NO PLUNGER SHAFT ELECTROMAGNET MOVING MAGNET LINEAR ACTUATOR

RELATED APPLICATIONS

[0001] This patent application is mainly related to earlier patent granted invention title: Levitation and Propulsion Unit (LPU), filed under PCT application PCT/SG2006/000055, filing dated 14 March 2006, and its related countries applications. PCT applications: Rapid Action Enabled and High Driving Force Electromagnet Moving Magnet Linear Actuator, PCT/SG2021/050132, filing date: 12 March 2021; Levitation and Propulsion Unit – Two (LPU-2), PCT/SG2021/050240, filing date: 30 March 2021; Levitation and Propulsion Unit – Four (LPU-4), PCT/SG2021/050397, filing date: 07 July 2021.

[0002] The patent granted invention title: Levitation and Propulsion Unit (LPU) is a thrust generating device as claimed to generate resultant force to create motion from centrifugal force and magnetic flux expansion without mass ejection and/or momentum exchange, unlike current propulsion technologies as in automobile, drone, airplane, helicopter, rocketry, train, boat, bicycle, scooter, wheelchair, or even walking.

[0003] The PCT application title: Rapid Action Enabled and High Driving Force Electromagnet Moving Magnet Linear Actuator is an electromagnet actuator device as claimed to enable rapid action and high driving force of actuator plunger to mainly meet invention, Levitation and Propulsion Unit (LPU) application requirements and other similar field device application requirements, or in electromagnet actuator application with similar requirements.

[0004] The PCT application title: Levitation and Propulsion Unit – Two (LPU-2) is an improved version of patent granted Levitation and Propulsion Unit (LPU) where there are lesser moving parts to generate resultant force or motion.

[0005] The PCT application title: Levitation and Propulsion Unit – Four (LPU-4) is an improved version of patent granted Levitation and Propulsion Unit (LPU) incorporating electromagnet actuator to generate resultant force or motion.

FIELD OF THE INVENTION

[0006] As stated in earlier PCT application under Rapid Action Enabled and High Driving Force Electromagnet Moving Magnet Linear Actuator, moving magnet actuator is a category of electromagnet linear actuator device to use in earlier invention, Levitation and Propulsion Unit (LPU), other LPU's inventions and other similar field of device. Electromagnet linear actuator device is a direct drive device, and widely used in range of applications mainly for control and switching functions and others, including riveting, hammering, disk drives, automotive valves, vibration isolators, hole punchers,

electrical relay devices, etc. There are many embodiments and size of electromagnet linear actuator to meet certain application requirements as reflected in following prior arts, example: US patent 10326349B2, US patent 6043730, US7128032B2 and US patent 10365124B2. The basic composition of such linear actuator comprises mainly of a stator coil or series of stator coils and a ferrous/ferromagnetic material on moving armature/plunger, or magnets on moving armature/plunger within and facing the stator coils – as in US patent 7989994B2, US patent 7128032B2 and US patent 6756705. Other configuration like in US patent 4318038, US patent 5345206 and US patent 5768395, where the stator comprises of permanent magnets and the coil on moving armature/plunger. The main advantages of electromagnet linear actuators are: it's simple design, enable duo directional armature/plunger action, relative fast response, high linear acceleration and a low maintenance cost. The main drawbacks are: hysteresis in ferrous material used, low energy efficiency, and need high impulse current to coil to meet armature/plunger acceleration and thrust requirement, which lead to high heat from coil.

BACKGROUND OF INVENTION

[0007] This No Plunger Shaft Electromagnet Moving Magnet Linear Actuator invention as illustrated in drawings, is an improvement to earlier version of PCT application PCT/SG2021/050132 of title: Rapid action enabled and high driving force electromagnet moving magnet linear actuator invention. In which this electromagnet actuator invention there is no physical plunger shaft in the device. It leverages the high density magnetic repulsive flux between the two repelling magnets in the electromagnet device as the medium for force transmission instead of a physical medium – a plunger shaft. This is mainly to meet the need for:

1. compactness;
2. simplicity;
3. less weight,
4. scalability;
5. no friction between plunger shaft and stator inner wall, and

still enable rapid action and high driving force cycle, in the electromagnet actuator for inertia propulsion application requirement, for similar field device requirement, or for different field device with similar requirement.

BRIEF SUMMARY OF THE INVENTION

[0008] This preferred embodiment-1, fig-1 & fig-8, the electromagnet moving magnet linear actuator invention, the design mainly incorporate no plunger shaft, used high flux

density permanent magnets at magnet 06 and 10 with same polarity facing each other at both ends or near ends of the stator coil 08, no plunger shaft connects the magnet 06 and magnet 10, and stator 09 and casement member 14 are of non-ferrous material like aluminum, titanium, stainless steel, brass, polymer, alloy, composite, plastic, ceramic or likewise materials, to mainly reduce hysteresis issue to lower system latency.

[0009] This preferred embodiment-1, fig-1 & fig-8, of no plunger shaft electromagnet actuator invention comprises mainly of two main components:

a) a stator coil assembly, fig-2, a fixed main component to secure to application - its basic function to generate magnetic flux; and
b) two moving magnets with no plunger shaft, a movable main component - its basic function to deliver or receive force within the application.

[0010] The novelty and main differentiating features in preferred embodiment-1, fig-1 & fig-8, of this no plunger shaft electromagnet moving magnet linear actuator invention compare to earlier stated prior arts of electromagnet moving magnet linear actuators like US patent 7989994B2, US patent 7128032B2, US patent 6756705, and PCT application PCT/SG2021/050132, prior art search of US2014/0111035A1 & CN2416578Y are:

A) No plunger shaft between the two magnets in the electromagnet actuator device;

B) At the two magnets, in which magnet 10 is arranged at one end or near end, and the other magnet 06 at the other end or outside the stator coil 08, and each magnet of different size and strength;

C) The two magnets of high flux density permanent magnets arranged with same pole facing each other at both ends of stator coil – see fig-1. This enables very effective use of both attraction and repulsion forces at the same time from one energized stator coil 08 with the two magnets, even without the plunger shaft. This can enable relatively smaller stator coil size, lesser current input to coil and less heat from coil, hence lesser or any opposing coil field at return or upward phase of cycle, to enable rapid action;

D) Only magnet 10 can move within the stator and magnet 06 cannot move within the stator;

E) The size of magnet 06 is arranged wider than the stator coil opening to interact more effectively with energized stator coil flux in application;

F) The compressed magnetic repulsive flux zone 05 in application is a biased force to hold magnet 06 and magnet 10 at default position, even without a plunger shaft, and it enhance the actuator rapid action.

BRIEF DESCRIPTION OF THE VIEWS OF THE DRAWING

[0011] The following drawings are for illustration only. Each drawing mainly to show the main components layout to each other to support related description. The construction, size, configuration and composition of each component can differ in product to meet component constrains, application constrains, and/or further outlines described in various embodiments.

[0012] Fig-1: Sectional view illustration only of the no plunger shaft electromagnet moving magnet linear actuator assembly wherein it comprises mainly of two magnets – magnet 10 and magnet 06, with same polarity facing each other at ends of the stator coil assembly fig-2, to create the magnetic repulsive flux zone 39 within the stator. Other parts are: a centrally arranged guiding shaft 04 (optional component), impact element 22, casement plate 14, stator 09, stator coil 08, packing element 20, spacer member 16 and bracing member 15. The view includes a magnet 25 component in which it is not part of the device invention but a component in the application of the device to create the magnet repulsive flux zone 05. This drawing indicates a possible device interfacing approach with the application component needed to meet the device application requirement.

[0013] Fig-2: Sectional view illustration only of a typical cylindrical profile of stator assembly and its plan view illustration. It mainly comprises of stator coil 08, stator 09, spacer member 16, casement members 14 and bracing member 15.

[0014] Fig-3: Sectional view illustration only of similar view at fig-1, in which include magnet 23 to magnet 06.

[0015] Fig-4: Sectional view illustration only of similar view at fig-1, in which include magnet 23.

[0016] Fig-4a: Sectional view illustration only of similar view at fig-1, in which reflects magnet 23 possible position and possible magnet 25 of application component.

[0017] Fig-5: Sectional view illustration only of similar view at fig-1, in which reflects magnet 23 possible position and possible magnet 25 of application component.

[0018] Fig-5a: Sectional view illustration only of similar view at fig-1, in which reflects magnet 23 possible position and possible magnet 25 of application component.

[0019] Fig-6: Sectional view illustration only of similar view at fig-1, in which reflects magnet 23 possible position and possible magnet 25 of application component.

[0020] Fig-6a: Sectional view illustration only of similar view at fig-1, in which reflects magnet 23 possible position and possible magnet 25 of application component.

[0021] Fig-7 & 7a: Sectional view illustration only of similar view at fig-1, in which illustrate the device in a scaled down configuration, reflecting magnet 23 possible position and possible magnet 25 of application component.

[0022] Fig-8 & 8a: Sectional view illustration only of similar view at fig-1, in which illustrate the device in a scaled down configuration, reflecting magnet 06 possible position and possible magnet 25 of application component.

DETAILED DESCRIPTION OF THE INVENTION

[0023] The basic structure of an electromagnet actuator involves a plunger shaft or an armature to secure the magnets within the stator coil. The plunger shaft or armature act as a physical mechanical component to secure the magnets or other components in position within the stator. It is also the main component for force transmission in an electromagnet actuator device and with its application. The plunger shaft also needs support component like bearing at ends of stator to ensure alignment which entails bearing housing, etc. This common type of electromagnet actuator configuration may not meet the finer needs of new application requirements.

[0024] This No plunger shaft electromagnet actuator is a moving magnet linear actuator, without the plunger shaft to secure the magnets within the stator coil. The magnets are secured in position by the two magnets - magnet 10 & magnet 06, arranged with same polarity facing each other which creates the magnetic repulsive flux zone 39 within the stator to force the magnet to each end of the stator. Wherein the magnet 10 is resisted from further movement by the device casement plate 14 and magnet 06 is resisted by the magnetic repulsive flux zone 05 – see fig-1 & fig-8. This arrangement allows reduction in device overall weight and remove the plunger shaft material properties consideration affecting device rapid cycle, like hysteresis, flux interference between coil and magnets, friction between plunger shaft and stator inner wall, its effect on the device center of gravity and etc.

[0025] The magnetic repulsive flux between the magnet 10 and magnet 06 and/or magnet 23 serve the function of the missing plunger shaft in the actuator. Therefore, the magnetic flux strength and density at magnet 10 and magnet 06 and/or magnet 23 need to create an adequate magnetic repulsive flux strength to push each other apart within

the stator at default position. This high density magnetic repulsive flux between the two repelling magnets also enhanced the device rapid cycle action.

[0026] This electromagnet actuator configuration is mainly to meet the need for compactness, simplicity, scalability and lesser weight device, in the electromagnet actuator for inertia propulsion application requirement.

[0027] In this preferred embodiment-1, the electromagnet moving magnet linear actuator design, reflected at fig-1, similarly leverages on:

1) High flux density magnet at magnet 06 and 10, - to relatively reduce current in coil to induce action;
2) Arrangement of permanent magnets at magnet 06 and 10 at both ends of a coil leverages the two areas of highest concentration of magnetic flux of both energized coil and permanent magnets, - to enable rapid action;
3) Both permanent magnets 06 and 10 orientated with same polarity facing each other with stator coil in-between. This creates focused attraction effect at one end of the energized coil and focused repulsion effect at the other end of energized coil, - this duo effects further enables rapid action.
4) Incorporation of non-ferrous materials at 04, 09, 14, 15, 16, 20 and 22 to overcome conventional electromagnet actuator drawbacks related to hysteresis, - to reduce hysteresis issue to enable further rapid action.

[0028] Application of this No plunger shaft electromagnet moving magnet linear actuator is mainly in inertia propulsion devices and in similar field device, or in different field device application with similar requirement. The size of each main component is scalable to meet application requirement. Similarly, the design of this no plunger shaft electromagnet actuator and its embodiments is scalable, apply in one unit or in combination of more than one device unit to meet application requirements. Its usage is mainly in lifting function and in people mobility on Earth and in Space.

[0029] Other embodiments of this No plunger shaft electromagnet moving magnet linear actuator invention design are:

Embodiment-2: include preferred embodiment-1, wherein include magnet 23 to magnet 06 to enhance or improve magnet 06 magnetic flux configuration – see fig-3 for illustration.

Embodiment-3: include preferred embodiment-1 or embodiment-2, wherein there is no magnet 06 – see fig-4, 4a, 5, 5a, 6, 6a and fig-7 for illustration

Embodiment-4: include embodiment-3, wherein magnet 10, magnet 23 or magnet 06 is arranged at end, near end, within or outside of stator coil 08.

Embodiment-5: include preferred embodiment-1 to embodiment-4, wherein there is no centrally arranged guiding shaft 04.

Embodiment-6: include preferred embodiment-1 to embodiment-5, wherein it comprises more than one individual control coil on stator to enable control and/or tracking of plunger travel via systematic energizing and sensing of each coil or coils.

Embodiment-7: include embodiment-6, wherein the stator comprises one or more magnets.

Embodiment-8: include preferred embodiment-1 to embodiment-7, wherein magnet 06 and/or magnet 23 comprises of one or more magnets of flux coupling or locking profile or to create a magnetic repulsive flux coupling or locking profile to the application magnet 25. Where the magnet can be bar magnet, disc magnet, ring magnet, array of magnets, Halbach magnet, composite of magnets, and/or electromagnet.

Embodiment-9: include embodiment-1 and embodiment-2, wherein there is no magnet 10.

Embodiment-10: include embodiment-8, wherein magnet 10 is of magnet profile to create a magnetic repulsive flux coupling or locking with magnet 23 and/or magnet 06.

Embodiment-11: include embodiment-1 to embodiment-10, wherein the magnet 10, magnet 06 and/or magnet 23 comprises of high-density permanent magnet in profile of bar magnet, ring magnet, other profile permanent magnet, array of magnets, Halbach magnet or composite of magnets and/or other materials, to meet application, or not high-density permanent magnet to meet application.

Embodiment-12: include Embodiment-11, wherein the electromagnet actuator comprises of main components stator coil 08 with or without the stator 09 and the two magnets – magnet 10 & magnet 06 and/or magnet 23, with or without centrally arranged guiding shaft, in which the main components are incorporated into the application.

Embodiment-13: include Embodiment -11, wherein the material of stator, guiding shaft and/or casement member of ferrous and/or non-ferrous material to meet application requirement.

CLAIMS

1. A thrust generating electromagnet actuator device in the field of inertia propulsion able to generate a rapid action and high driving force comprising:
   a stator;
   a stator coil;
   and two magnets;
   where each magnet is arranged with same polarity facing each other;
   where one magnet is arranged at one end, near end or within the stator coil and the other magnet arranged at the other end or outside of the stator coil;
   where the stator coil is arranged for exerting a magnetic field on the two magnets;
   where one magnet can travel in the stator and the second magnet cannot travel in the stator;
   whereby the thrust generating electromagnet actuator device is capable of delivering a force or receiving a force.

2. A device as claimed in claim-1, wherein there are more than two magnets.

3. A device as claimed in claim-1, wherein there is one magnet.

4. A device as claimed in claim-1, claim-2 or claim-3, wherein the stator is arranged to hold more than one stator coil.

5. A device as claimed in claim-1, claim-2 or claim-3, wherein the stator is arranged to include one or more magnet.

6. A device as claimed in claim-1, claim-2 or claim-3, wherein one or more magnet of high flux density permanent magnet in profile of bar magnet, disc magnet, ring magnet, array of magnets, Halbach magnet, composite of magnets, and/or electromagnet, or not of high flux density magnet.

7. A device as claimed in claim-1, claim-2 or claim-3, wherein the electromagnet device, the stator and the magnet not of cylinder/round profile.

8. A device as claimed in claim-1, claim-2 or claim-3, wherein the two magnets of different size.

9. A device as claimed in claim-1, claim-2 or claim-3, wherein the material of stator and casement plate of ferrous and/or non-ferrous material.

10. A device as claimed in claim-1, claim-2 or claim-3, wherein there is no stator.

11. A device as claimed in claim-1, claim-2 or claim-3, where the two repelling magnets at the stator coil can move within the stator.

12. A device as claimed in claim-1, claim-2 or claim-3, wherein there is a centrally arranged guiding shaft.

13. A thrust generating electromagnet actuator as claimed in claim-1, claim-2 or claim-3, wherein it is not used in the field of inertia propulsion.