel along the guide rails 15. These external disturbances generally comprise high frequency vibrations due mainly to the unevenness of the guide rails 15 and relatively low frequency forces 16 produced by asymmetrical loading of the car 1, lateral forces from the traction cable and air disturbance or wind forces. The disturbances are sensed by the positions sensors 11 and accelerometers 12 which produce signals that are fed into the controller 19.

[0013] In the controller 19, the sensed position signals are compared with reference values P_{ref} at summation point 17 to produce position error signals ep. The position error signals e_p are then fed into a position feedback controller 20 which produces an output signal F_p which is restricted to a maximum absolute value F_{max} by a limiter 22. The value of F_{max} depends on the temperature T_{act} of the electrical actuators 10 and on their ability to endure thermal stress. This temperature limitation is fully described in our co-pending Application "Thermal Protection of Electromagnetic Motors". The output F_{pL} from the limiter 22 is fed into summation point 23.

[0014] The signals from the accelerometers 12 are inverted at a summation point 18 and fed into an acceleration feedback controller 21 as acceleration error signals e_a. The output F_a from the acceleration controller 21 is combined with the output F_{pL} from the limiter 22 at summation point 23. The resulting output control signal F is used as the input for a power amplifier (not shown) to produce current for the actuators 10 to counteract the disturbance forces and thus reduce vibrations on the car 1.

[0015] The output F_a of the acceleration controller 21 contains a broad band of frequencies and the amplitude of the higher frequency signals can be relative large. To detect instability it is not sufficient to look at the amplitude of the signal; time duration has also to be weighted. A good measurement of stability is the moving root mean square or RMS value. It is a measure for the energy or power that is contained in a signal and time duration weighting can be chosen freely. The moving RMS value can be compared with a maximum admissible value and if it exceeds the admissible value an error flag is set true. The error signal will then deactivate the active ride control system and the elevator car will continue its operation with passive vibration damping. Deactivate can mean switch off or to gradually reduce the current supplied to the actuator 10. In the present embodiment the output signal F_a of the acceleration controller is squared in block 24. The squared signal has always a positive sign. In block 25 the squared signal is filtered through a first order low pass filter. The time constant of the low pass filter has to be defined by knowledge of the system and based on experience. In block 26 the square root of the filtered signal is calculated. Since the signal is a vector signal, which contains several values, the maximum value is chosen in block 27 and therefore the output from block 27 represents the signal with the largest RMS amplitude. It is compared against a maximum admissible value F_{a_max} in block 28. If the largest RMS signal is greater than the admissible value, an error flag Err_Fa is set true and the active ride control system is switched off. The admissible value again is derived by knowledge of the system and based on experience. The active ride control system is reactivated after a predetermined time period.

[0016] It will be appreciated that the guide assemblies 5 may incorporate guide shoes rather then rollers 6 to guide the car 1 along the guide rails 15.

Claims

1. An apparatus for damping vibrations of an elevator car (1), the elevator car (1) guided along rails (15) by guide elements (6), comprising:

   a plurality of sensors (11,12) mounted on the car (1) for measuring vibrations transverse to a direction of travel;
   at least one actuator (10) positioned between the car (1) and the guide elements (6);
   and a closed-loop feedback controller (19) responsive to signals from the sensors (11,12) to produce a controller output signal (F) to energize the actuator (10)

   CHARACTERISED IN THAT the controller (19) includes a comparator (28) to temporarily deactivate the actuator (10) if a selected component (F_a,F_p,F) of the controller signal (F) is greater than a predetermined value thereby preventing the onset of instability.

2. An apparatus according to claim 1, wherein the plurality of sensors (11,12) includes a position sensor (11) and an accelerometer (12), the controller (19) comprises a position controller (20) and an acceleration controller (21) responsive to the signals from the position sensor (11) and accelerometer (12) respectively, outputs (F_p,F_a) from the controllers (20,21) are combined to provide the controller output signal (F).

3. An apparatus according to claim 2, wherein the selected component of the controller signal (F) is an output (F_a) from the acceleration controller (21).

4. An apparatus according to claim 3, wherein the output (F_a) from the acceleration controller (21) is passed through a root-mean-square determining unit (24,25,26,27) and a maximum value determined is input to the comparator (28).

5. An apparatus according to any one of claims 2 to 4 wherein the controller (19) further comprises a lim-

iter (22) to restrict the output (F_p) from the position controller (21) to a maximal value (F_p) dependent on the temperature of the actuator (10).

6. A method for reducing oscillations of an elevator car (1), the elevator car (1) guided along rails (15) by guide elements (6), comprising the steps of:

measuring oscillations of the car (1) transverse to a direction of travel; and
providing a control signal (F) for energising at least one actuator (10) positioned between the car (1) and the guide elements (6) in response to the measured oscillations

CHARACTERISED BY
deactivating the actuator (10) if a component of the control signal (F) is greater than a predetermined value and thereby preventing the onset of instability.

7. A method according to claim 6, wherein the step of measuring oscillations includes measuring a position and an acceleration of the car (1) and the step of deactivating the actuator (10) occurs if an acceleration component (F_a) of the control signal (F) is greater than the predetermined value ($F_{a\ max}$).

8. A method according to claim 7 further comprising the step of restricting a position component (F_p) of the control signal (F) to a maximal value (F_{pL}) depending on the temperature of the actuator (10).

Fig. 1

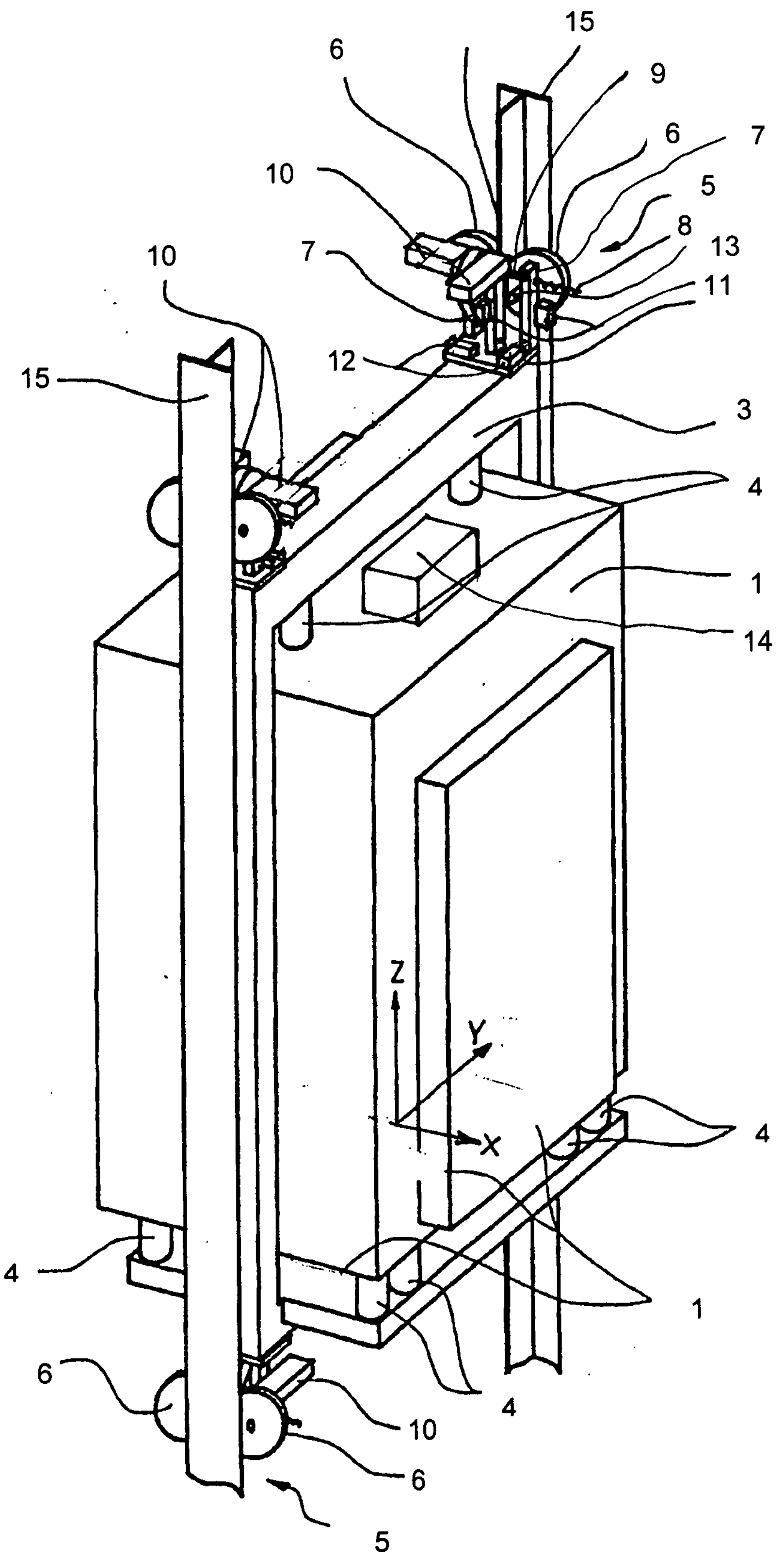
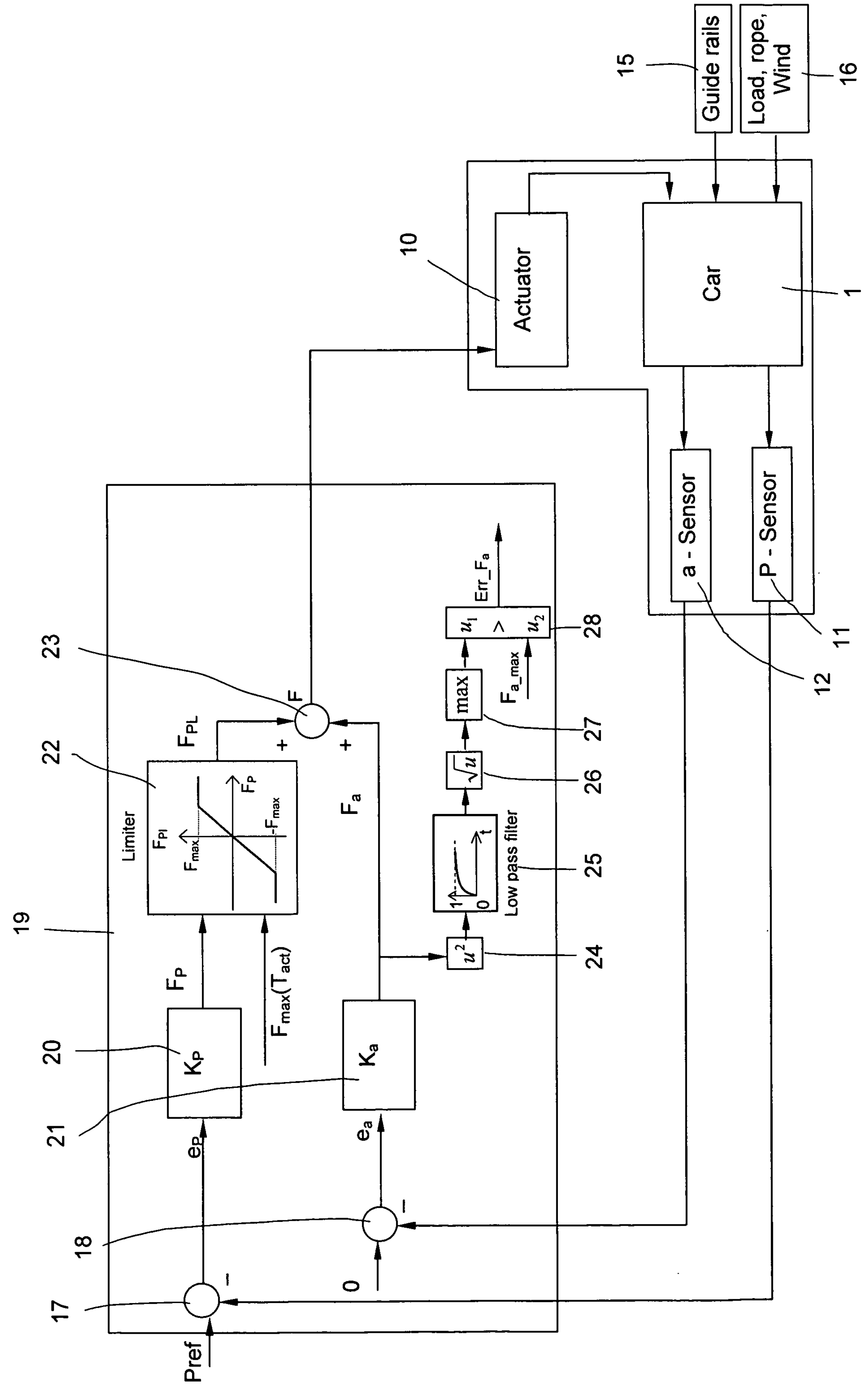


Fig. 2


Guide rails
15
Load, rope, Wind
16
Actuator
10
Car
1
a - Sensor
12
P - Sensor
11
19
Limiter
22
F_{Pl}
F_{max}
$-F_{max}$
F_P
F_{PL}
F
23
+
+
F_a
$F_{max}(T_{act})$
K_P
20
K_a
21
e_P
e_a
F_P
17
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>
u_2
28
F_{a_max}
Err_F_a

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 04 02 9142

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TECHNICAL FIELDS SEARCHED (Int.Cl.7)

B66B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	19 April 2005	Trimarchi, R

CATEGORY OF CITED DOCUMENTS

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82