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(54) **SUSPENDED PAYLOAD PLATFORM THRUSTED BY FLUID MASS FLOW GENERATORS**

MITTELS FLÜSSIGKEITSMASSENFLUSSGENERATOREN VORGETRIEBENE AUFGEHÄNGTE
NUTZLASTPLATTFORM

PLATEFORME POUR CHARGE UTILE SUSPENDUE UTILISANT LA POUSSÉE PRODUITE PAR
DES GÉNÉRATEURS DE FLUX DE MASSES FLUIDES

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Description

TECHNICAL FIELD

[0001] The present invention relates to thrusting a payload platform suspended like a pendulum on a single cable or on parallel cables attached to a supporting element. The pendulum like suspension system may include complex multi-body or multi-cable sections but at least one section of it is limited to a single cable or parallel cables. In particular, and not by way of limitation, the present invention is directed to thrusting a payload platform of an aerial tethered robot or a suspended rescue system or a crane system.

BACKGROUND

[0002] The concept of the aerial tethered system was inspired by deep sea marine robotics where a host ship uses a tethered robot to survey the site of a shipwreck and deploy tiny robotic agents from the tethered robot into an opening within the sunken vessel. This concept was applied to aerial systems.

[0003] In US-2007200027 patent publication an aerial robot is disclosed. The aerial robot may include at least one pair of counter-rotating blades or propellers, which may be contained within a circumferential shroud or a duct. The aerial robot may have the ability to hover and move indefinitely getting the electric power through a tether anchoring the robot to a ground station. The robot is suitable for remote observation, environment detection, communication, but due to the lifting force powered by fans not suitable for carrying heavy payloads.

[0004] A design of a tethered aerial robot is presented by P. J. McKerrow and D. Ratner originally published as: McKerrow, PJM & Ratner, D, The design of a tethered aerial robot, IEEE International Conference on Robotics and Automation 2007, Rome, Italy, 10-14 April 2007, 355-360. Copyright 2007 IEEE; in which the concept of a tethered aerial robot swinging on the end of a tether is described. In this approach the weight of the robot is carried by the tether and the thrusting force is generated by two fans with parallel axis. The critical issue in such suspended systems is the under-actuation of the suspended payload. The two ducted fans with parallel axes can only provide a one-directional thrust force and a resulting moment acting upon the suspended payload as independent control inputs. Thus, the number of actuators is lower than the degrees of freedom of the suspended payload.

[0005] However the problem mentioned above can be extended to any payload platform suspended like a pendulum on single cable or on parallel cables and actuated by thrusting forces irrespective of the application in the technology, i.e., a suspended payload platform can be a part of a robotic system or that of a crane structure as well.

[0006] Pendulum-like suspension systems that include single or parallel cables do not allow the actuation of the payload platform through the cables only. The re-

quired position and orientation of the payload can only be provided with the use of additional actuators, because of the pendulum-like behavior of these systems.

[0007] We have set ourselves the objective with this invention to improve the thrusting of suspended payload platforms.

[0008] Document EP 0 806 775 A1 relates to a method for movement correction and positioning of a suspension device. A correction device is arranged at the second end of the suspension device adapted to generate a force which provides acceleration in a fluid such that the position of the second end of the suspension device is corrected. The correction device is furnished with correction members (14, 16) that can be either propeller device (14) or nozzle means (16) for generating the force. In one embodiment two correction members (14, 18) (Fig. 2), in other embodiments (Fig 3 and 4) three or four correction members (14, 16) are used that are rotatable up to 360°. By use of rotatable correction members, force with any kind of horizontal direction can be applied, although direction of force generated by the correction members have to be controlled by e.g. a joystick (17).

[0009] Document GB 2 141 088 A relates to an aerial load-lifting system in which the weight of a load is balanced by a lighter-than-air (LTA) unit (1) and the horizontal movement is provided by a helicopter unit (2) and/or a VTOL airplane unit. Rotating of the payload around the vertical axis is not controlled at all it can turn around freely therefore the system is not suitable for orientating a payload.

[0010] Although in one embodiment of the document the helicopter units are multiplied (Fig. 13), the orientation of the payload is not provided.

SUMMARY

[0011] The present invention involves a new system which solves the aforementioned problems, as well as other problems that will become apparent from an understanding of the following description.

[0012] The invention is based on the recognition that a payload platform suspended like a pendulum on single or parallel cables can only be controlled with serious limitations by a single direction thrust force or a pair of thrust forces. So the object of the invention is to provide a system of thrust forces of fluid mass flows for moving a payload platform the weight of which is compensated by pendulum-like single or parallel suspending cables attached to a suspending element. In the system of thrust forces the fluid mass flows are generated by at least six fluid mass flow generators each of them providing a force vector.

[0013] Fluid mass flow generator is a system that determines the magnitude and the direction of the thrust force vector produced by emission of fluid or solid body particles. In particular, and not by way of limitation, fluid mass flow can be made by an axial or radial fan without or within a tube, nozzle with routed fluid mass flow from

an external or on board compressor, nozzle with routed fluid mass flow from an external or on board fluid bottle, fluid storage tank. In particular, and not by way of limitation, for vectoring, including the reversing of the thrust produced by the previously listed systems, the source of thrust can be turned, deflectors including slewable nozzles or controlled valves can be used at the inlet (s) or outlet (s) of the source of the fluid mass flow, and variable blade pitch impellers can be applied.

[0014] In a possible embodiment, a six fluid mass flow generator based design is described.

[0015] In possible embodiments the fluid mass flow generators are fans, preferably ducted fans provided with reversible blade pitch impellers.

[0016] With six mass flow generators, six lines of action of the thrust force vectors are coplanar, or are grouped into three pairs of parallel lines of action thrust force vectors that can be axis-symmetrical to the bisectors of an equilateral triangle.

[0017] The most important advantage of the invention is that the payload platform suspended like a pendulum on single or parallel cables is fully actuated.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] In the following, the essential features of the invention will be described in detail by showing two preferred embodiments, with reference to the figures of the attached drawing.

FIGURE 1 shows a simplified model of the pendulum-like suspended payload platform.

FIGURES 2/a, 2/b, 2/c and 2/d present concepts for pendulum-like single and parallel cable based suspending systems.

FIGURE 3/b shows an arrangement of fluid mass flow generators (for simplicity modeled by ducted fans) and the supplied thrust force for six fluid mass flow generators.

FIGURE 4 shows a possible embodiment of a six fluid mass flow generator based design.

DETAILED DESCRIPTION

[0019] As it is seen in FIGURE 1, the main operating functions that the pendulum-like suspended payload platform PP should provide are: compensating for the gravity by using single or parallel cables attached to the supporting element SE, and making thrust for controlling the position and orientation of the payload PL.

[0020] The swinging out of the payload is described by the nutation angle, while its polar displacement is described by the precession angle. In addition, turning the payload is characterized by the rotation angle about an axis fixed to the payload. The roll and pitch of the payload,

e.g., and not by way of limitation, is to be set by additional fluid mass flow generators or by using windable orienting cables.

[0021] The detailed analysis of the engineering systems and physical processes that fit the requirements has resulted in the mechanical and control related design principles for generating concepts for the pendulum-like suspended payload platform. It was found that for full actuation of the nutation, precession and rotation of the payload, a possible solution is the use of fluid mass flow generators such as ducted fans. In addition, it was concluded that auxiliary suspending cables can be used to compensate for the roll and pitch of the payload.

[0022] In FIGURES 2/a, 2/b, 2/c and 2/d, some possible solutions are presented for the pendulum-like suspension system composed at least in part of single or parallel cable segments. Solutions described in FIGURE 2/b, 2/c and 2/d utilizing windable cables for the actuation of the roll and pitch of the payload platform, while concept in FIGURE 2/a requires complementary actuators such as fans, gyros, etc.

[0023] In case of the pendulum-like suspended payload platform, the primary design constraint is the amount of the required thrust. By seeing that the nutation of the payload platform is proportional to the fluid mass flow generated, it should be maximized in order to provide a large working volume. On the other hand, by increasing the fluid mass flow, the noise and the blow of the unit may become disturbing and the size/weight of the device may constrain the applicability of the whole system.

[0024] Making and vectoring the thrust, and rotating the payload were analyzed in parallel to the two concepts with different (high and low) thrust requirements.

[0025] In FIGURE 3/b six identical fluid mass flow generators are utilized. Considering these generators as ducted fans it is apparent that the thrust supplied by the smaller fans will be lower, however they provide better maneuverability for the suspended payload platform. This is because the special triangular arrangement of the fans that ensures closely uniform thrusting.

[0026] FIGURE 4 shows the possible embodiment of a six fluid mass flow generator based design.

[0027] The concept utilizes ducted fans as thrust source, since these devices have lower weight (and smaller size) compared to other solutions.

[0028] The six fluid mass flow generator based concept, by varying the performance of the individual fans, the generating moment can rotate the payload without the need of further actuators. Hence, this concept results in an easier solution for rotating the suspended payload platform and the payload.

[0029] When the payload platform is to be stopped in a hanging down position (at zero nutation), a three fluid mass flow generator based design (not part of the claimed invention) reaches a singular position. If the thrust force is not reversible, a small change of the position of the payload platform may require infinite angular accelerations. Reversing of the thrust may also be need-

ed for the orientation of the payload platform when it hangs vertically down. In addition, the moment generated by the opposite direction thrust forces can be used to compensate for the inertial effects of the payload.

[0030] According to the above considerations, it can be concluded that a design concept based on three fluid mass flow generators should incorporate two ducted fans arranged in parallel and a complementary ducted fan with transversal air mass flow, while the thrusting forces should be reversible at all ducted fans. However, with six fluid mass flow generators, the role of the fluid mass flow generators cannot be separated. They are identical to each other and contribute to the thrusting and turning of the payload platform equally.

[0031] Although preferred embodiments of the present invention have been illustrated in the accompanying Drawings and described in the foregoing Detailed Description, it is understood that the invention is not limited to the embodiments disclosed and to the use of ducted fans as fluid mass flow generators, but is capable of numerous rearrangements, modifications, and substitutions without departing from the concept of the invention as set forth and defined by the following claims.

Claims

1. A payload platform (PP) the weight of which is compensated by suspension system connected to a suspending element and thrustured by fluid mass flows;
 - the suspension system is composed in part or in whole of single or parallel suspending cable segments,
 - the fluid mass flows are generated by flow generators implemented as fans,
 - each of the fluid mass flow generators provides a thrust force vector (F_T),**characterized in that,**
 - at least six fluid mass flow generators are implemented, the
 - line of action of each thrust force vector (F_T) in respect to the payload platform (PP) is coplanar to the other thrust force vectors (F_T) that are grouped by three pairs of parallel lines of action, and
 - the parallel lines of action of the three pairs of the thrust force vectors (F_T) are axis-symmetrical to the perpendicular bisectors of the sides of an equilateral triangle.
2. The payload platform of claim 1 **characterized in that**, the fans are six ducted fans.
3. The payload platform of claim 1 **characterized in that** the fluid mass flow generators are adapted to control the rotation of the payload platform.

Patentansprüche

1. Nutzlastplattform (PP), deren Gewicht durch ein Aufhängungssystem kompensiert wird, das mit einem Aufhängeelement verbunden ist und durch Fluidmassenströme vorgetrieben wird;
 - das Aufhängungssystem besteht teilweise oder ganz aus einzelnen oder parallelen Aufhängungskabelsegmenten,
 - die Fluidmassenströme werden durch Stromgeneratoren erzeugt, die als Ventilatoren implementiert sind,
 - wobei jeder der Fluidmassenstromgeneratoren einen Schubkraftvektor (F_T) bereitstellt,**dadurch gekennzeichnet, dass**
 - mindestens sechs Fluidmassenstromgeneratoren implementiert sind, wobei die Wirkungslinie jedes Schubkraftvektors (F_T) bezogen auf die Nutzlastplattform (PP) koplanar zu den anderen Schubkraftvektoren (F_T) ist, die als drei Paare von parallelen Wirkungslinien gruppiert sind, und
 - die parallelen Wirkungslinien der drei Paare der Schubkraftvektoren (F_T) achsensymmetrisch zu den Mittelsenkrechten eines gleichseitigen Dreiecks sind.
2. Nutzlastplattform nach Anspruch 1, **dadurch gekennzeichnet, dass** die Ventilatoren sechs Flügelräder sind.
3. Nutzlastplattform nach Anspruch 1, **dadurch gekennzeichnet** die Fluidmassenstromgeneratoren angepasst sind, um die Drehung der Nutzlastplattform zu steuern.

Revendications

1. Plateforme de chargement (PP) dont le poids est compensé par un système de suspension connecté à un élément en suspension et poussé par des flux de masse de fluide ;
 - le système de suspension étant composé en partie ou en totalité de segments de câbles simples ou parallèles en suspension,
 - les flux de masse de fluide étant générés par des générateurs de flux se présentant sous forme de ventilateurs,
 - chacun des générateurs de flux de masse de fluide fournissant un vecteur de force de poussée (F_T),**caractérisée en ce que**
 - au moins six générateurs de flux de masse de fluide sont mis en oeuvre, la ligne d'action de chaque vecteur de force de poussée (F_T) par

rapport à la plateforme de chargement (PP)
étant coplanaire aux autres vecteurs de force
de poussée (F_T) qui sont groupés par trois paires
de lignes d'action parallèles et

- les lignes d'action parallèles des trois paires
de vecteurs de force de poussée (F_T) sont sy-
métriques à l'axe des bissectrices perpendicu-
laires des côtés d'un triangle équilatéral. 5

2. Plateforme de chargement selon la revendication 1, 10
caractérisée en ce que les ventilateurs sont six
soufflantes canalisées.

3. Plateforme de chargement selon la revendication 1, 15
caractérisée en ce que les générateurs de flux de
masse de fluide sont aptes à contrôler la rotation de
la plateforme de chargement.

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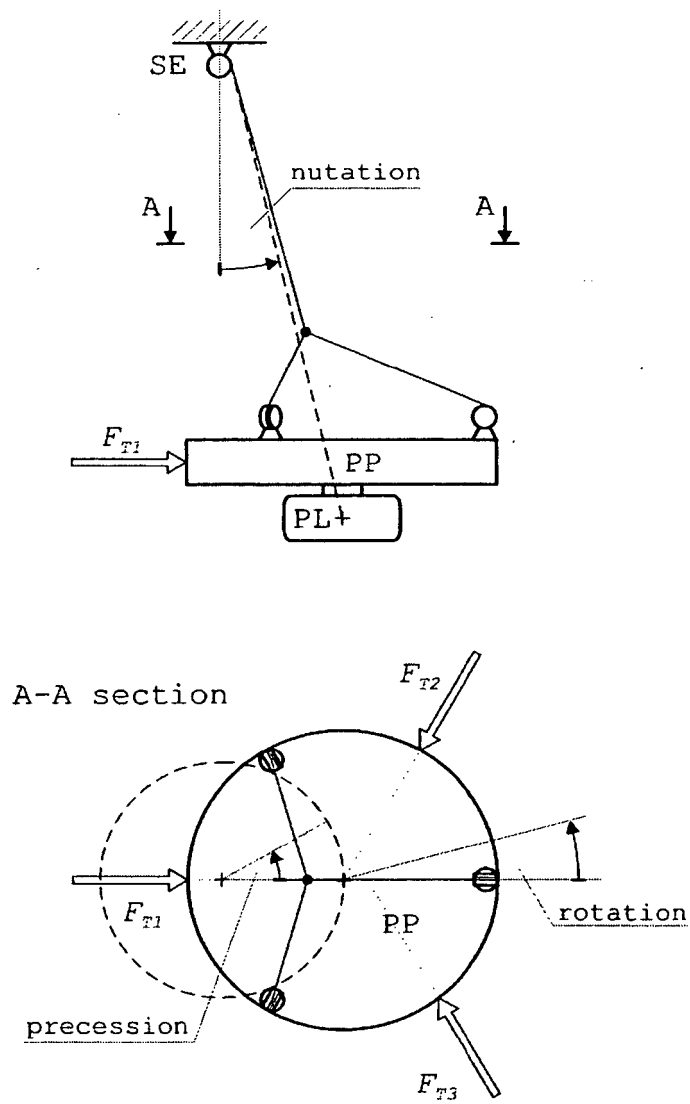


Figure 1

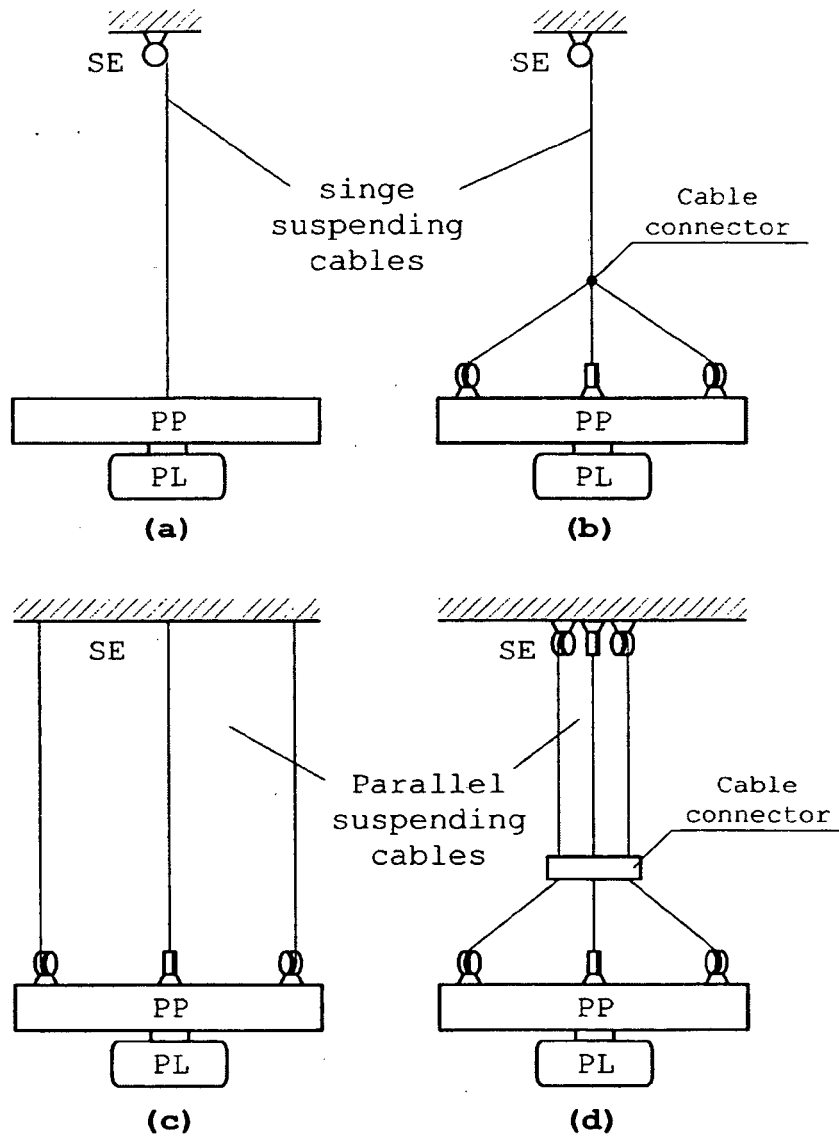
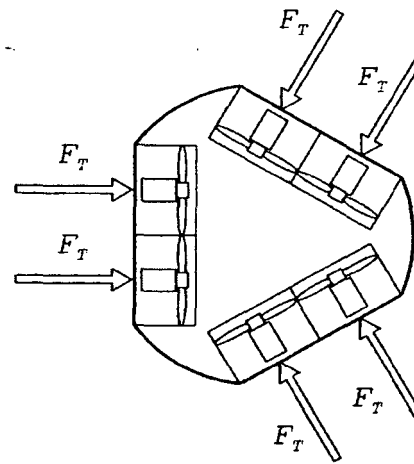


Figure 2



$$\max(F_{T,main}) = 2F_T$$

$$\max(F_{T,trans}) \approx 1.7F_T$$

(b)

Figure 3

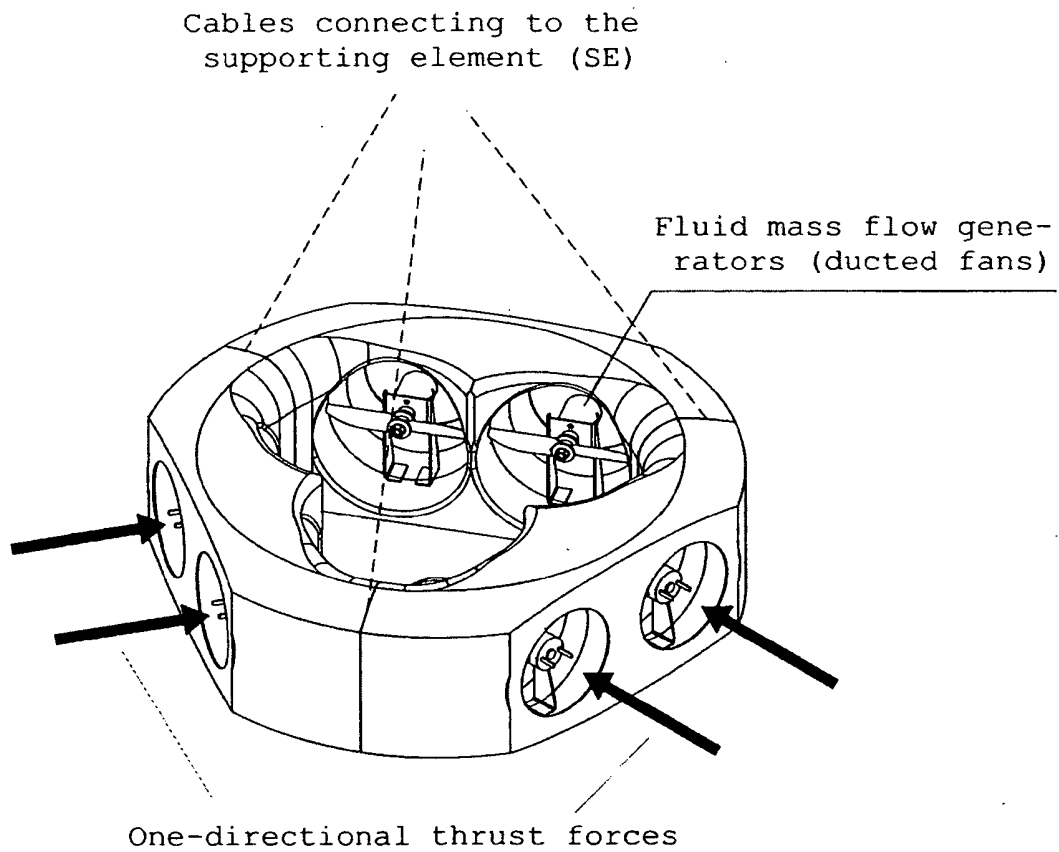


Figure 5

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 2007200027 A [0003]
- EP 0806775 A1 [0008]
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Non-patent literature cited in the description

- The design of a tethered aerial robot. **MCKERROW, PJM ; RATNER, D.** IEEE International Conference on Robotics and Automation 2007, Rome, Italy. IEEE, 10 April 2007, 355-360 [0004]