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Declarations under Rule 4.17:

— *of inventorship (Rule 4.17(iv))*

[Continued on next page]

(54) **Title**: VIDEO CAMERAS LINEAR OSCILLATION STABILIZER

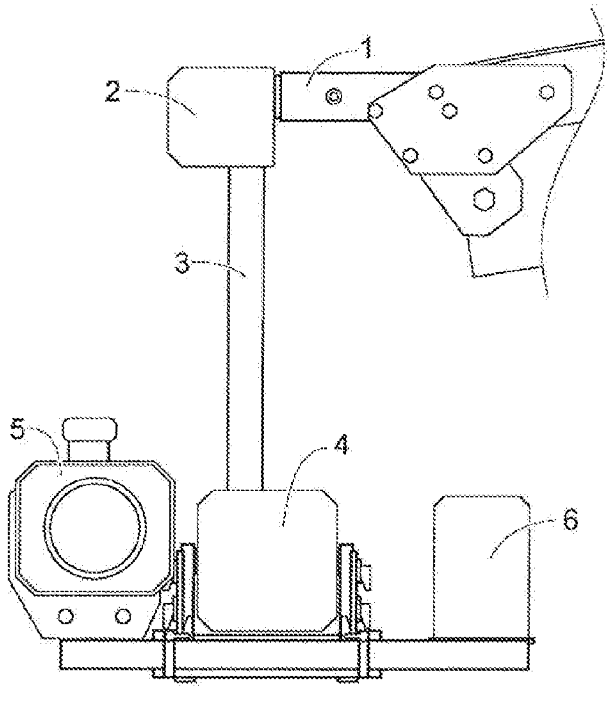

Fig. 1

(57) **Abstract**: Assembly that comprises cardan joint converts the linear oscillations of unstable base Into the angular oscillations of the camera base. To avoid resonance vibrations in the cardan joint, servo drives are provided that receive feedback from the active forces. Servo drives allow the unstable base to swing and vibrate without transmitting vibrations to the stabilized part. A sensor for measuring oscillations is mounted on the stabilized part. Signal from oscillation sensor controls the servo drives for compensation of active force that would make swinging of stabilized part. Thus the servomechanism performs the function of active dampers and prevents harmonic oscillations in the assembly. Both horizontal and vertical oscillations can be stabilized. Angular oscillations of the camera are stabilized by additional rotational assembly. While the design is relatively simple, it ensures high damping ratio in a wide range of vibration frequencies and amplitudes. Besides camera applications, it can be also used to stabilize other equipment on mobile platforms.

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VIDEO CAMERAS LINEAR OSCILLATION STABILIZER

Field of the invention

The invention relates to equipment for oscillation damping and reduction of unbalanced forces resulting from movements.

Background of the invention

Utility model patent No. CN201834213 (U) describes a linear oscillation stabilizer for video camera. The stabilizer comprises a base platform, a load platform, vibration suppressor, four double-parallelogram type connecting mechanisms, arranged between four edges of the base platform and the load platform. Angular displacement is converted into the linear displacement using these four double-parallelogram type connecting mechanisms. The major flaw of this mechanism is that they can stabilize oscillations that have small amplitude. Another flaw is a free play in joints, which results in additional vibrations.

Patent No. US8882088 (B2) describes a horizontal axis shock and vibration isolators for camera platform. The device comprises a bottom plate and a top plate attached the bottom plate using a universal joint that allows the top plate to pivot in an articulated manner about two mutually perpendicular axes relative to the bottom plate. In this invention the camera is fixed to the universal joint. The major flaw of this device is the fact that linear oscillations are converted into angular oscillations without balancing the latter. In addition, the load mass center point is located above the joint, which reduces stability and requires the use of stiffer dampers.

Common drawback of both above solutions is the use of passive dampers. Oil-filled dampers are widely used nowadays. The use of passive dampers results in reduced efficiency of a stabilizer and limited frequency range of oscillations being damped. In such cases additional technical solutions are required to limit high-frequency oscillations. Low-frequency oscillation stabilization capability is limited by mechanical limit of the stabilizer platform shift.

Short description of the invention

Application No. LT2014012 describes angular oscillation stabilizer for video camera equipment. The stabilizer is attached to a vertical stand. The stand inclination is compensated by a rotary assembly on the level of center of mass of the equipment being stabilized. Stabilization of linear oscillations is not described in this patent. Further description includes the attachment method of the stabilizer which allows reducing linear horizontal oscillations of unstable base.

Short description of the drawings

Fig. 1 depicts a stabilizer for video camera which is to be attached to the boom of lifting crane. Marked positions: 1 – attachment to the boom of the crane; 2 – cardan joint with active dampers; 3 – mounting stand for the vertical stabilizer; 4 – camera rotation and angular stabilization assembly; 5 – camera; 6 – counterweight.

Fig. 2 depicts a motion diagram of stabilizer elements in case of horizontal swinging of the crane boom. Marked positions: 7 – cardan joint; 8 – vertical stand; 9 – camera rotation assembly attachment; 10 – assembly's position in case of shift to the left; 11 – assembly's position in case of shift to the right; 12 – crane boom oscillation amplitude; 13 – shift trajectory of the rotation assembly.

Fig. 3 depicts example of a stabilizer for linear oscillations in vertical direction. Marked positions: 14 – unstable base; 15 – joint axis; 16 – servo drive; 17 – lever; 18 – gyro sensor; 19 – spring; 20 – stabilized equipment.

Fig. 4 depicts a composition of stabilizer axes. Marked positions: 21 – axis for compensation of vertical oscillations; 22 – axis for compensation of lateral swinging; 23 – axis for compensation of longitudinal swinging; 24 – axis for panoramic rotation and stabilization; 25 – axis for lateral tilt and stabilization; 26 – axis for longitudinal tilt and stabilization.

Fig. 5 depicts cardan joint for attaching video camera to the lifter; it comprises the housing, the fixture for attaching the joint to the lifter element (28), and the fixture for attaching the joint to the suspended platform of the video camera (29).

Fig. 6 depicts the arrangement of active dampers inside the housing of cardan joint, comprising active first-axis damper (30), and active second-axis damper (31).

Fig. 7 depicts side view of the active damper, comprising shaft (32), support for attachment to the housing, motor (34), reducing gear (35), driving coupling (36), driven coupling (37), spring (38), and optical sensor of displacement (39).

Fig. 8 depicts front view of the active sensor, comprising first motor with reducing gear (40), second motor with reducing gear (41), motor mounting frame (42), damper (43), frame for attachment to the frame (44), input belt (45), driving coupling (46), spring (47), driven coupling (48), and shaft (49).

Fig. 9 depicts rotation speed sensor, comprising the shaft or active damper (50), gear (51), belt (52), and DC generator (53).

Detailed description of the invention

Horizontal oscillations of unstable base (1) are converted into angular oscillations of the vertical stand (3) under the action of cardan joint (2). Movements of camera (5) are delayed from movements of boom (1) due to inertia. Oscillations of frequency higher than own swinging frequency of camera (5) on vertical stand (3) are effectively suppressed. To prevent resonance, servo drives are provided on cardan joint axis (2). Servo drives contain elastic elements and force sensors, which provide feedback to the servo drive controller. Such servo drives are described in patent LT6113 and patent application LT2014013. Such servo drives have internal feedback that depends on applied force and do not interfere with rotation in case of neutral control signal. Servomechanisms perform a function of active dampers. Servomechanisms receive control signals from electronic gyro, which is located on the vertical stand (3). Operational speed of servomechanisms must be sufficient to respond to resonant frequency of oscillations. Thus the active damper eliminates swinging, but does not prevent stabilization of vibrations with higher frequency. Unstable base (1) and rotation stabilization assembly (4) can be equipped with acceleration sensors (accelerometers). Acceleration sensors allow the microcontroller to separate additional unstable base (1) oscillations from own resonant vibrations of rotation assembly (4). Such measurements allow further adjustment of control signal for servomechanism in order to improve the operation of the stabilizer in low frequency range.

Prototype device operation data, as example, is provided below:

Length of vertical stand (3): 0,5 m.

Period of own oscillations: 1,5 s.

Amplitude of stabilized oscillations: up to 0.3 m.

Mass of stabilized equipment (6, 7): 10 kg.

Max torque of servo drives: 10 N*m.

Fig. 2 depicts positional changes of stabilized object (9) in case of horizontal oscillations of unstable base (7) at the maximum amplitude (12).

Fig. 3 depicts an example of vertical-direction linear stabilizer. Spring (19) balances the gravitation force of stabilized equipment (20). Lever (17) functions in the same manner as the vertical stand (3) from the example given in Fig. 1. Gyro sensor (18) controls operation of servo drive (16). Servo drive (16) is aligned with the joint axis (15). The assembly is attached to the unstable basis (14).

Fig. 4 depicts a six-axis layout of linear (21-23) and angular (24-26) oscillation stabilizer. The first axis (21) connects the stable base with the vertical vibration stabilizer arm. The second and the third axis (22, 23) comprise a cardan joint, which ensures stabilization of horizontal swinging movements. Vertical stand for load fixation is attached to the cardan joint. Axis of rotation (24) in horizontal plane runs along the vertical stand. The fifth axis (25) provides lateral tilt and stabilization. The sixth axis (26) provides longitudinal tilt and stabilization. Stabilized equipment is attached to the sixth axis (26). All axes are consistently arranged perpendicular to each other. All axes are equipped with servo drives for control and stabilization.

The advantage of the described solution is relative simplicity of construction and high vibration suppression factor over a wide frequency and amplitude range.

The main area of application of the invention – camera stabilizers. It can also be used for stabilization of other equipment mounted on movable platforms.

Most video cranes are using standard joints for attaching a suspension with a video camera. This allows installation of a universal joint with an active damper between a crane and a suspension device. Such a device is shown in Figure 5 and Figure 6. Attachment to the crane (28) is located above the universal joint (27), attachment to the stabilized platform with a camera (29) is located under the universal joint (27). Active dampers (30, 31) are located in the housing of the universal joint (27). The axes of the universal joint are located at different levels, and it is acceptable in this case. The center of mass stabilized equipment is much lower with respect to the universal joint (27).

Figures 7-9 depict an active damper device located in the housing of the universal joint (27). Attachment of the stabilized platform with a video camera is attached to a shaft (32, 49, 50). A servomechanism is fixed in a housing of the universal joint (27) on a frame (33, 44). The servomechanism has two motors (34, 40, 41) and two reducers (35, 40, 41). Control signals for the motors (40, 41) are sent with an offset in an opposite direction. When the shaft (32, 49, 50) is stationary, the motor and reducer (40, 41) retain the mechanical tension in opposite directions. Maximum torque is achieved when both motors (40, 41) are working synchronously. [Such technical solution is described in patent No. LT5753]. When the generated force is often reversed, double engine runs smoother and quieter.

To reduce noise, the motors are mounted on a separate frame (42) which is connected to the frame (44) through elastic dampers (43). The torque on the shaft (32) is transmitted through a flexible coupling (36-38). The driving coupling (36, 46) is connected to the reducers (35, 40, 41) of the motors via a drive belt (45). The use of the belt reduces noise of the stabilizer. The driven coupling (37, 48) is rigidly attached on the shaft (32, 49). The driving coupling (36, 46) is mounted on a separate bearing. The force is transmitted through springs (38, 47). At zero torque, the springs (38, 47) are oriented radially. With increase of torque the springs (38, 47) are deflected and the lever arm is increased. In this case the servomechanism controls the force more precisely at small loads and coarser at high loads. Such technical solution is described in patent application PCT-LT2014-000016.

Torque is measured using an optical displacement sensor (39) which is placed between the driving coupling (36) and the driven coupling (37). The force produced by the motors (34, 35) and the load force on the shaft (32) are measured. Servomechanism actively reduces mechanical resistance and does not hinder rotation of the load. An electromagnetic velocity sensor (51-53) is mounted for the active dampers. A pinion (51) is mounted on the shaft (32, 49, 50). The belt (52) transmits rotation to the DC motor (53). In this case, the motor (53) operates as a generator. A voltage proportional to the rotational speed is generated by the motor (53). The servomechanism generates a torque proportional to the measured velocity, but in opposite direction. High-speed performance of the servomechanism is sufficient to inhibit harmonic frequency oscillations of the pendulum. Pendulum in this case is a platform with a camera (3-6). Different forces are required for inhibition of different masses. A microcontroller determines the rate of the reaction in the process of auto-calibration after powering up the device (27, 2). For calibration, the servo motor creates vibrations and increases the reaction to achieve the desired stability.

Claims

1. Video camera linear oscillation stabilizer transforming linear oscillations of unstable base into angular oscillations of camera attachment stand, **characterized in that** a servo drive is installed between the unstable base and the camera stand, containing an elastic element and a force sensor, providing feedback to the servo drive motor controller.

2. Video camera linear oscillation stabilizer according to Claim 1, **characterized in that** camera attachment stand is equipped with gyro sensor, which sends control signals to the servo drive.

3. Video camera linear oscillation stabilizer according to Claim 1, **characterized in that** acceleration sensors are installed between the unstable base and stabilized part and the signals thereof are processed by microcontroller, which controls operation of the servo drive.

4. Video camera linear oscillation stabilizer according to Claim 1, **characterized in that** the servo drive has a position sensor and the active force of the servo drive is proportional to the speed of sensor data exchange.

5. Video camera linear oscillation stabilizer according to Claim 1, **characterized in that** an electromagnetic generator is used instead of rotation speed sensor.

6. Video camera linear oscillation stabilizer according to Claim 1, **characterized in that** the servo drive causes the camera attachment stand to oscillate in order to automatically establish feedback ratio.

7. Video camera linear oscillation stabilizer according to Claim 1, **characterized in that** the camera attachment stand is connected to the unstable base by means of a cardan joint, where axis of the joint of camera attachment stand is located above the center of mass of the stabilized part.

8. Video camera linear oscillation stabilizer according to Claim 1, **characterized in that** there is a spring between the camera and the unstable base and the servomechanism acts on the stabilized part via a lever.

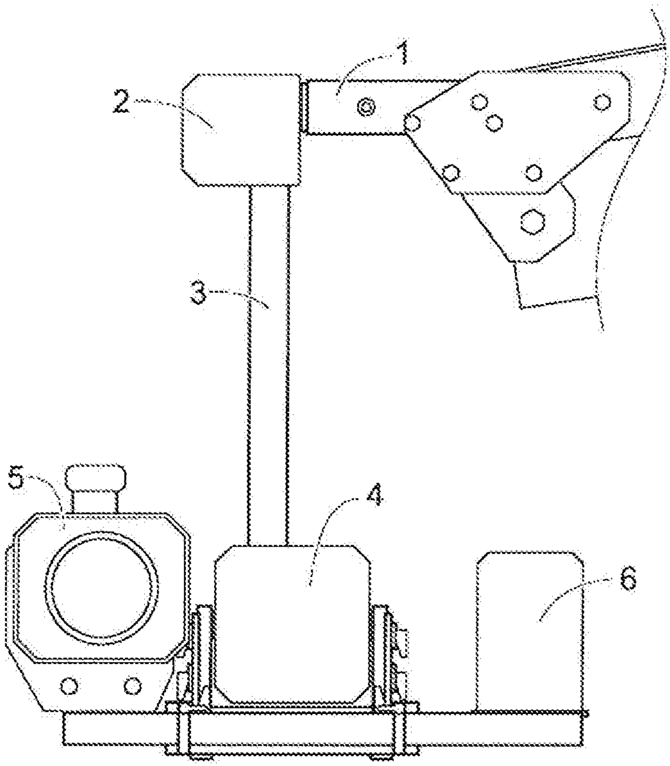

Fig. 1

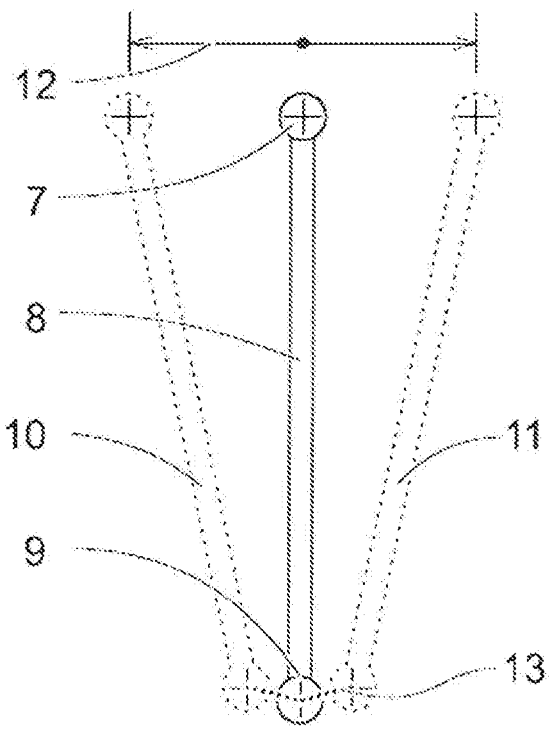

Fig. 2

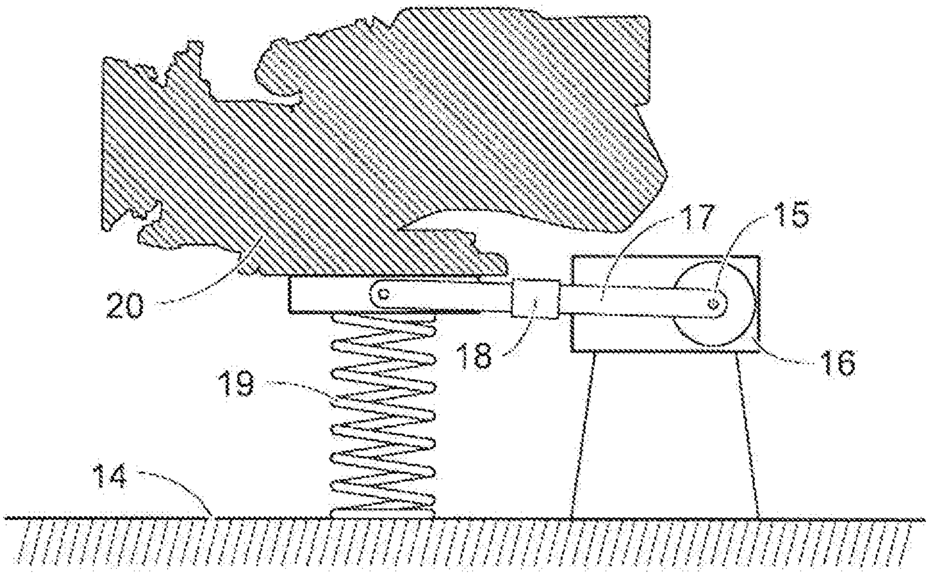

Fig. 3

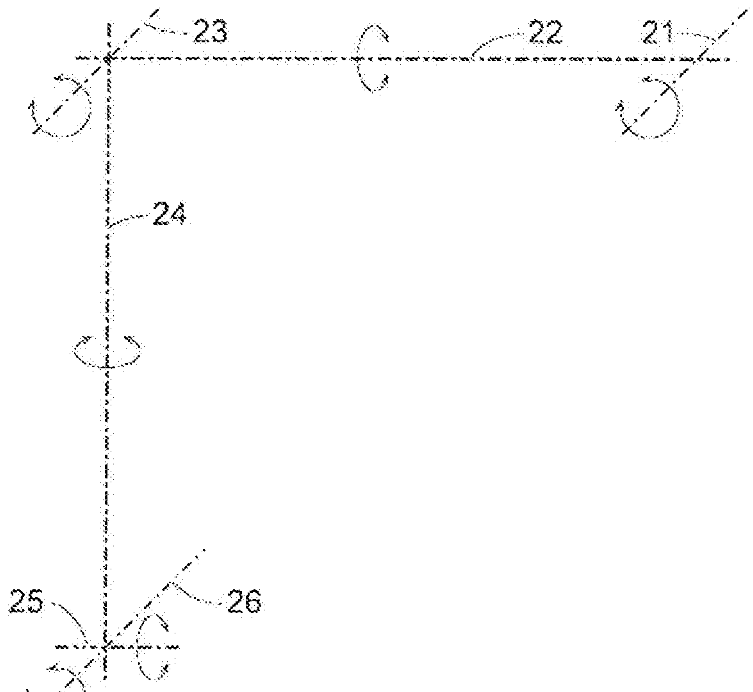

Fig. 4

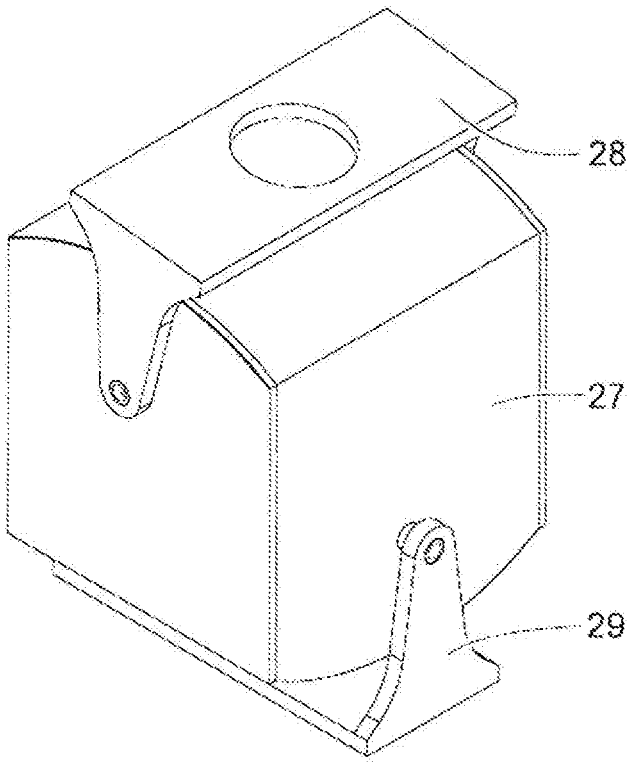

Fig. 5

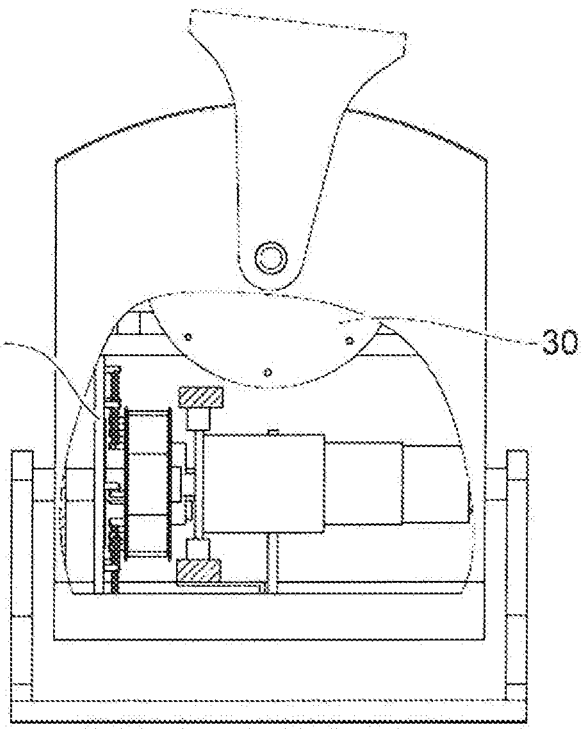

Fig. 6

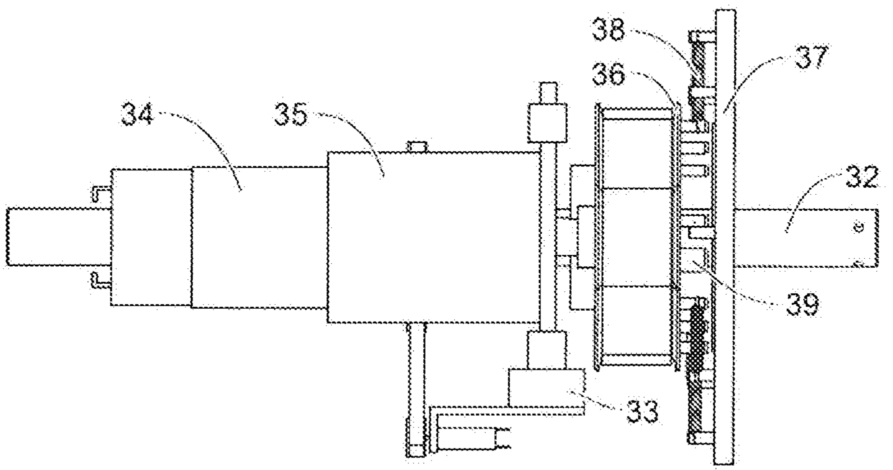

Fig. 7

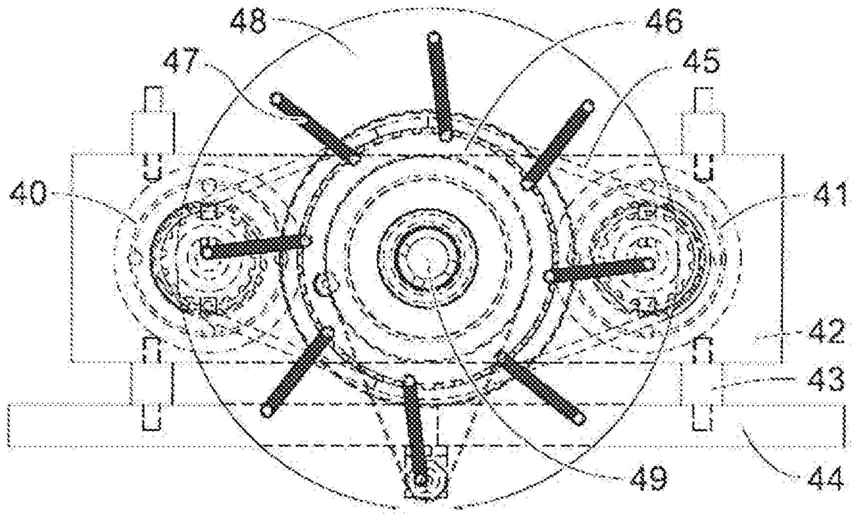

Fig. 8

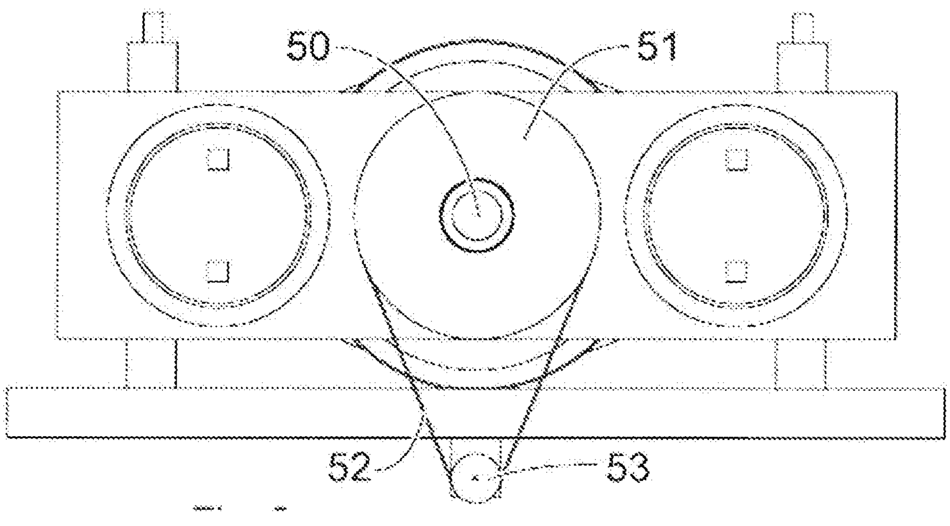

Fig. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/LT2015/000008

A. CLASSIFICATION OF SUBJECT MATTER
INV. F16M11/18 F16M11/10 F16M11/20 G02B27/64 H04N5/232
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F16M G02B H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2009/257741 A1 (GREB RICHARD G [US] ET AL) 15 October 2009 (2009-10-15) paragraph [0008] - paragraph [0068]; figures 1-15	1-8
A	KR 2013 0002490 A (NES & TEC CO LTD [KR]) 8 January 2013 (2013-01-08) figures 1-8	1-8
A	US 3 638 502 A (LEAVITT JOHN N ET AL) 1 February 1972 (1972-02-01) column 5 - column 6; figures 1-9	1-8
A	US 2011/221900 A1 (REICH STEFAN [DE]) 15 September 2011 (2011-09-15) figures 1-5	1

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
7 June 2016	20/06/2016

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2

INTERNATIONAL SEARCH REPORT

International application No
PCT/LT2015/000008

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 897 223 A (TRITCHEW STEVEN [CA] ET AL) 27 April 1999 (1999-04-27) figures 1-8 -----	1
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2

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/LT2015/000008

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