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(71) Applicant(s):
Converteam Ltd
(Incorporated in the United Kingdom)
Boughton Road, RUGBY, Warwickshire, CV21 1BU, United Kingdom

(72) Inventor(s):
Eric Anthony Lewis

(74) Agent and/or Address for Service:
Serjeants
25 The Crescent, King Street, LEICESTER, LE1 6RX, United Kingdom

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(56) Documents Cited:
GB 0641476 A **GB 0546572 A**
US 3968947 A **US 2666879 A**

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(54) Abstract Title: **Apparatus for accelerating and decelerating a trolley, or similar moving assembly**

(57) An apparatus for accelerating and decelerating a trolley 8 along a track that can be used as a catapult to launch aircraft and unmanned aerial vehicles (UAVs) from the deck 2 of a ship. The apparatus includes a linear motor having a stator assembly 3 and a reaction plate 10 attached to the trolley for accelerating the trolley 8 along the track in an accelerating direction. Return means is provided for decelerating the trolley 8 by absorbing and storing at least part of the kinetic energy of the trolley and reversing the direction of travel of the trolley by releasing the stored kinetic energy in such a way that the trolley travels back along the track in a return direction opposite to the accelerating direction.
The return means may include a spring.

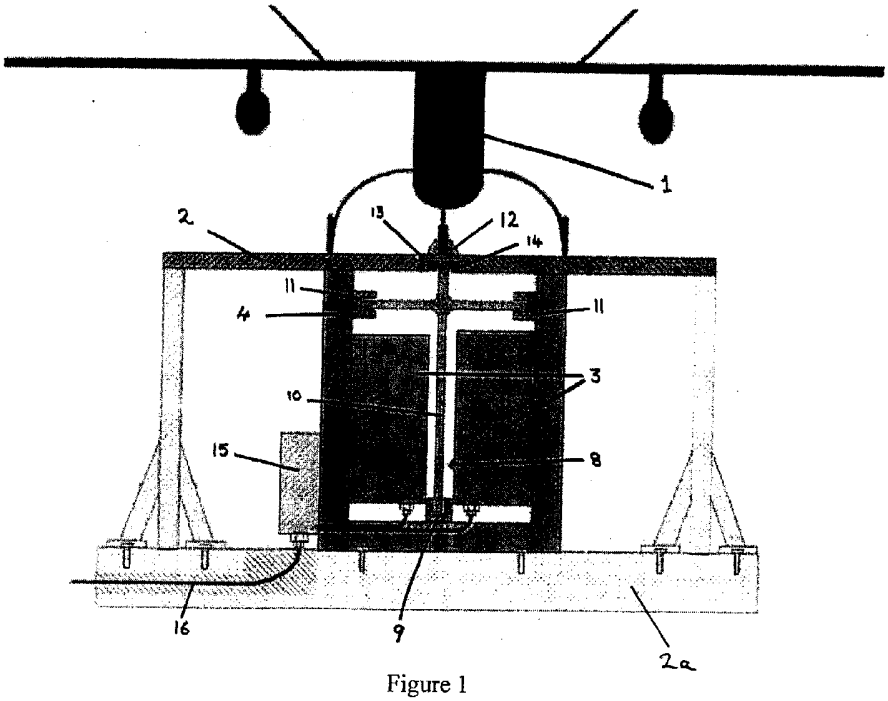

Figure 1

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patents Rules 1995

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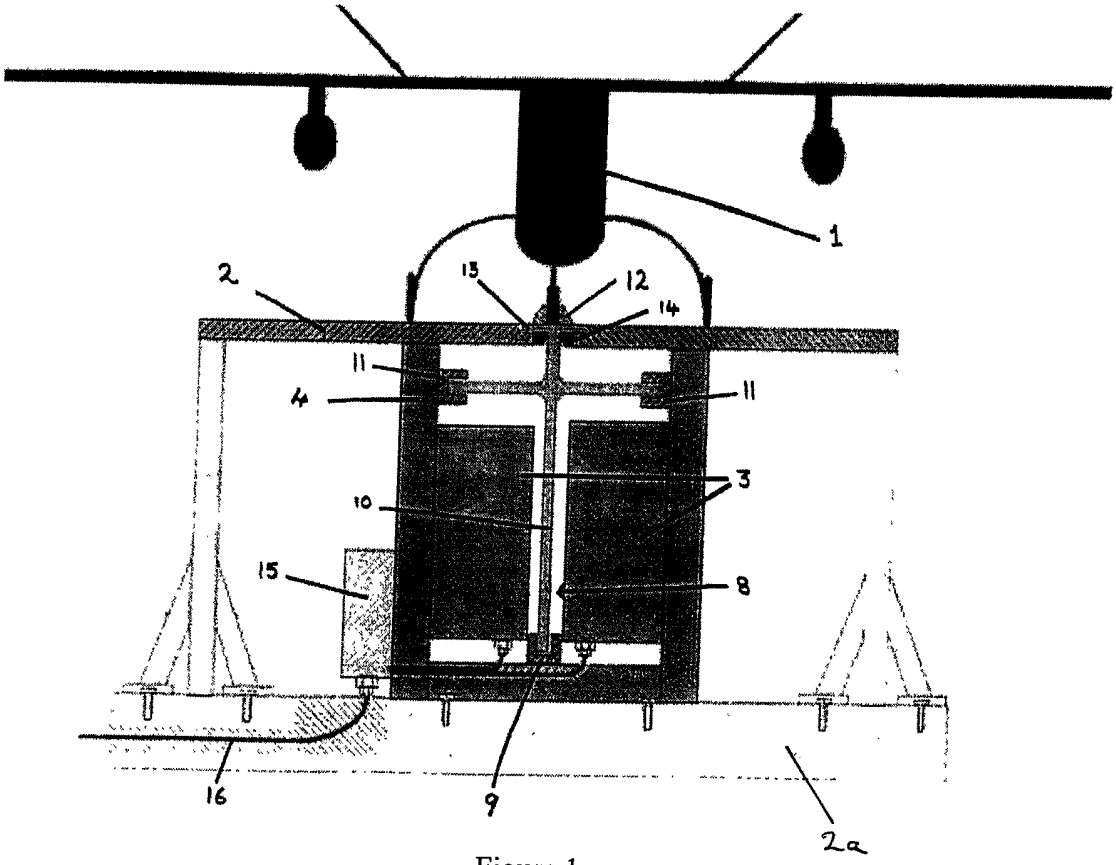

Figure 1

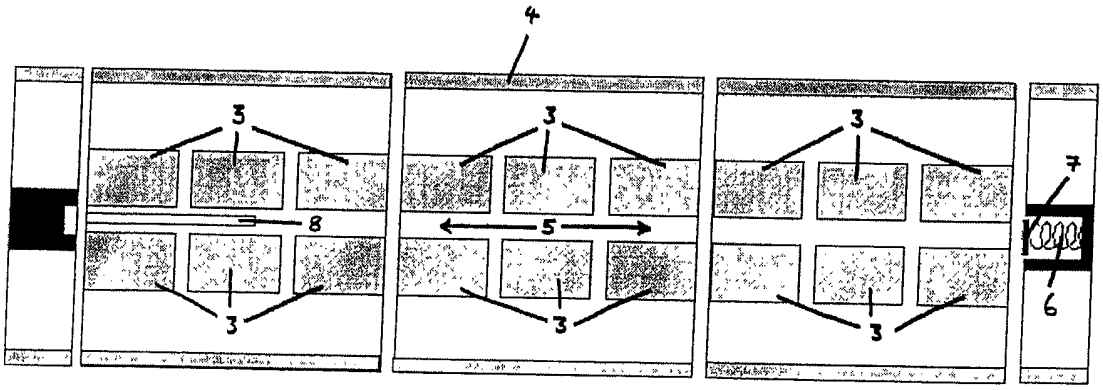

Figure 2

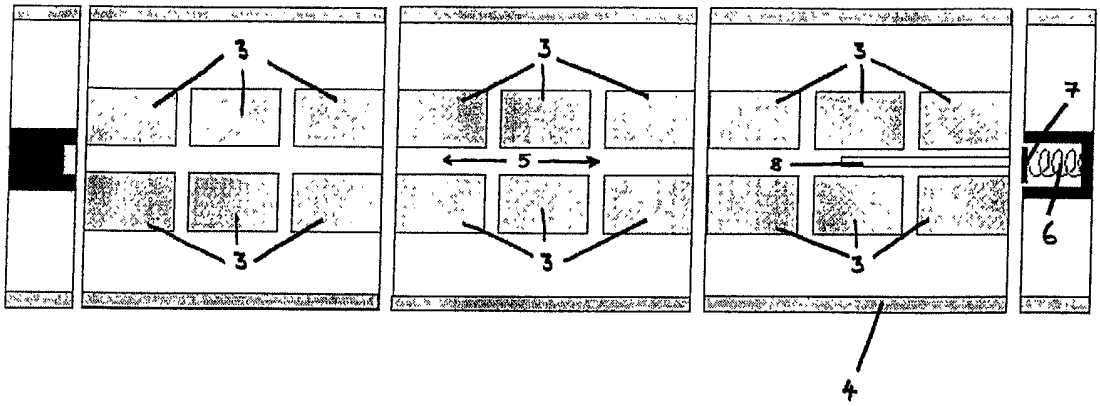

Figure 3

TITLE

Apparatus for accelerating and decelerating a trolley, or similar moving assembly

DESCRIPTION

Technical Field

The present invention relates to an apparatus for accelerating and decelerating a trolley, or a similar moving assembly, and in particular to an apparatus that can be used as a catapult system to launch an aircraft or unmanned aerial vehicle (UAV) from the deck of a ship by releasably securing the aircraft or UAV to the trolley and accelerating it along a track.

Background Art

Steam powered catapult systems for launching aircraft from the deck of a ship are well known. They typically include a trolley that runs along a straight track provided in the deck. The aircraft is releasably secured to the trolley, which is then accelerated along the track such that the aircraft reaches a very high velocity, for example 70 m/sec, over a relatively short distance, for example 150 m. At some point along the track, the aircraft is released from the trolley and is launched from the deck of the ship. The trolley must then be decelerated and this is typically achieved using a water brake. This means that the deck of the ship must accommodate both an acceleration distance and a deceleration distance. Although the deceleration distance is usually much shorter than the acceleration distance (because the weight of the trolley alone is only a small fraction of the combined weight of the trolley and the aircraft), it would still be advantageous if the deceleration distance could be reduced. This would lead to a corresponding reduction in the overall track length and allow aircraft or in the future unmanned aerial vehicles (UAVs) to be launched from a shorter deck. Alternatively, if the overall track length remained the same, a shorter deceleration distance would allow aircraft or UAVs to be accelerated more slowly or to a higher velocity. It would also allow heavier aircraft or UAVs to be launched from ships that would not normally have a long enough deck to accommodate them.

Some modern ships have electric propulsion systems and so there is no steam available to drive a conventional catapult system. Accordingly, there is a need for an alternative type of catapult system that relies on electrical power rather than steam, and in particular one that has a reduced deceleration distance.

One way of accelerating a trolley along a track is to use a linear motor. In fact, linear motors are often used to accelerate (and also in some cases decelerate) the passenger carriages of theme park rides and carriages that form part of crash test equipment. In a conventional linear motor (such as a single- or double-sided linear induction motor, for example) a reaction plate is accelerated along a stationary stator assembly by the force created in the reaction plate by the magnetic flux and the current flowing in the stator assembly. The reaction plate is normally secured to the trolley such that it extends down alongside the stator assembly. The stator assembly is normally powered from an ac supply network by a conventional variable frequency converter. Power can also be supplied back to the converter if the linear motor is used to decelerate the trolley. However, the trolley is often decelerated by providing a set of stationary permanent magnets that generate a braking force in the reaction plate as it passes through the magnetic field of the permanent magnets. The use of permanent magnets does not require any form of control and will decelerate the carriage even in the event of a power cut, for example. Other means must then be provided to return the trolley to its start position. In the case where the trolley is decelerated using stationary permanent magnets, the stator assembly of a secondary linear motor can be provided in parallel with the permanent magnets to move the trolley back along the track until the reaction plate is once again alongside the stator assembly of the linear motor used to accelerate the trolley in the accelerating direction. The linear motor can then be used in reverse to return the trolley to its start position by controlling the variable frequency converter system that is used to power the stator assembly.

Summary of Invention

The present invention provides an apparatus for accelerating and decelerating a trolley along a track, the apparatus comprising:

a linear motor having a stator assembly and a reaction plate attached to the trolley for accelerating the trolley along the track in an accelerating direction; and

return means for decelerating the trolley by absorbing and storing at least part of the kinetic energy of the trolley and reversing the direction of travel of the trolley by releasing the stored kinetic energy in such a way that the trolley travels back along the track in a return direction opposite to the accelerating direction.

The apparatus is particularly suitable for use as a catapult system that can be used to launch an aircraft or unmanned aerial vehicle (UAV) from the deck of a ship by releasably securing the aircraft or UAV to the trolley. However, it can be used for any similar mechanical application where a trolley (or the like) is accelerated along a track, decelerated and then sent back along the track in the opposite direction.

All pre-existing ways of decelerating a trolley that has been accelerated using a linear motor rely on the principle of absorbing all of the kinetic energy in the trolley so that it comes to a complete stop. In contrast to this, the apparatus converts at least part of the kinetic energy of the trolley into stored energy and then releases this to accelerate the trolley in the return direction. The return means can therefore be any component part or assembly that fulfils this requirement, such as a spring. The spring can be a coil spring (either compression or torsion) or an elastomeric spring made of rubber or plastics material, for example. The spring may act directly on the trolley or may be incorporated into an assembly such as a hydraulic or pneumatic piston and pressure vessel, for example. The part of the return means that comes into direct contact with the trolley may include a layer of rubber or some other elastomeric material to minimise the initial deceleration of the trolley on impact.

It will be readily appreciated that the amount of kinetic energy absorbed by the return means can be selectively varied to determine the velocity of the trolley in the return direction. For example, if the majority of the kinetic energy is absorbed by the return means then the acceleration of the trolley in the return direction will be fairly small. The reverse is true if very little of the kinetic energy is absorbed by the return means.

Once the trolley is moving in the return direction, the linear motor can be used to decelerate the trolley and bring it to a stop at its start position. In other words, the kinetic energy of the trolley can be absorbed by the linear motor and can be returned to the ac supply network through the variable frequency converter. This also has the effect of minimising the heat generated in the return means by dissipating it in the stator assembly and reaction plate of the linear motor.

The apparatus greatly reduces the distance needed to decelerate the trolley. In fact, in many cases the distance to reach full braking can be reduced to zero and where the apparatus is used as a catapult system the trolley can impact with the return means immediately after the aircraft or UAV has been launched. The reduction in the deceleration distance means that the overall length of the track can be reduced, with a corresponding reduction in weight and cost. This might allow a catapult system to be installed in a ship with a deck that would otherwise be too short for a conventional steam catapult. If the overall length of the track is kept the same, the reduction in the deceleration distance means that the trolley can be accelerated more slowly (reducing the stresses on the aircraft or UAV) or to a higher velocity. It would also allow heavier aircraft or UAVs to be launched.

The linear motor can be single- or double-sided. In other words, the linear motor may have a stator assembly that extends along one side of the reaction plate or the reaction plate can be sandwiched between a pair of parallel stator assemblies. Any suitable linear motor can be used. Alternatives include a linear induction motor where the reaction plate is made of copper, aluminium or any other suitable metal for example, a linear permanent magnet motor where the reaction plate is made of a magnetic material, or a linear synchronous motor with windings on the trolley.

The apparatus preferably further comprises a guiding mechanism for guiding the reaction plate and/or the trolley as it moves along the track.

If necessary, a return means may be provided at both ends of the track so that if the linear motor fails for any reason and is not able to decelerate the trolley as it moves

back along the track in the return direction, the trolley will eventually reach the end of the track where the return means will decelerate the trolley by absorbing and storing at least part of the kinetic energy of the trolley and reversing the direction of travel of the trolley by releasing the stored kinetic energy in such a way that the trolley travels back along the track in the accelerating direction. The trolley will then eventually come to a stop because of friction, windage and spring return losses.

The apparatus preferably further includes means for finally stopping the trolley, preferably but not exclusively using the same linear motor used to accelerate the trolley.

Drawings

Figure 1 shows a vertical cross section through a catapult assembly according to the present invention;

Figure 2 shows a horizontal cross section of the catapult assembly of Figure 1 with a trolley at its starting position; and

Figure 3 shows a horizontal cross section of the catapult assembly of Figure 1 with the trolley at its launch position and immediately before it impacts with the returning means.

A catapult assembly according to the present invention will now be described with reference to the attached drawings.

The catapult assembly of the present invention is installed just below the deck 2 of a launch assembly that is mounted above the deck 2a of a ship. The catapult assembly consists of a number of stationary stator assemblies 3 of a linear induction motor, fixed in pairs inside a stator frame 4 and positioned alongside a linear acceleration path 5 (i.e. the track along which an aircraft or UAV 1 will be accelerated). The linear induction motor is double-sided and each pair of stator assemblies 3 is positioned such that there is a stator assembly on either side of the linear acceleration path 5 and there is a small vertical planar gap between them for accommodating a reaction plate (see below). A returning means 6 including a compression spring is

fixed at the end of the acceleration path 5 towards which the aircraft or UAV 1 will be accelerated. The returning means 6 has a protective contacting surface 7 that faces the linear acceleration path 5 and protects the returning means from being damaged when it impacts with the trolley (see below).

A trolley 8 is fixed in position between the stator assemblies 3 of the linear induction motor in such a manner that it will be accelerated along the linear acceleration path 5 when the linear induction motor is operated. The trolley 8 is elongate and substantially cross-shaped in vertical cross section. The lower end of the trolley slidably rests in a vertical guide rail 9, which runs along the linear acceleration path 5 just below the stator assemblies 3. The lower vertical portion of the trolley 8 is substantially a reaction plate 10 made of a metallic material and which is accelerated by the stator assemblies 3 of the linear induction motor. The horizontal arms of the trolley 8 have ends that slidably rest in horizontal guide rails 11, which are fixed to the stator frame 4 just above the stator assemblies 3 and are parallel to the linear acceleration path 5. The trolley 8 has at its upper end a nose wheel attachment 12 fixed to the upper surface of a nose wheel support 13. The nose wheel support 13 supports the aircraft or UAV 1 as it is accelerated and is capable of quickly and automatically releasing the aircraft or UAV 1 when it reaches a predetermined launch point along the linear acceleration path 5. The nose wheel support 13 protrudes through a slot in the deck 2 of the ship such that the slot is aligned along the linear acceleration path 5 and is positioned directly above the stator frame 4. A deck seal 14 seals the deck 2 of the ship along the length of the linear acceleration path 5 and around the trolley 8. Terminal boxes 15 that control the linear motor are fixed to the outside of the stator frame 4 and are attached via electric wiring 16 to a converter (not shown), which in turn is attached to an ac power network (not shown) which supplies power to the stator assemblies 3.

When the trolley 8 is accelerated along the linear acceleration path 5 by the stator assemblies 3 of the linear induction motor, it is guided by the vertical guide rail 9, the horizontal guide rails 11 and the deck seal 14 in such a manner that it may only move linearly along the linear acceleration path 5 in an accelerating direction. When the

trolley 8 reaches the end of the linear acceleration path 5, it impacts against the contacting surface 7 of the returning means 6 and compresses the compression spring. Expansion of the compression spring then accelerates the trolley 8 back along the linear expansion path 5 in the opposite direction.

In order to launch an aircraft or UAV 1 the trolley 8 is positioned at its starting position, as shown in Figure 2. The aircraft or UAV 1 is attached, via its nose wheel, to the nose wheel attachment 12 of the trolley 8. The rear wheels of the aircraft rest on the deck 2 of the ship. The linear induction motor is then operated and the trolley 8 and aircraft or UAV 1 are accelerated along the linear acceleration path 5 by the stator assemblies 3. When the trolley 8 reaches the launch point, as shown in Figure 3, the aircraft or UAV 1 is released and is launched off the ship. Immediately after release, the trolley 8 comes into contact with the contacting surface 7 of the returning means 6 and is decelerated to a stop by the returning means 6. During this deceleration at least part of the kinetic energy of the trolley is stored as potential energy in the compression spring of the returning means 6 with the remainder being dissipated as other forms of energy. The stored potential energy is then returned, as kinetic energy, to the trolley 8 by the expansion of the compression spring and the trolley 8 is accelerated along the linear acceleration path 5 in a return direction back towards its starting position.

Preferably the movement of the trolley 8 to its starting position will be controlled by the stator assemblies 3 in such a manner that it returns back to, and stops at, its starting position. This may be achieved by using the stator assemblies 3 as a brake to decelerate the trolley by absorbing kinetic energy from the trolley 8 and directing power back to the ac supply network through the converter (not shown). However, if the kinetic energy returned to the trolley 8 by the compression spring of the returning means 6 is not sufficient to return it to its start position, then the stator assemblies 3 can be operated in reverse to move the trolley 8 back along the linear acceleration path 5.

CLAIMS

1. An apparatus for accelerating and decelerating a trolley along a track, the apparatus comprising:

a linear motor having a stator assembly and a reaction plate attached to the trolley for accelerating the trolley along the track in an accelerating direction; and

return means for decelerating the trolley by absorbing and storing at least part of the kinetic energy of the trolley and reversing the direction of travel of the trolley by releasing the stored kinetic energy in such a way that the trolley travels back along the track in a return direction opposite to the accelerating direction.

2. An apparatus according to claim 1, wherein the return system includes a spring.

3. An apparatus according to claim 2, wherein the spring is a coil spring.

4. An apparatus according to claim 2, wherein the spring is an elastomeric spring.

5. An apparatus according to claim 2, wherein the spring is a hydraulic spring.

6. An apparatus according to claim 2, wherein the spring is a pneumatic spring.

7. An apparatus according to any preceding claim, wherein the linear motor is single-sided.

8. An apparatus according to any of claims 1 to 6, wherein the linear motor is double-sided.

9. An apparatus according to any preceding claim, wherein the linear motor is a linear induction motor.

10. An apparatus according to any of claims 1 to 8, wherein the linear motor is a linear synchronous motor.

11. An apparatus according to any of claim 1 to 8, wherein the linear motor is a linear permanent magnet motor.

12. An apparatus according to any preceding claim, further comprising a guiding mechanism for guiding the reaction plate and/or the trolley as it moves along the track in the accelerating direction and the return direction.

13. An apparatus according to any preceding claim, wherein the linear motor is powered by a variable frequency converter.

14. An apparatus according to any preceding claim, further comprising means for stopping the trolley.

15. An apparatus according to claim 14, wherein the means for stopping the trolley is the linear motor.

16. An apparatus substantially as herein described and with reference to Figures 1 to 3.

INVESTOR IN PEOPLE

Application No:	GB 0502987.1	**Examiner:**	Carsten Nielsen
Claims searched:	1-16	**Date of search:**	11 July 2005

Patents Act 1977 : Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance	
Y	1-16	GB 0546572 A	(GILLESPIE CO) See column 1, line 11-16, column 2, line 62-77, column 3, line 38-49, column 7, line 53-60, and figures
Y	1-16	GB 0641476 A	(WESTINGHOUSE ELECTRIC INTERNATIONAL) See column 1, line 12-24, column 2, line 53-57, column 3, line 18-54, column 4, line 68-77, and figures
Y	1-16	US 2666879 A	(GODSEY et al) See column 1, line 1-21, column 3, line 12-18, column 5, line 11-17, and figures
Y	1-16	US 3968947 A	(SCHLEGEL et al) See Abstract and figures and column 2, line 58-61 and column 5, line 14-16

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art
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B64F, B64G, B64D, G01M, F41B, F41F, A63H, H02K

The following online and other databases have been used in the preparation of this search report:

WPI, EPODOC