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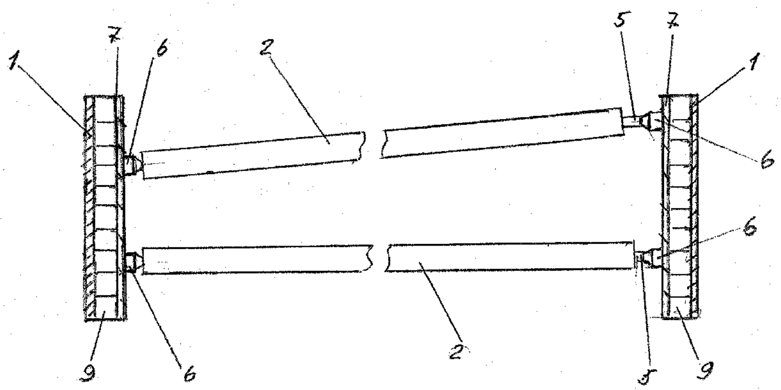

Fig 1

(57) Abstract: An electro-magnetic variable cycloidal rotor or marine propeller with few moving parts besides the blades and the counterweights which generally move inversely to the blades. Blades are propelled by means of generating magnetic forces vectored and time- sequenced by the control system, while blades' trajectories and all other parameters of their operation are determined and continuously optimized by the control system and are independent from each other, can be individually optimized for different purposes such as lift or thrust generation or providing force vectors for stabilizing the craft or increasing its maneuverability, and may be traveling at different speeds while changing as needed; their angles of attack relative to changeable virtual pivot axis whose location is selected by the control system, as well as spatial positioning and if needed dynamically varying their cross-sectional shape. Blade dynamic cross-sectional shape changes are also likewise produced by vectored magnetic forces and can allow fishtail-like or indulating thruster-like propulsion techniques. Number of blades in active operation can also be optionally determined by the control system depending on the operating regime, whereas unused blades and counterweights are kept in parking bays. Prior to the onset for the advancing blades of the compressibility effects optionally the blades movement area can be moved vertically within the larger rotor operating area to shield the advancing blades behind a wing structure or fairings, while the lift is efficiently generated by the retreating blades in subsonic environment. The blades' movements are largely unconstrained by the rotor structure except the overall dimension of its operating area and the need to keep at least a minimal distance from the other blades.

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Title of the Invention

VARIABLE ROTOR OR PROPELLER

Relationship to other Applications

This Application claims benefit of US Provisional Patent Application Serial No. 61/698,603 filed on September 8, 2012.

1. Field of the Invention

This invention relates to rotors and propellers and particularly to cycloidal rotors and propellers that enable the blades to follow variable and generally non-circular orbits.

2. Description of the Prior Art

At the present time in a number of countries there are ongoing research programs on cycloidal rotors as a potential replacement for the helicopter type rotors due to the low efficiency and many other shortcomings of the helicopter type rotors. Several of these research programs succeeded in producing flying prototype cyclocopters employing cycloidal rotors. U.S. Patent No. 5,265,827 and 6,932,296 describe examples of prior art incorporating a circular orbiting cycloidal rotor. However for prior art cycloidal rotors with a circular blade orbit, the period in each revolution during which a blade can produce the desired aerodynamic effects and the kinds of aerodynamic effects that can be produced, are limited by the circular geometry of the orbit and only two available degrees of movement; rotational around the central axis and rotational blade pitch – this severely limits their efficiency and makes it difficult to achieve stable flight. The limited efficiency, which is nonetheless higher than that of the screw type marine propellers, is also the case for the cycloidal propellers used in the marine applications, which need not produce lift and only provide thrust. For example they along most of the trajectory produce forces' vector components that are perpendicular to the direction of thrust which cancel out, but the engine power is wasted on their generation. These propellers could be made more efficient if their blades' trajectory was not circular, but rather of the optimized shape. The recently allowed US Patent Application No. 12/074,362 filed by this author describes *inter alia* cycloidal rotors with dynamically variable blade trajectories. For these prior art variable cycloidal rotors with generally non-circular blade orbits in the above referenced pending application, the blades will be able, to the extent that these rotors' structures allow, to follow the optimized non-circular trajectories; with relative wind, angle of attack and spatial positioning of the blades continuously optimized by the control system for the best possible efficiency or the highest possible lift or the highest possible forward speed or the most silent operation. However this design has limitations: the blades cannot travel through the hub area and the blades' linear speeds are a function of their radial distance from the rotor's axis of rotation. Also the blade pivot points are fixed which limits the ability to control the relative sizes of the leading and trailing edge vortexes and accordingly prevents efficiently using certain promising trajectory types especially the ones involving substantial blade pronation or supination. Blade cross-sectional shapes are not dynamically variable which prevents the utilization of various propulsion techniques by the blade itself. Also, depending on the speed of rotation, substantial Magnus effect forces can be generated by the rotating shafts which are not necessarily in the desirable direction. Furthermore these rotors have relatively high mechanical complexity with many moving parts including separate means for controlling the radial position and the angle of attack for each blade and also the means for moving the counterweight associated with each blade. The relative mechanical complexity of these rotors leads to increased cost, decreased reliability and more frequently required maintenance.

Regarding the two-dimensional actuators there is a variety of them, wherein the US patent applications 20100024587 and 20110094327 provide representative examples of the prior art. These pending patents describe X - Y two-dimensional actuators where there are separate motive means to produce movement along both of the perpendicular axis X and Y in the horizontal plane thereby generating a combined movement along the desired trajectory. All of these prior art actuators have relatively high mechanical complexity with many moving parts which inevitably translates into high initial cost and high maintenance cost, yet their functionality is limited; they are unable to turn and/or flex the objects being moved and can only move one object or a packed together plurality of objects along one trajectory at a time. They certainly cannot move a plurality of objects or a plurality of points on a single object along different trajectories at different speeds and directions of travel simultaneously. Accordingly in the robotic or bio-mimetic applications typically a plurality of actuators and servomotors of different types and functions is used making the said applications costly and time consuming to develop and manufacture, unreliable and costly and difficult to maintain.

3. Summary of the Invention

One object is to enable the rotor blades to pursue any aerodynamically desirable trajectories, independently from the other blades in terms of speed, direction and the angle of attack without the constraints imposed by the rotor structure in prior art variable blade trajectory rotors: such as inability of the blades to travel through the hub area and also the blades linear speeds being a function of their radial distance from the rotor's axis of rotation.

Another object is to minimize the complexity of the rotor mechanical structure and to eliminate most of the moving parts except the blades themselves and the counterweights which generally move inversely to the blades.

Another object is to be able to dynamically change each blade's angle of attack, its spatial positioning and optionally its cross-sectional shape without using the dedicated actuators for these purposes.

Another object is to be able to dynamically change the location of the virtual axis about which the blade turns when changing its angle of attack.

Another object is to be able to change the number of blades being actively used by the rotor depending on the flight regime.

Another object is to be able at high subsonic airspeeds to shift the rotor's area of blades' movement vertically within its larger operating area prior to the onset on the advancing blades of the compressibility effects, so that the advancing blades whose angle of attack is to be set to zero then, can be shielded from the oncoming airflow either by a wing structure or fairings while the lift is efficiently produced by the retreating blades in the sub-sonic environment.

4. Brief Description of the Drawings

Fig 1 shows a rotor of the present invention with blades located between two end plates with magnetic vectoring means mounted on said plates.

Fig 2 shows a magnetic vectoring unit with turnable iron core mounted between the layers of wires laid across one another.

Fig 3 shows the blade made of elastic material which has 3 spars extending along the blade span and having magnetic footers mounted on their ends, with said footers riding on an air cushion over the cover of the end plate.

Fig 4 shows a blade's end with an attached magnetic footer comprising a Halbach Array of magnets. Said footer is riding over the cover of the end plate.

Fig 5 shows diagrams of vectors of magnetic forces produced by a magnetic vectoring unit at moments in time T1 and T2.

Fig 6 shows location of the blades and counterweights on the end plate operating area for the case when they are located on the same end plate. Parking area on the end plate for another blade and a counterweight for it, are also shown.

Fig 7 shows three blade ends with footers riding on the cover of an end plate with another end plate for the counterweights, mounted behind the end plate for the blades. Both end plates are rigidly connected so that the inertial forces originating in one end plate are cancelled out by the opposite inertial forces produced by the other end plate.

Fig 8 shows an end plate exerting magnetic forces upon the footers mounted on a robotic leg. The ability of said leg to be thus moved in a trajectory suitable for walking or running is demonstrated by an interrupted line.

Fig 9 shows a version of this invention with one blade mounted on a ship stern, consisting of three hinged parts with one end plate and the end of the blade not facing the end plate pivotally attached to an actuated movable arm.

Fig 10 shows a version of this invention with one end plate for the blades, one end plate for the counterweights, with the ends of the blades not facing the end plate pivotally attached to a rotatable platform, which may be power driven.

5. Description of Preferred Embodiments

In the 3 embodiments presented below the blades are to be propelled due to forces created by the magnetic fields interaction between the magnetic fields generated by magnetic field generating components installed on the blades ends and the magnetic fields generated by the magnetic field generating components installed on a stationary support structure.

First embodiment of this invention consists of two end plates facing each other at a distance corresponding to the blades' length (Fig 1), said plates have bases (1) made of magnetically attractable material such as steel, ferrous materials or non-ferrous magnetic alloys although could also include of permanent or electric magnets suitably placed on said base to make the magnetic field in the operating area stronger. Where appropriate, for this and other embodiments, permanent magnets may be assembled into Hallbach Arrays to have their magnetic field focused in one desired direction. Said bases can be flat or of other shapes such as for example shallow concave. On said bases is mounted a plurality of the electro-magnetic vector units assembled together like the squares of a chessboard (Fig 2), each consisting of a layer of conducting wires laid in one direction (3) and connected to the power circuit on both ends and another such layer of wires laid across it (4). Each electro-magnetic vector unit is provided with a separate direct current supply for all of its wire layers laid in the same direction, with the ability to reverse the direction of the current by known means such as polarity switches, and to vary its amperage for all the layers laid in the same direction by known means such as rheostats. There can be multiple such layers of wires laid as described above in a magnetic vector unit. While copper wiring can be used, it would be preferable for the aircraft applications to use the carbon nanotube wiring, as it is about 80% lighter than the copper wiring with comparable electric properties. Between the layers of wires, cores (10) optionally can be mounted, which are made of soft iron or another ferrous magnetizable material, while they can be made stationary and of a round shape, it is preferable to make them turnable like compass to align with the resulting electro-magnetic field. Between the two plates with magnetic vector units mounted on them are placed the airfoil (or hydrofoil for marine applications) blades (2) at least one end of each blade is provided with telescoping retractable extension(5) to accommodate the blade length variation, as its spatial positioning between the end plates changes. The blades (Fig 3) will have at their ends magnetic footers (6) consisting of strong permanent magnets or other kind of magnets, such as for example continuously energized electric magnets operating under high temperature superconductivity with very high electric current strength and producing magnetic fields of very high intensity. The said footers are magnetically attracted to the base (1) underlying the vector units on each end plate. At least 2 magnetic footers at each end of the blade, one near the end of the leading edge of the blade and one near the end of the trailing edge are needed for the design where in addition to moving along their trajectory only the change of the angle of attack is needed, without the cross-sectional shape change. For the design where the blade is to be flexed to change its cross-sectional shape, at least 3 or 4 magnetic footers at each end of the blade, mounted separately each at the end of a spar (11) running the length of the blade will be required. The blades for the designs where they are expected to be dynamically flexed will comprise hinges and/or elastic materials such as various elastomers as shown in Fig 3, to make such flexing of their cross-section possible. To prevent the friction of the magnetic footers against the surface of said vector units, a layer of a porous material or a perforated cover will be installed covering the whole area of the vector units on each plate (7). It will be connected to the pressurized air supply distribution tubing to provide air lubrication for the magnetic footers – the control system will direct the flow of the pressurized air to areas where the said footers pass. Likewise for the marine applications water lubrication can be used. However seawater is an electricity conductor and to prevent the induction of electric currents in it, rubber or similar material skirting around each magnetic footer will need to be used, so that a very small and rather constant quantity of water within the skirting moves together with the magnetic footer, thus avoiding water movement relative to the magnetic field. Alternatively ball rollers or other kinds of known rollers could be mounted next to magnetic footers and by riding on the solid cover of vector units will prevent the friction of magnetic footers against said cover.

Second embodiment of this invention will have two end plates consisting of electric magnets (13) mounted on support frames (Fig 4) and also the blades with magnetic footers as described above and also comprising the air or water lubrication means as described above or ball rollers mounted next to magnetic footers and riding on the solid cover (7) of electric magnets comprising the end plates to prevent the friction of magnetic footers against said cover. This embodiment can be implemented differently with magnets on the footers mounted parallel to the surface of the vector units cover so that the magnets (13) can attract or repulse both poles of the footer magnets and the footer magnets could be mounted turnably, coupled with a miniature turn actuator, to be able to generate a magnetic force vector in the needed direction by steering these footer magnets. In that case electric power will need to be provided for the blades which can be done as described for the third embodiment. Along the perimeter of the operating area of each end plate a delimiting barrier (12) is installed to prevent the blades going outside the operating area in case of a malfunction – where appropriate that feature may be implemented in other embodiments.

Third embodiment of this invention will have magnetic vector units instead of the footers at the end of the blades and the end plates will be assembled either of the electric magnets, of which the most preferred type will be the continuously energized high-temperature superconductivity electro-magnets with very high electric current strength and producing magnetic fields of very high intensity, or the strong alloy-based permanent magnets and mounted on a support frame. The high temperature superconductivity for today's state of the art in that field occurs at the maximum temperature of – 135° C (due to the ongoing research it can be reasonably expected to reach much higher levels in the future), whereas the readily commercially available and inexpensive liquid nitrogen provides much lower temperatures (boiling point -196° C) and thus a small amount of it or another suitable liquid gas could be used to maintain the required temperature of the thermally insulated super-conducting electromagnets for the needed duration, such as for example the duration of the flight. For the blade mounted electro-magnetic vector units to work, the electric power will need to be provided to the moving blades which can be accomplished by electrifying the end plates' surfaces (7) facing the ends of the blades on which the vector units are mounted and using elastic contact electrodes mounted on blades ends with these electrodes pressing against the electrified surfaces thus providing the blades with electric power. Alternatively a number of known methods for the wireless transfer of the electric current to the moving blades such as for example electrostatic or electro-dynamic induction methods can be used. As in other embodiments the means to prevent the friction of the electro-magnetic vector unit at the ends of the blades and the cover of magnets on the end plates will need to be provided and may comprise air lubrication means or rollers. The magnetic vector units facing an end plate will need to be placed on a magnetically attractable base such as steel or ferrite or have a magnet mounted on said base to reinforce the magnetic field traversing the footer's magnetic

vector unit.
There is a possibility of another embodiment of this invention as a two dimensional actuator for generating a movement of any given trajectory and if needed in combination with turning or rotational movement for at least one moveable object for use in robotics and bio-mimetics. For that embodiment only one end plate may be sufficient (Fig 8) although to generate larger forces two end plates would be preferable. An object to be moved in the above-described manner with magnetic footers mounted at the expected force application points on it, is to be placed at the said end plate or between two such end plates. On Fig 8 such an object to be moved is a robotic foot (16). The design of the electro-magnetic means to exert forces on its footers and the footers themselves can be similar to what was described for either one for the first 3 embodiments. To prevent the friction of the magnetic footers against the cover of the end plate(s) either the lubrication means or the roller means can be provided along the lines of what was described for the first embodiment.
For the rotor/propeller embodiments (Fig 6), parking bays (17), which are the separate areas of the end plates structured the same way as the end plates, comprising the same elements and adjacent to the end plate operating area, for parking blades and counterweights when they are not in use, may optionally be provided. This option allows varying the number of blades in active operation for different operating regimes. The blades can enter the bays with the required angle of attack and be locked in that position by a known locking mechanism or the angle of attack can be controlled inside the parking bay using by magnetic force vectoring. Alternatively the blades could be prevented from moving out of their place by known means such as actuated bars while in a parking bay, but otherwise allowed to align with the flow, like a wind vane thereby neutralizing them aerodynamically.
In order to propel the blades along their orbits large forces will need to be generated and accordingly large reaction forces will dynamically act on the end plates in a variety of directions generating vibration. There are many known ways to suppress vibration, such as for example installing the said end plates on various damping mounts. However it is also possible to prevent the said vibration by canceling out the large reaction forces, produced when the blades are propelled, by means of using the counterweights moving

inversely to the blades and generating forces generally equal to those resulting from the blades movement, but acting in the opposite direction. For the rotors or propellers where the blades relative positions are not going to change the counterweights equipped with the same motive means as the blades, that is: either magnetic footers as the blades for the first and second embodiments or the vector units for the third embodiment, can be placed on the same end plates in the opposite positions to that of the respective blades to be moved inversely to the blades (Fig 6). For the rotors where the blades are to move freely without regard to preserving the blades relative positions (Fig 7) the counterweights (15) equipped with the same motive means as the blades will be placed on the auxiliary end plates (18) generally identical to the respective end plates used to move the blades, in the closest possible proximity, parallel to them and rigidly connected to the respective end plates and/or the structure these end plates are mounted on. The counterweights associated with each end plate will generally be equal in number to the blades' ends, have mass sufficient to balance out the respective ends of the blades, will generally be in the opposite positions and generally will move inversely to the said ends of the blades.
Optionally for rotors' operation at the high subsonic, transonic and possibly higher airspeeds the pertinent end plates would be made longer than would otherwise be the case along the rotor's vertical axis to extend the rotor's operating area vertically. Also either a wing structure or some other structure such as fairings can be provided in front of the rotor operating area and adjacent either to the upper or lower boundary of the rotor operating area, depending on where the advancing blades are, to make it possible to shield the advancing blades from the oncoming airflow prior to the onset of the compressibility effects as the rotorcraft's airspeed increases.
In the embodiments where the bases (1) are made of steel or other conducting materials are used, they may need to be divided into insulated segments to reduce the formation of the induced current eddies, although cut-outs in the shapes suitable for suppression of the formation of such currents or channeling them in the desirable directions can also be employed. An alternative solution would be the use for making the bases of magnetically attractable, but electrically non-conducting materials such as ferrites.
It is possible to implement a rotor or a propeller of the three above described embodiments by using only one end plate on which a blade's end with magnetic footers

for the first two embodiments or footers with magnetic vectoring unit for the third embodiment would ride while the other blade end would be attached by a suitable pivoted connection of a known type (Fig 9) such as a ball joint (19) installed at either a fixed point or on an actuated arm (22) to be able to extend the overall stroke of the blade and also to avoid it forming a too large angle with the central axis of this propeller, wherein the blade would consist of hinged parts (20) comprising spars (21) attached to the plate (24) mounted on said ball joint (19). At the end of the blade are the active magnetic elements, such as footers or vector units (23). The propeller in this example is installed on ship's stern (25), where upon the structural support element (26) the end plate (28) is mounted on vibration damping mounts (27). It is also possible to implement the blade with built in spars which would be made of elastic material, such as an elastomer and thus would be bendable with few or no hinged connections. Alternatively the blades can be pivotally attached (Fig 10) to a rotatable platform (29) wherein said platform can optionally be power driven via shaft (30). The blades (33) will be attached to said rotatable platform via ball pivots (31), the other end of the blades will have magnetic footers or magnetic vectoring units (32) which are mounted on extendable, telescoping on the ends facing the end blades, spars (not shown). Behind the end plate moving the blades and rigidly attached to it by structural elements (35) is the second identical end plate (36) for moving the counterweights (34) The first above described version would be functionally similar to the wings or fins of the biological flyers and swimmers who have their wings or fins either in a fixed position at one end or pivotally affixed to a moveable arm on one end while moving the free end of their wings/fins along an optimized trajectory and in most cases dynamically changing the said limbs' cross-sectional shapes – which means that when perfected the one end plate versions of the three embodiments are likely to perform comparably to the said biological counterparts of theirs. The version of this embodiment with one end of the blade connected via pivoted attachment to a rotatable platform (Fig 10) – would be suitable for attaching a plurality of blades, either all orbiting about a central area while following an optimized and generally non-circular trajectory or possibly differing, optimized for different purposes trajectories. The lighter weight, more secure blade attachment to the rotor and simpler design are the advantages that the versions of the three embodiments with one end plate offer compared to the versions of these embodiments with two opposing end plates, whereas the versions of the three embodiments with two end plates will offer the highest freedom of movement for the blades which can be used to reach the highest efficiency or the highest performance levels in terms of speed or lifting power or the thrust force and likely the highest summary forces propelling the blades as the motive forces will be generated at both blade ends.

For all embodiments it may be desirable to have constant feedback for the control system, as it cannot be expected to always determine the amount and direction of the forces required to move the blades exactly and needs to know the exact current positions on the end plates of each blade's end to adjust and modify its control signals in view of the trajectory that it needs to produce. However for the three embodiments related to the propellers and rotors, preferably it should also be aware of the flow speeds and directions, as well as the pressure distribution along each blade's span in order to constantly adjust and optimize each blade end's trajectory in conjunction with varying each blade's angle of attack while turning it relative to the variable and optimally selected for a given point in time virtual pivot axis, as well as possibly also in conjunction with dynamic change of the cross-sectional shape of the blade in order to generate the required force vectors of the lift and/or thrust for the aircraft or water craft respectively. To achieve these objectives the miniature infrared transmitters or other kinds of known transmitters; mounted on at least one side of each blade at both ends of each blade and a plurality of receivers installed in a predetermined pattern on both end plates will enable the control system at any given moment to determine by well known methods based on the signal direction and possibly its strength as well, the exact location of the each blade's end and to receive via the same transmissions the air data/flow data from the sensors located along each blade's span preferably on both of its sides. For the possible embodiment describing two-dimensional actuators, a similar arrangement with transmitters located on the part(s) being moved and receivers located on the end plate(s) will be used for providing moving part(s) location feedback to the control system.

The control system will consist of a number of interconnected modules. In the main module, the processing of the control inputs for the aircraft, together with the air data on the aircraft level and of the each rotor feedback data will focus on determining the proper operating regime for each rotor. Once such a regime is selected, the operating parameter combinations for a given regime stored in the memory tables of operating parameters will be retrieved; including the timing and sequence of locations for each blade end's each footer's positions, which will unambiguously define all aspects of the blades motions and optionally when the blades cross sectional shape is changeable, also including the blades' footers positions determining the blades' cross-sectional shape at any given instant as well as the number of blades in active operation. These operating regime parameters will be adjusted accordingly to meet the pilot/operator commands and the current air data for the whole aircraft – with that the power requirements will be determined and communicated to the control module running the engine/generator combination or any other power source used by the aircraft. These regime level parameters from the main module will be transmitted to the module finalizing the control commands using the feedback from the blades related to the blades ends' actual positions, speed, direction of travel and the blade level air data, thus each blade's operating parameters will be continuously adjusted and optimized in real-time. Additional processing in this module will produce the control commands for the counterweights – these control commands generally will be identical to the control commands for the blades except the position of the counterweights will be opposite to that of the blades and the counterweights will generally move inversely to the blades. However in cases where there is a change in the blade mass distribution, such as due to the blade's cross-sectional shape changes this module will determine the appropriate counterweight trajectory adjustment. From the blade control module the adjusted blade control commands and counterweight control commands will be continuously transmitted to the magnetic elements control module; translating these commands into signals activating or de-activating electromagnets and/or magnetic vector units and setting the strength and direction of the currents sent through them as well as the sequence and timing of the said activations, de-activations and the current strength/direction changes. The adjusted control commands will also be sent to a module operating a pressurized air (or seawater) lubrication system if the same is used in a given installation. That module will open or close the appropriate valves with the appropriate timing and sequence to allow the continuous location shifting of the air (or seawater) cushions between the end plates surfaces and the blades' footers corresponding to the blades ends' movements.

6. Sketches and Diagrams.

Provided Separately

7. Operation.

The first and third embodiments feature the electro-magnetic vector units. Each vector unit operates as follows; magnetic field emanating from the blade's footer (6) in the first embodiment (or from the magnets on the end plate in the third embodiment) passes through the electro-magnetic vector unit (9) while reaching the base of the end plate (1) which either comprises magnets or is made of magnetically attractable material such as steel. When a direct current is passing through one layer of wiring (3) in the magnetic vector unit through which extends a magnetic field a force vector perpendicular to the direction of the wires is generated, acting on the wires in that layer and accordingly the same size force vector is acting on the magnetic footer, but in the opposite direction. The amount of force is proportional to the amperage of the current going through that layer (Fig 5). Likewise a force vector perpendicular to the direction of wires is generated in the second layer of wires (4) which is laid across the first layer of wires, these two vectors when combined produce the vector sum of the two vectors of force acting on the wires and accordingly on the vector unit as a whole. The iron core (10) will align with the resulting magnetic field vector and strengthen it. In the first embodiment a force acting on a footer of the blade will be equal and in the opposite direction to the vector sum of forces acting on the wires in the vector unit. As we can change the direction of current in each layer and the amperage of current going through each layer from 0 to maximum we can thus produce the vector sum of these 2 forces pointing in any desired direction among the 360 degrees possible thus applying a force vector to the blade's footer in the required direction. If there is a plurality of the laid across each other layers of wires in a given magnetic vector unit, then the resulting vector will be a vector sum of vectors from all the wire layers. Similar action is taking place at other footers of a given blade and at footers of other blades which has the effect of driving the blades in the desired direction while changing their angle of attack relative to the selected by the control system virtual axis and the blades' cross-sectional profile if needed. In the second embodiment electric magnets (13) on the end plates are sequentially activated at least one at a time by the control system in a manner assuring that on any given time a magnetic force vector is acting on each of the blades footers and is propelling it in the required direction with the force required to make that part of the blade move along the desired trajectory with the desired speed and acceleration while changing its angle of attack relative to said virtual axis as needed and dynamically flexing it cross-sectionally if needed. A variation of this embodiment is possible where the magnets are mounted parallel to the surface of the end plate's cover (7) and the magnets on the end plate are activated to act attractively or repulsively on both poles of the said magnets. The said magnet is turnable by a miniature actuator controlled by the control system which makes it turn in the required direction which would allow to only activate the magnets directly in front and behind the footer magnet (13). Known means such as polarity switching are used for the direct current reversal and for the amperage change, such as rheostats. These means are to be used in proper sequence and with the required timing to provide the current of the needed direction and amperage for each set of layers laid in the same direction of each magnetic vector unit which are to be used for a particular blade trajectory and operating regime. Instead of varying the amperage it is possible to vary the number of wires within each layer that are switched on. To maintain the rotor balance the dynamic counterbalancing is used. The placement and function of the counterweights were adequately described in the Description section and will not be re-iterated here, but are included by way of reference. If a blade is changing shape cross-sectionally and possibly bending along its span the control system can be provided with the ability to adjust the related counterweight's trajectory to balance out these changes in blade mass distribution.

The set up and arrangement of the blade end's location and air data feedbacks from the blades, in conjunction with their functional description were adequately provided in the Description section and will not be re-iterated here, but are included by way of reference. Likewise, the design and description in terms of function of the control system and the program modules comprising it, were adequately provided in the Description section and will not be re-iterated here but are included by way of reference.

For rotor's operation at the high subsonic, transonic and possibly higher airspeeds optionally it can be made possible to shift the rotor's area of blades' movement either up or down depending on where the advancing blades are within its larger operating area at the onset of compressibility effects for the advancing blades, so that the advancing blades whose respective part of the trajectory will be flattened and the angle of attack is to be set to zero then, can be shielded from the oncoming airflow either by a wing structure or fairings and the lift is efficiently produced by the retreating blades in the sub-sonic environment.

8. Ramifications.

These rotors/propellers will be exceptionally simple mechanically with few moving parts besides the blades themselves and the counterweights whereas they will have the unique combination of abilities being able to continuously select the optimum combination of each blade's independent trajectory and direction of travel unlike the prior art practically without any limitations imposed by the rotor structure, while also varying the spatial positioning, angle of attack relative to control system selected virtual axis and if needed dynamically changing the cross-sectional shape of the blade. The latter will enable them to use fishtail-like or undulating thruster-like propulsion techniques. For certain operating regimes the blades may not need to travel, but can rely on dynamically varying their shapes for example fishtail-like. Propellers based on these principles will most efficiently generate the thrust or propulsive force, likely better than any and all prior art propellers because they would have a number of unmatched operating capabilities and the possibility of using these capabilities in optimum combinations.

Robotic and bio-mimetic applications are also highly suitable for the 2 dimensional actuators based on these principles and described above – on Fig 8 we demonstrate the use of this actuator for a robotic application with the ability to walk. Instead of two joints; hip and knee in animals or humans only one such actuator will be sufficient to make the "leg" move in any desired trajectory suitable for walking or running. The same would apply to fins or wings in bio-mimetic applications - in such applications the complex movements of the fins or wings can be readily replicated and improved upon as these two-dimensional actuators capabilities are not limited by the typical constraints of the muscle-skeletal structure.

9. Claims

What claimed is:

1. An apparatus for generating a thrust force in at least one desired direction having at least one blade mounted for motion in a manner suitable for generating said thrust; blade supporting means operative to confine the blade to movement within a predetermined volume of space; magnetic field interaction means mounted on each blade and on blade support means operative to move at least one part comprising the blade in a manner conducive to generating said thrust; control system means for directing each blade motion by determining the required operating parameters and energizing the said magnetic field interaction means to produce magnetic forces resulting in each blade's movement consistent with said operating parameters.

2. An apparatus of Claim 1 wherein blade supporting means comprise at least one end plate having a support structure on which are mounted magnetic field vectoring means which are a component of said magnetic field interaction means.

3. An apparatus of Claim 2 where said magnetic field vectoring means consist of a plurality of assemblies each comprising at least one set of conducting wires laid in one direction and at least one set of conducting wires laid across the first said set of wires for producing a magnetic force vector when said sets of wires are energized by the control system.

4. An apparatus of Claim 1 where said magnetic field interaction means consist of a plurality of magnets whose ends of the same polarity face the end plate cover upon which the blades' ends ride.

5. An apparatus of Claim 4 where magnets are continuously energized electro-magnets operating under the conditions of high temperature superconductivity with very high electric current strength and producing magnetic fields of very high intensity.

6. An apparatus of Claim 3 wherein each said assembly comprising sets of wires further includes at least one core made of suitable material to reinforce the magnetic field produced by the said sets of wires.

7. An apparatus of Claim 2 where said magnetic field interaction means comprise at least one magnetic footer mounted on each blade's end that is facing the end plate wherein said footer further includes at least one magnet.

8. An apparatus of Claim 2 where said magnetic field interaction means comprise at least one magnetic footer mounted on each blade's end that is facing the end plate wherein said footer further includes a constantly energized electro-magnet operating under the conditions of high temperature superconductivity with very high electric current strength and producing magnetic field of very high intensity.
9. An apparatus of Claim 2 where said magnetic field vectoring means comprise a plurality of electro-magnets wherein the energizing of at least one such magnet in the vicinity of each blade footer will produce a magnetic force vector acting on each footer and thus on the whole blade.
10. An apparatus of Claim 2 wherein said blades comprise parts attached to each other by hinged connections extending along the blade span whereas each blade part is operatively connected with at least one said magnetic footer adjacent to its end and facing the end plate to enable the blade to change its cross-sectional shape when a magnetic force vector is acting on said footers.
11. An apparatus of Claim 2 wherein said blades comprise rigid spars extending spanwise to ends of which facing said end plate are attached said magnetic footers, whereas the blades are made of elastic material to enable their bending cross-sectionally.
12. An apparatus of Claim 2 comprising a blade whose end not facing said end plate is attached by pivoted connection to an arm movable by an actuator to increase the blade range of movement.
13. An apparatus of Claim 2 comprising a plurality of blades whose ends not facing said end plate are attached by pivoted connections to a rotatable platform.
14. An apparatus of Claim 4 wherein each blade footer comprises at least one said assembly and each said assembly comprises at least one set of conducting wires laid in one direction and at least one set of conducting wires laid across the first said set of wires for producing a magnetic force vector when said sets of wires are energized by the control system.
15. An apparatus of Claim 2 further including counterweights equal in number to the number of blades in operation, generally located in a position opposite to the position of the associated blade and generally moving in the direction opposite to that of the blade.
16. An apparatus of Claim 15 wherein said counterweights are located on an auxiliary

end plate generally identical to the respective end plate moving the blades and with two said end plates rigidly connected.

17. An apparatus of Claim 2 comprising said end plates which are elongated vertically and mounted behind a fixed structure located near either one of the vertical boundaries of both said end plates so that the advancing blades trajectory can be moved vertically to shield it behind said fixed structure to minimize the compressibility effects affecting said advancing blades.

18. An apparatus of Claim 2 comprising at least one wireless signal transmitter installed on each blade's end and at least one receiver installed on a suitable stationary part of said apparatus, wherein each said receiver transfers the received signal data to said control system for determining the exact location of each blade's end at any moment in time.

19. An apparatus of Claim 18 further comprising at least one flow data sensor on at least one side of each blade with said flow data being transmitted via said transmitter to maintain said control system's awareness of blade operating conditions.

20. A method of generating thrust in at least one desired direction comprising the steps of:

a) Providing an apparatus comprising magnetic field interaction means mounted on at least one moveable blade and on a stationary part of said apparatus ;

b) Providing the Computer Control System to run the said apparatus;

c) Running the pertinent components of Computer Control System to determine the required operating regime comprising the desired operating parameters corresponding to the operating conditions and control input;

d) Running the pertinent components of the Computer Control System to determine the motion data set corresponding to said required operating regime, comprising each blade end's time-sequenced positions for each its magnetic footer on each end plate, whereby said motion data set will determine each blade's motion types and parameters for any given moment;

e) Running the pertinent components of the Computer Control System to determine the magnetic force vector needed to act on each said footer of each blade on any given moment to assure that said each footer of each blade reaches each its designated location point at the specified moment in time according to said motion data set;

f) Running the pertinent components of the Computer Control System to make the determination for each said magnetic force vector the locations and the number of magnets activated as well as strength, direction and time-sequence of the electric current sent through them by the control system and to energize said magnets in accordance with said determination;

g) Running the pertinent components of the Computer Control System to receive and process each blade end location feedback to adjust if needed the force vectors direction and size determinations;

h) Running the pertinent components of the Computer Control System to receive and process each blade's flow data from sensors installed on it to adjust if needed the said force vectors direction and size determinations;

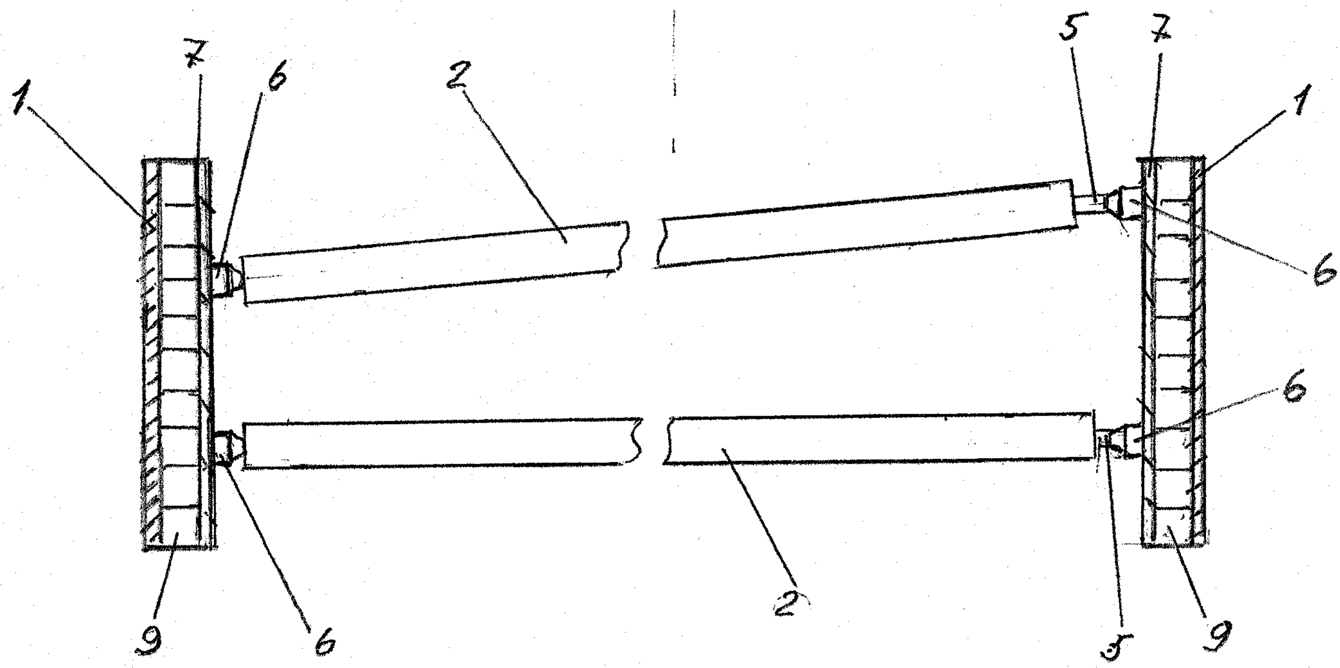


Fig 1

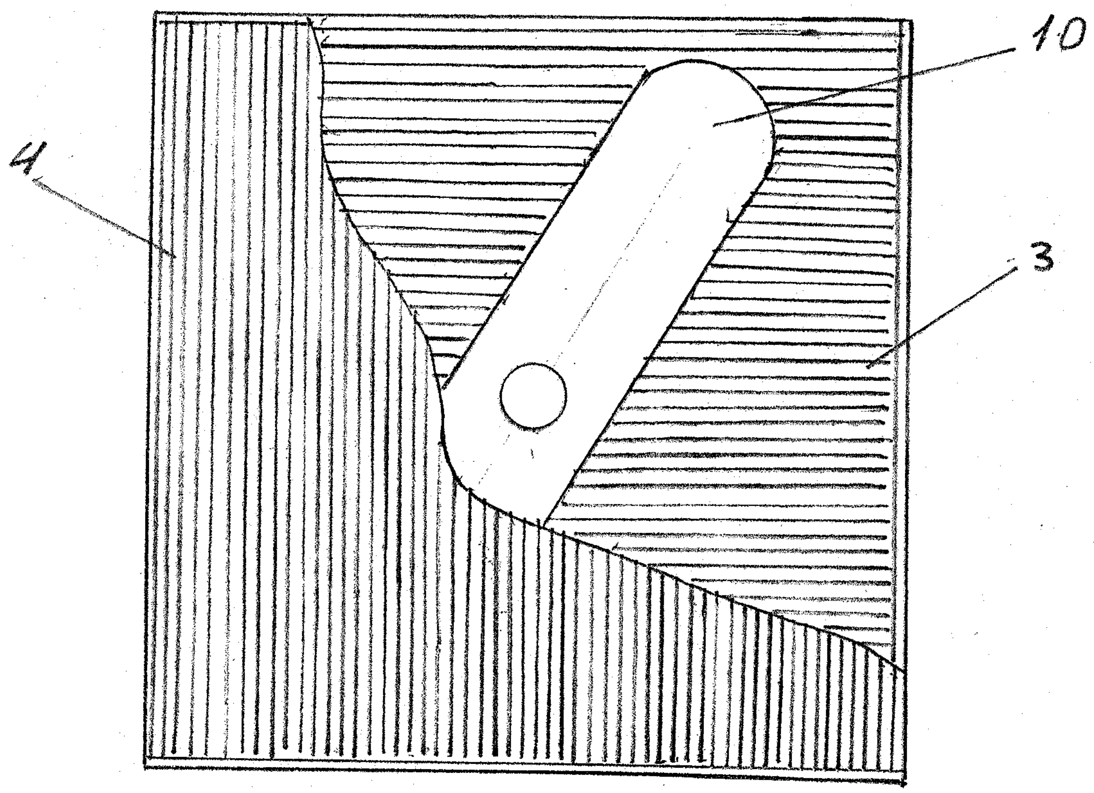


Fig 2

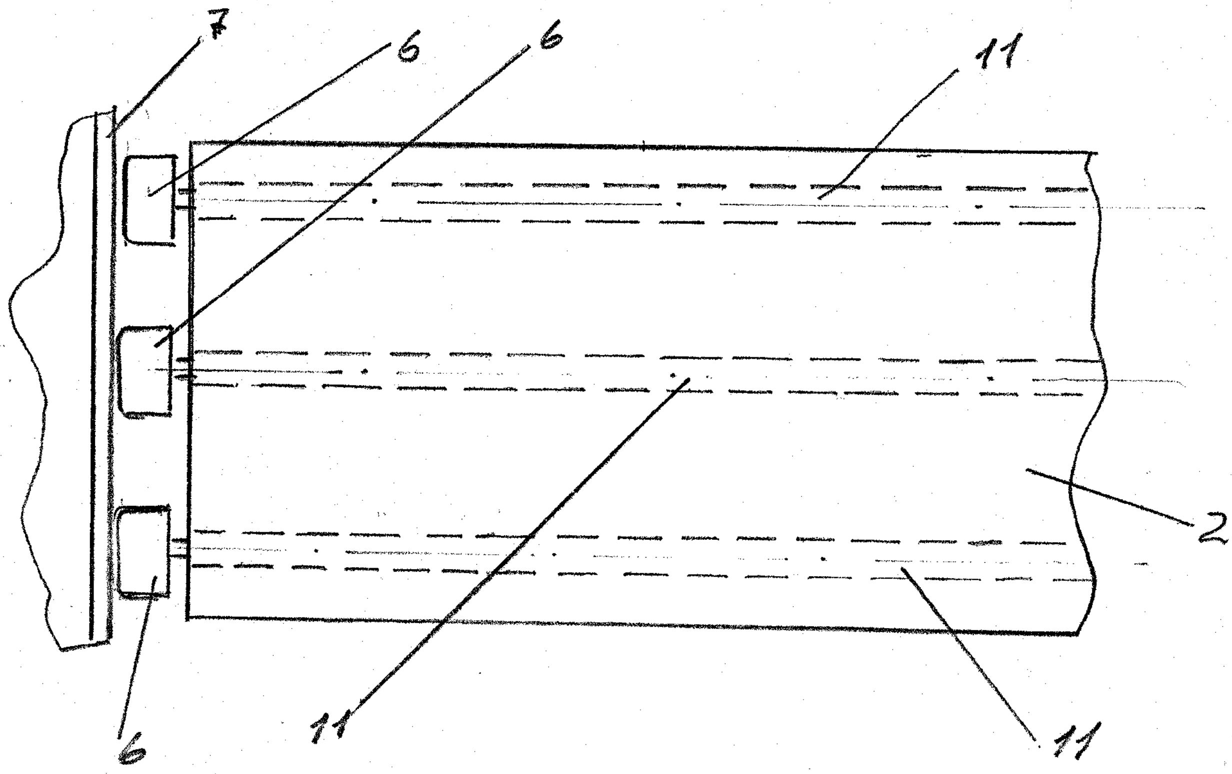


FIG 3

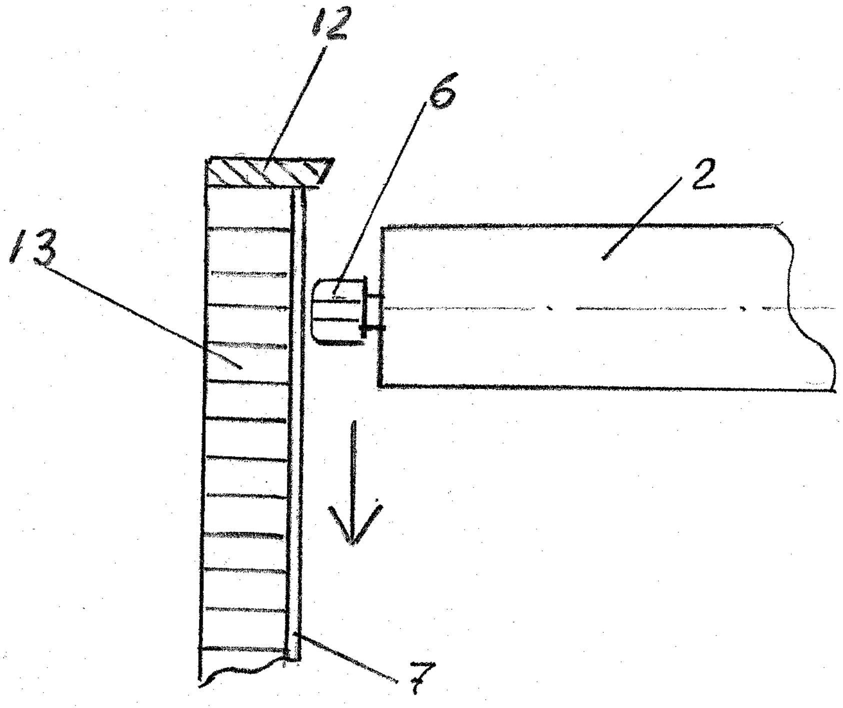


FIG 4

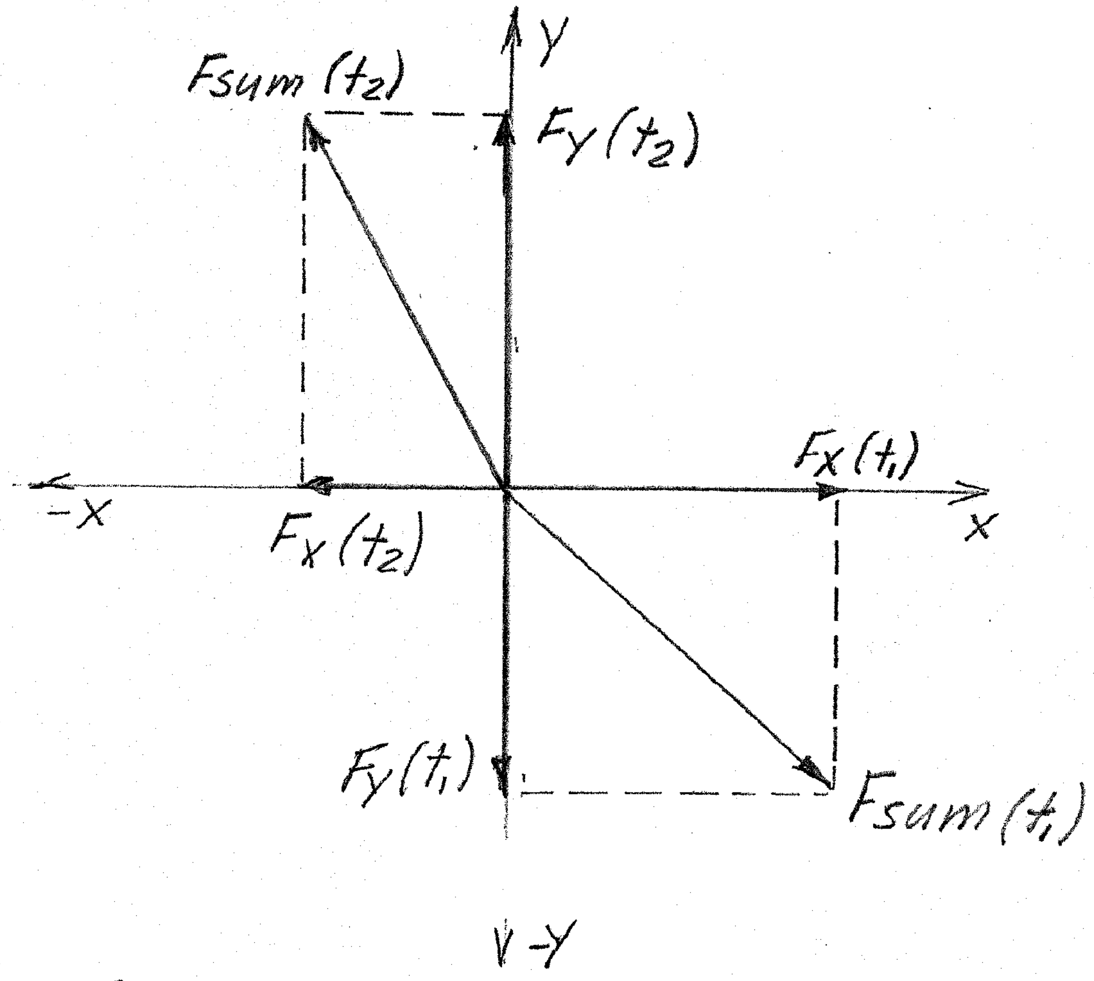
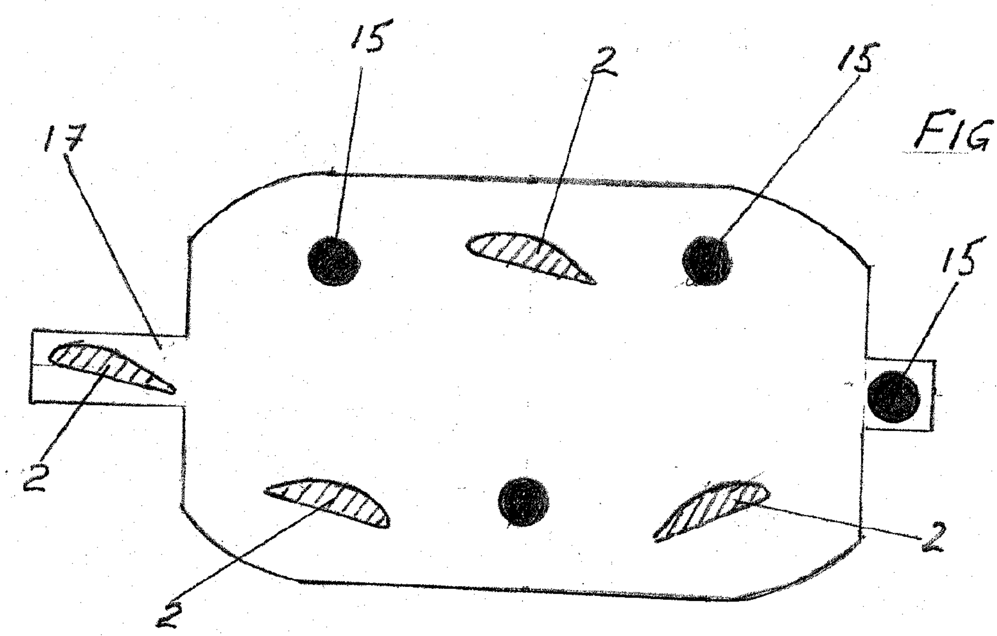


FIG. 5 (Vectors of forces at times t1 and t2)

FIG 6



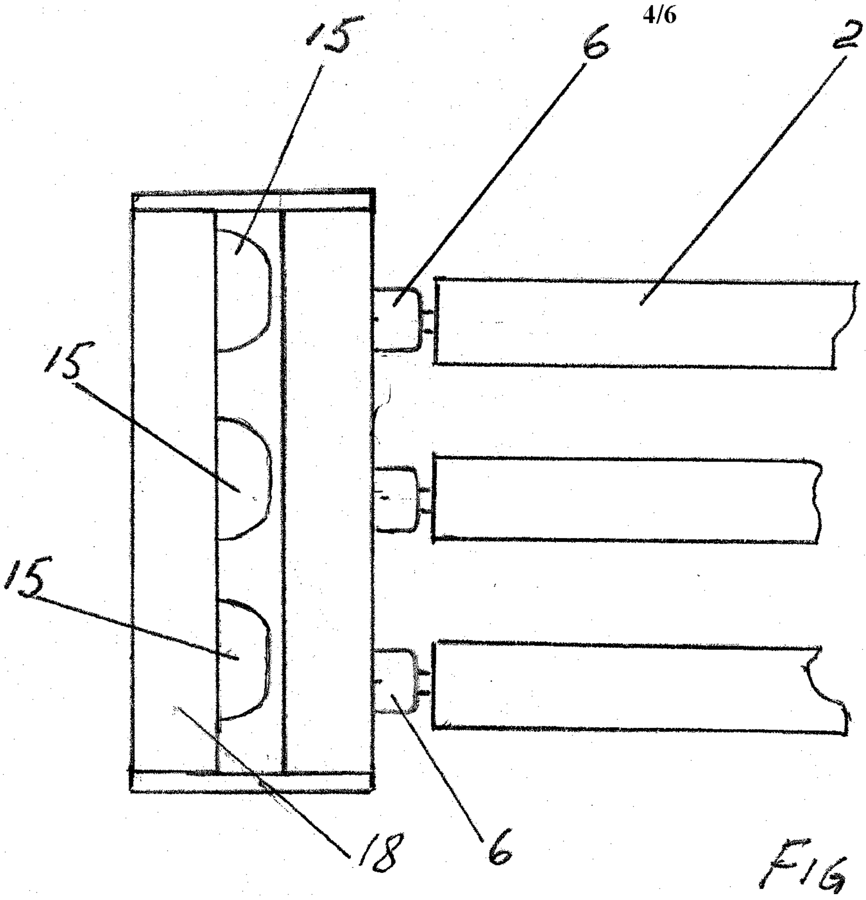


FIG 7

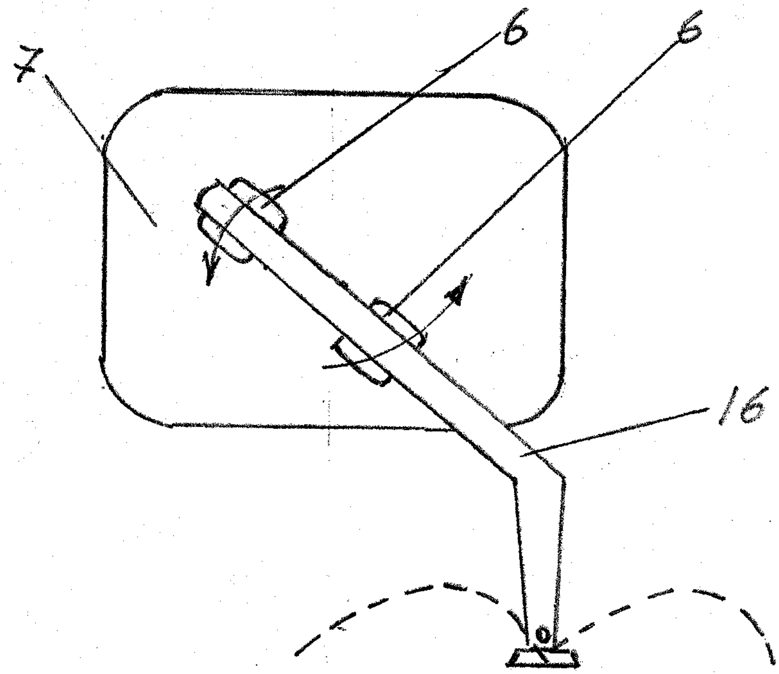


FIG 8

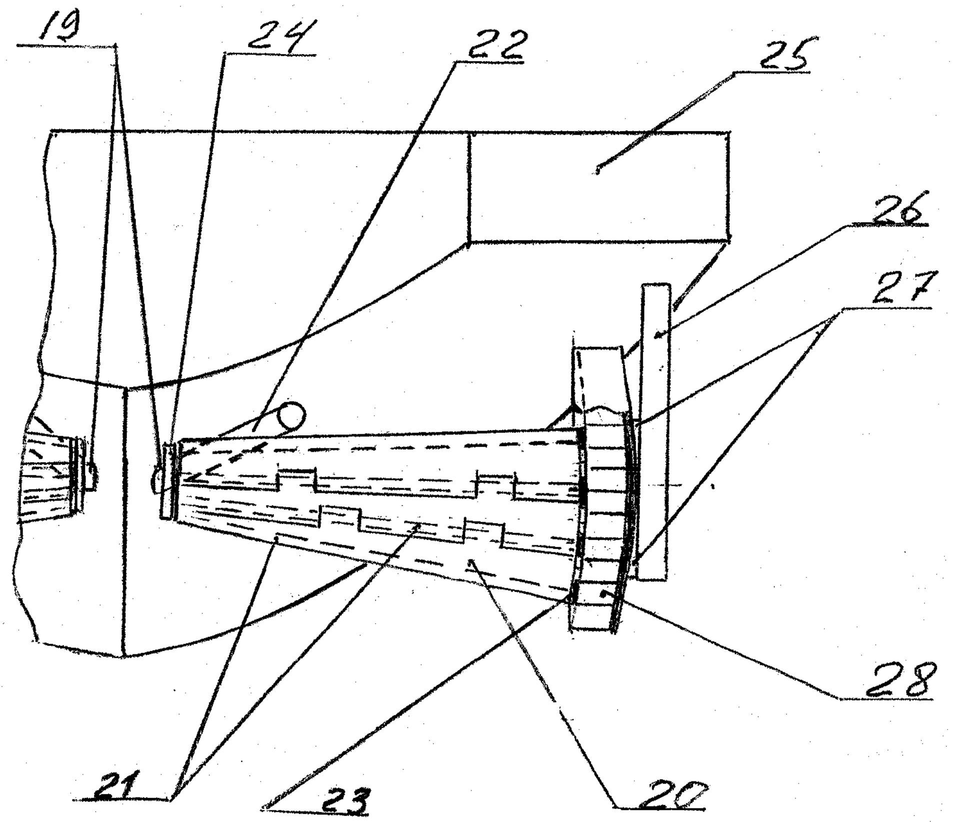


Fig 9

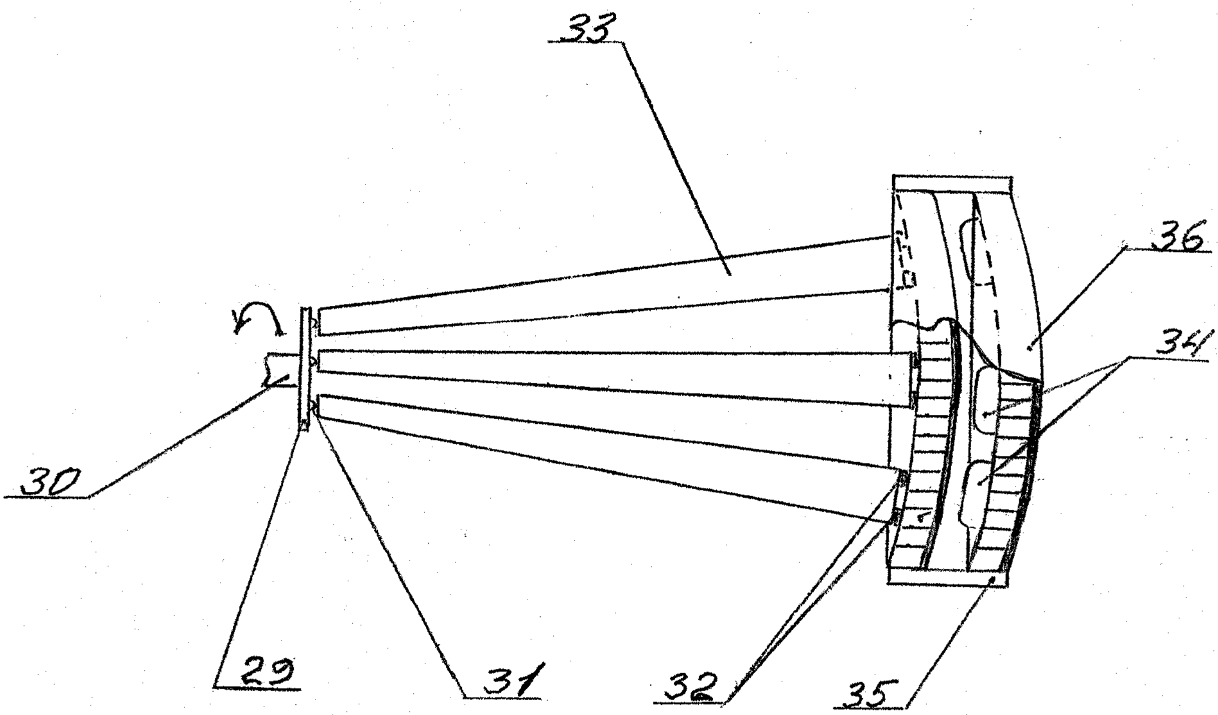


FIG 10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL2013/050755

A. CLASSIFICATION OF SUBJECT MATTER
IPC (2013.01) B64C 39/00, B64C 11/00, B64C 27/00

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)
IPC (2013.01) B64C 39/00, B64C 11/00, B64C 27/00, H02K 1/00, B63G 8/00

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)
Databases consulted: USPTO, THOMSON INNOVATION, Esp@cenet, Google Patents

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4648345 B John 10 Mar 1987 (1987/03/10) whole	1-4,6,7,9,10,14
Y	whole	5,8,11-13,15-19
A	whole	20
X	US 20050106956 A Robert 19 May 2005 (2005/05/19) whole	1-4,6,7,9,10,14
Y	whole	5,8,11-13,15-19
A	whole	20
X	GB 2388095 A Daggar 05 Dec 2003 (2003/12/05) whole	1-4,6,7,9,10,14

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
31 Dec 2013	31 Dec 2013

Name and mailing address of the ISA:	Authorized officer
Israel Patent Office Technology Park, Bldg.5, Malcha, Jerusalem, 9695101, Israel Facsimile No. 972-2-5651616	GUTKIN Solomon Telephone No. 972-2-5651763

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL2013/050755

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	whole	5,8,11-13,15-19
A	whole	20
A	US 5967749 B Stephen 19 Oct 1999 (1999/10/19) whole	1-20
A	US 20070257494 A Firmiliano 08 Nov 2007 (2007/11/08) whole	1-20

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IL2013/050755

Patent document cited search report	Publication date	Patent family member(s)	Publication Date
US 4648345 B	10 Mar 1987	NONE	
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		GB 2388095 A	05 Nov 2003
US 5967749 B	19 Oct 1999	NONE	
US 20070257494 A	08 Nov 2007	NONE	