

Method of preventing collision of two lift cages movable in the same shaft of a lift installation, and corresponding lift installation

The invention relates to a method of preventing collision of two lift cages, which are movable in the same lift shaft of a lift installation, according to the introductory part of claim 1, and a lift installation, which is operable according to this method, according to the introductory part of claim 6.

Lift installations with several lift cages in the same shaft, which are also termed multi-mobile lift installations, usually have a respective driving and braking system per lift cage. Moreover, such lift installations are equipped with a collision protection system by which collisions of the lift cages are to be avoided.

Apart from conventional electronically controlled collision protection systems a lift installation with a collision protection system with electromechanical switching mechanisms able to be mechanically triggered has been described by European Patent Application EP 06 120 359. The disclosure of this European Patent Application is regarded as an integral part of the present application. The mentioned collision protection system is simple in construction and reliable in its operation. However, it is disadvantageous that its triggering takes place merely when a critical minimum distance between two approaching lift cages is fallen below without further braking criteria such as, for example, the relative speed between the lift cages or the instantaneous effective distance, in each instance after triggering of the stopping brake, being taken into consideration. Particularly in the case of high cage speeds and emergency situations it cannot be guaranteed with ultimate certainty that a further lift cage disposed above or below still stops at the right time to avoid a collision.

It is now the *object of the invention*

- to propose a method in order to trigger, in the case of a multi-mobile lift installation, an additional braking when the distance between the lift cages further reduces, notwithstanding triggering of stopping brakes by means of a collision protection system, so that an immediate emergency stop is required, and
- to create a multi-mobile lift installation operable according to this method.

The emergency stop system shall in this connection be conceived as far as possible so

that it does not oblige any enlargement of the shaft cross-section.

Fulfilment of the object takes place

- by the features of claim 1 for the method and
- by the features of claim 6 for the lift installation.

Advantageous examples of embodiment and developments of the invention are circumscribed by the respective dependent patent claims.

The new lift installation comprises at least one upper lift cage and at least one lower lift cage. The two lift cages can move vertically upwardly and downwardly, substantially independently of one another, in a common lift shaft of the lift installation.

The upper lift cage has a first driving and braking system comprising a first stopping brake (preferably a motor brake). The lower cage has a second driving and braking system which includes a second stopping brake (preferably a motor brake). According to the invention the first lift cage is additionally equipped with a first cage (emergency) brake and the second lift cage with a second cage (emergency) brake, the function of which is explained in more detail further below.

Moreover, the lift installation has a collision protection system in order to avoid collisions between the lift cages. The collision protection system preferably comprises a first electromechanical switching mechanism at the upper lift cage and a second electromechanical switching mechanism at the lower lift cage, by which retardation of the upper lift cage by the first stopping brake and/or retardation of the lower lift cage by the second stopping brake can be triggered. However, the lift cages and the collision protection system can, in particular, be constructed - but do not necessarily have to be constructed - in accordance with EP-06120359.

According to the invention an emergency stop system is in addition provided. The emergency stop system is so designed that after triggering of the retardation or braking by the stopping brakes it continuously or repeatedly ascertains the instantaneous movement state of the two lift cages and triggers an additional braking of one or both moved lift cages by means of an associated cage brake if this, with consideration of the movement state of the lift cages on the one hand and with consideration of ascertainable braking criteria on

the other hand, is necessary.

The movement state of the lift cages is *inter alia* and substantially a function of their relative speed.

Braking criteria can in principle be ascertained in advance, but advantageously the instantaneous movement state of the lift cages is included.

Further details and advantages of the invention are described in the following by way of an example of embodiment and with reference to the drawing, in which:

Fig. 1 shows a multi-mobile lift installation according to the state of the art in a strongly simplified, schematic illustration;

Fig. 2 shows a collision protection system and an emergency stop system at a multi-mobile lift installation in a strongly simplified, schematic illustration;

Fig. 3 shows a diagram for illustration of the method according to the invention; and

Fig. 4 shows details of a particularly preferred example of embodiment.

Fig. 1 shows a simple lift installation 10. Such lift installations are, as mentioned further above, known under the designation multi-mobile lift installations. The lift installation 10 has a lift shaft 11 in which an upper lift cage A1 and a lower lift cage A2 can move vertically. As long as a critical minimum distance $d(0)$ between the two lift cages A1, A2 is maintained, i.e. during normal operation where the instantaneous spacing d_i is greater than the critical minimum distance $d(0)$, the lift cages A1, A2 can move independently of one another in the lift shaft 11. The lift installation 10 has a driving and braking unit, wherein preferably each of the lift cages A1, A2 has an individual driving and braking system.

The lift installation 10 additionally has a collision protection system 20. The collision protection system 20 comprises a first electromechanical switching mechanism 21 which is arranged in a lower region of the upper lift cage A1 and a second electromechanical

switching mechanism 22 which is arranged in an upper region of the lower lift cage A2. The two switching mechanisms 21, 22 are mounted in vertical alignment one above the other.

The collision protection system 20 of the lift installation 10 preferably comprises, for each lift cage A1, A2, an individual safety circuit in which several safety elements such as, for example, safety contacts and safety switches, are arranged in series. The corresponding lift cage A1 or A2 can be moved only if its safety circuit and thus all safety contacts *integrated therein* are closed. The safety circuit is connected with the driving and braking unit of the lift installation 10 or the driving and braking systems of the lift cages A1, A2 in order to interrupt travel operation of the corresponding lift cage A1 and/or A2 if the safety circuit is opened by actuation of the corresponding electromechanical switching mechanism 21 and/or 22.

The first switching mechanism 21 comprises a weighting body 23 with a weight G suspended at an elongate flexible support element 24, which in turn is fastened at the lower region of the upper lift cage A1. The entire vertical dimension of the support element 24 and the weighting body 23 substantially corresponds with the critical distance $d(0)$ to be maintained between the lift cages A1, A2.

The second switching mechanism 22 comprises a mechanical sensor in the form of a lever 28 (see Fig. 2), which acts on a contact switch 34.

In the normal case, i.e. when the spacing d_i between the lift cages A1 and A2 is greater than the critical distance $d(0)$, the weighting body 23 hangs freely at the support element 24, which is disposed under tensile stress and kept stretched by the weight G of the weighting body 23.

If the lift cages A1, A2 approach to such an extent that the instantaneous space d_i thereof falls below the critical distance d_0 then the weighting body 23 impinges on the lever 28 of the second electromechanical switching mechanism 22. The tensile force exerted by the weighting body 23 on the support element 24 thereby reduces and thus substantially the tensile stress in the support element 24.

Due to the considerable reduction in the tensile stress in the support element 24 the safety

circuit of the first driving and braking unit of the upper lift cage A1 is opened. Retardation of the upper lift cage A1 by means of the first stopping brake (for example, designed as a motor brake) is thereby triggered. Through the impinging of the waiting body 23 on the lever 28 the safety circuit of the second driving and braking unit of the lower lift cage A2 is opened at virtually the same time. Retardation of the lower lift cage A2 by means of the second stopping brake (for example, designed as a motor brake) is thereby triggered.

However, the emergency stop system according to the invention can also be used in lift installations 10 of which the collision protection system is of different design or of which the stopping brakes can be triggered in a different manner and/or which are equipped with a safety bus system instead of the mentioned safety circuits.

According to the invention the lift installation 10 has, in addition to the collision protection system 20, the emergency stop system by which after retardation of one or both lift cages A1, A2 by one or both stopping brakes an additional retardation of the moved lift cages A1 and/or A2 can be achieved. Triggering of this additional retardation takes place with consideration of the instantaneous movement state of the lift cages A1, A2 and on the basis of emergency stop criteria.

The emergency stop system of the invention can comprise constructional elements of the collision protection system 20 and additional constructional elements, i.e. the emergency stop system in this case is at least partly integrated in the collision protection system 20.

In the case of a collision protection system of a lift installation 10 according to the invention and in accordance with Fig. 2 it is provided that the flexible support element 24 is not fastened directly or fixedly at the lower region of the upper lift cage A1 or at a lever disposed there, but is mounted at a roller 30. The roller 30 is in turn rotatably fastened at the lower region of the upper lift cage A1. This fastening is not shown in Fig. 2. The roller 30 has an internal energy store 31 (or an attached energy store 31, as shown in Fig. 4), preferably in the form of a spiral spring, which exerts a force having a tendency to so rotate the roller 30 (in the illustrated example this rotation would act in clockwise sense) that the flexible support element 20 is wound up on the roller 30. In the normal case, i.e. when the instantaneous spacing d_i between the lift cages A1 and A2 is greater than the critical distance d_0 , the roller 30 is blocked against rotation and, in particular, by the tension force which the flexible support element 24 loaded by the weight G of the

weighting body 23 exerts. This means that the roller 30 cannot, due to this blocking, be brought by means of its internal energy store 31 into rotation. As soon as a retardation of the lift cages A1, A2 has been initiated by the stopping brakes because the instantaneous distance d_i between the lift cages A1 and A2 falls below the critical distance d_0 , the emergency stop system or its control system is activated. In the present case this takes place by impinging of the weighting body 23 on a sensor (for example the lever 28 in conjunction with a switch 34) of the switching mechanism 22 of the lower lift cage A2. After impinging of the weighting body 23 the tension force in the flexible support 24, by which the roller 30 was blocked, diminishes. The roller 30 is now freed and rotates under the winding-up torque delivered by its internal force store 31 so that the flexible support element 24 is wound up on the roller 30. The release of the roller 30 takes place virtually simultaneously with the actuation of the electromechanical switching mechanisms 22 and the retardation of the lift cages A1, A2 by the stopping brakes thereof.

The roller 30 rotates after release thereof and in that case that part of the flexible element 24 substantially corresponding with the difference between the critical distance d_0 and the instantaneous spacing d_i of the lift cages A1, A2 is wound up. In this connection, however, the weighting body 23 does not have to be drawn upwardly. The winding-up torque exerted by the internal energy store 21 on the roller 30 thus has to exert on the flexible support element 24 a winding force which is less than the weight $G(23)$ of the weighting body 23, but greater than the weight $G(24)$ of the flexible support element 24, wherein the frictional forces also have to be taken into consideration.

The rotation of the roller 30 allows detection of the instantaneous movement state of the lift cages A1, A2 proceeding from the instantaneous angular speed ω_i and the instantaneous distance d_i between the lift cages A1 and A2. As soon as the roller 30 rotates, its angular speed ω_i , which is a function of time, is detected by an incremental transmitter 32. The instantaneous relative speed $v_i(\text{rel})$ of the lift cages A1, A2 can then be ascertained from this angular speed ω_i . The instantaneous distance d_i between the lift cages A1, A2 can then be similarly ascertained, either by means of a travel measuring sensor 35 or in computerised manner with utilisation of the instantaneous angular speed ω_i of the roller 30. Subsequently, it is clarified with consideration of the thus-ascertained movement state and the emergency stop criteria whether an additional retardation of one or both lift cages A1, A2 is to be triggered by the cage brakes thereof.

How this can be realised is explained by way of example in the following.

The following symbols are used:

d_0	critical distance (maximum detection distance)
d_i	instantaneous distance of the lift cages A1, A2
ω_i	instantaneous angular speed of the roller 30
$v_i(\text{rel})$	instantaneous relative speed of the lift cages A1, A2
v_i	instantaneous speed of one of the lift cages
$v_i(A1)$	instantaneous speed of the upper lift cage A1
$v_i(A2)$	instantaneous speed of the lower lift cage A2
$a(\text{min})$	minimum attainable retardation in an emergency stop
$s_{\text{stop}}(\text{min})\text{I}$	minimum stopping distance if only one lift cage A1 or A2 is in motion (i.e. if $v_i(\text{rel}) = v_i \text{ actual}$)
$s_{\text{stop}}(\text{min})\text{II}$	minimum stopping distance if both lift cages A1 and A2 are in motion (i.e. if $(v(\text{rel})/2) = v_i \text{ actual}$)

In addition, the following assumptions or rules apply:

If in the context of the present description both lift cages A1 and A2 are moving, then they approach at the same speeds $v_i(A1) \approx v_i(A2)$, wherein $v_i(A1)$ and $v_i(A2)$ are absolute values.

If a contact switch 34 of the safety circuit of the lower lift cage A2 is open and/or the instantaneous distance d_i between the lift cages A1 and A2 is less than the critical distance d_0 , then a retardation of each moved lift cage A1, A2 takes place through retardation by means of the stopping brakes thereof.

Emergency stop criteria

An emergency stop or a braking by one or both cage brakes is triggered, additionally to braking by the stopping brakes, if one of the following two emergency stop criteria is fulfilled:

Emergency stop criterion A: If a lift cage A1 or A2 is moving and the instantaneous

distance d_i between the cages A1 and A2 is less than or equal to the corresponding minimum stopping distance $s_{stop}(min)I$ then braking is triggered by the cage brake of the moving lift cage A1 or A2.

Emergency-stop criterion B: If both lift cages are moving and the instantaneous distance d_i between the lift cages A1 and A2 is less than or equal to the corresponding minimum stopping distance $s_{stop}(min)II$ then retardation is triggered by cage brakes of both lift cages A1 and A2.

For ascertaining the movement state and comparison with the emergency stop criteria, the following are detected or calculated:

By measurement: Is one cage not in motion?
 Is contact 34 of the safety circuit of the lower lift cage A2 open?

Through calculations: $v_i(A1) = v_i(A2) = v_i = 0.5 v_i(rel)$
 $s_{stop}(min)I = (v_i(rel))^2 / (2 * a(min))$

$$s_{stop}(min)II = (0.5 v_i(rel))^2 / (2 * a(min))$$

Fig. 3 shows a diagram by which the sequence of the entire braking process is explained by way of example with use not only of the stopping brakes, but also of the cage brakes.

Field F1 shows measured or available values, namely

$v_i(rel)$; d_i ; $v_i(1)$; $v_i(2)$; setting of the contact 34;

After these values are available, question A1 takes place.

It is ascertained by question Q1 whether the contact 34 may be open and/or $d_i < d_0$.

If question Q1 is answered by no N, then obviously no braking, neither by the stopping brakes nor by the cage brakes, is required.

If question Q1 is answered by yes Y, then according to field F2 triggering of the stopping brakes takes place, i.e. the emergency stop system is not caused to trigger an additional

braking by the cage brakes.

Then it is ascertained by question Q2 whether both lift cages are in motion.

If question Q2 is answered by no N, thus only one of the lift cages is in motion, then question Q3 is set.

By question Q3 it is ascertained whether d_i may be equal to or even smaller than $s_{stop(min)}$.

If question Q3 is answered by yes Y, thus the minimum stopping distance for this case is reached or exceeded, then according to field F3 an additional retardation by the corresponding cage brake takes place for an emergency stop.

If question Q3 is answered by no N, then a further question Q4 takes place.

It is clarified by question Q4 whether the relative speed of the lift cages may be zero.

If question Q4 is answered by yes Y, then this can only mean that now both cages are no longer in motion, because according to field F2 the stopping brakes are triggered and according to answer no N to question Q2 only one lift cage A1 or A2 is in motion. According to field F4 no further braking by use of cage brakes is then required, since obviously the braking action of the stopping brake has sufficed.

If question Q4 is answered by no N, then question Q2 is posed again.

If question Q2 is answered by yes Y, thus both lift cages A1 and A2 are in motion, then subsequently question Q5 is posed.

It is clarified by question Q5 whether d_i is the same as or even smaller than $s_{stop(min)}$.

If question Q5 is answered by no N, then question Q4 is posed for further clarification, i.e. it is clarified by question Q4 whether the relative speed $v_i(rel)$ of the lift cages A1, A2 may be zero. If this is the case, then according to field F4 no additional braking by cage brakes is necessary.

If, thereagainst, question Q5 is answered by yes y, then according to field F3 an additional braking by the cage brakes for an emergency stop takes place.

If more than two lift cages move in the same lift shaft 11, then an appropriate emergency stop system can also be fitted between these lift cages.

A currently particularly preferred form of embodiment of a significant part of the emergency stop system 21 is shown in Fig. 4. The roller 30 on which the support means 24 is wound up when it is not loaded by the weighting force of the weighting body 23 suspended thereat can be seen. Seated on the same shaft 42 as the roller 30 is a spring drive 31 which is here also termed energy store. An incremental transmitter 32 is attached by way of a coupling 40. A connection takes place by way of an adapter 41.

Patent Claims

1. Method of preventing collision of two lift cages (A1, A2), which move substantially independently of one another in a common shaft (11), of a lift installation (10), wherein a collision protection system (20) triggers a retardation of each moved lift cage (A1, A2) by a stopping brake when an effective distance (d_i) between the lift cages (A1, A2) falls below a critical minimum distance (d_k), characterised in that after triggering of the stopping brake an emergency stop system (21) is activated and that the emergency stop system (21)
 - ascertains, by means of a control system, instantaneous movement states of the lift cages (A1, A2) and
 - triggers, by means of cage brakes associated with the lift cages (A1, A2), an additional retardation of one or both lift cages (A1, A2) when the movement state thereof fulfils definable emergency stop criteria.
2. Method according to claim 1, characterised in that the emergency stop criteria are ascertained with consideration of the instantaneous movement states of the lift cages (A1, A2).
3. Method according to claim 1 or 2, characterised in that the control system for ascertaining the instantaneous movement states of the lift cages (A1, A2) repeatedly
 - detects the instantaneous relative speed ($v_i(\text{rel})$) of the lift cages (A1, A2) and
 - with consideration of the instantaneous relative speed ($v_i(\text{rel})$)
 - ascertains instantaneous effective distance (d_i) between the lift cages (A1, A2),
 - ascertains as emergency stop criteria an instantaneous minimum emergency stopping distance ($s_{\text{stop}}(\text{min})$ I, $s_{\text{stop}}(\text{min})$ II) and
 - ascertains whether the instantaneous effective distance (d_i) is smaller than or equal to the instantaneous minimum stopping distance ($s_{\text{stop}}(\text{min})$ I, $s_{\text{stop}}(\text{min})$ II) so as to then trigger the cage brake of each moved lift cage (A1, A2).
4. Method according to claim 3, characterised in that the control system detects the relative speed ($v_i(\text{rel})$) of the lift cages (A1, A2) in that a rotational frequency (ω_i) of a roller (30), which is fastened to the upper lift cage (A1) and on which is wound up a flexible support element (24) having an unwound length substantially corresponding with the

critical minimum distance (d_0), when on falling below of the minimum distance (d_0) a weighting body (23) impinges on the lower lift cage (A2) and in that case releases the roller (30) for rotation.

5. Method according to claim 4, characterised in that

- a tension force (G) exerted by the weighting body (23) on the support element (24) secures the roller (30) against rotation thereof before the weighting body (23) impinges on the lower lift cage (A2) and
- the roller (30) is released for rotation when the tension force (G) exerted by the weighting body (23) on the support element (24) ceases when the weighting body (23) impinges on the lower lift cage (a2).

6. Lift installation (10) with at least one upper lift cage (A1) and at least one lower lift cage (A2), which in normal operation of the lift installation (2) are vertically movable independently of one another in a common shaft (11), wherein

- the upper lift cage (A1) has a first driving and braking system with a first stopping brake and
- the lower lift cage (A2) has a second driving and braking system with a second stopping brake and wherein
- a collision protection system (20) is provided, by which triggering of the stopping brakes can be initiated when an instantaneous distance (d_i) between the lift cages (A1, A2) is less than a critical minimum distance (d_0), characterised in that an emergency stop system (21) is provided
- with a control system which is activated after triggering of the stopping brake and by which the instantaneous movement state of the lift cages (A1, A2) is detectable in the case of a further falling below of the minimum distance (d_0) after triggering of the stopping brakes and emergency stop criteria are ascertainable and
- with a first cage brake for the upper lift cage (A1) and a second cage brake for the lower lift cage (A2), wherein one or both cage brakes can be triggered when the emergency stop criteria are fulfilled.

7. Lift system (10) according to claim 6, characterised in that the control system for detecting the instantaneous movement state of the lift cages (A1, A2) after triggering of the holding brakes comprises:

- means for determining the instantaneous effective distance (d_i) between the lift cages (A1, A2),
- means for determining the relative speed ($v_{i(rel)}$) of the lift cages (A1, A2),
- means for determining the minimum stopping distance of the lift cages (A1, A2) with consideration of the relative speed of the lift cages (A1, A2),
- means for comparing the instantaneous minimum stopping distance with the instantaneous effective distance and
- means for triggering the cage brake of each moved lift cage (A1, A2) when the effective distance is less than or equal to the minimum stopping distance.

8. Lift system (10) according to claim 7, characterised in that the means for determining the relative speed and the effective distance of the lift cages (A1, A2) comprise

- a flexible support element (24)
 - with a first end which is fixed to a roller (30) and can be wound up on this roller (30) and
 - with a second end to which a weighting body (23) is fastened,
 wherein the length of the flexible support element together with the weighting body (23) corresponds with the critical minimum distance, and wherein
- the roller (30)
 - is rotatably fastened to the upper lift cage (A1),
 - comprises an internal energy store (31) by which a winding force can be exerted on the roller (30) by which the roller can be set into rotation,
 - is coupled with means (32) for detecting its rotational frequency,
 - is blocked against rotation by a tension force, which is exerted by the weighting body (23) on the support element (24), when the distance between the lift cages (A1, A2) is greater than the critical minimum distance and
 - rotates under the winding force when the weighting body (23) has impinged on the lower lift cage (A2),
- and with means for calculating the relative speed and the effective distance from the rotational frequency of the roller (30).

9. Lift system (10) according to claim 6, characterised in that the collision protection system (20) comprises:

- a first safety circuit with a first electromechanical switching mechanism (21), by which the stopping brake of the first lift cage (A1) can be triggered, at the first lift cage (A1) and
- a second safety circuit with a second electromechanical switching mechanism (22), by which the stopping brake of the second lift cage (A2) can be triggered, at the second lift cage (A2),

wherein the first switching mechanism (21)

- comprises the support element and the weighting body (23),
- is held under the weight of the weighting body (23) in a travel setting and by which
- the first holding brake can be activated after impinging of the weighting body (23), and

wherein the second switching mechanism (22)

- is arranged below the weighting body (23),
- is held in a travel setting before the impinging of the latter and by which
- the second holding brake is activatable after impinging of the weighting body (23).