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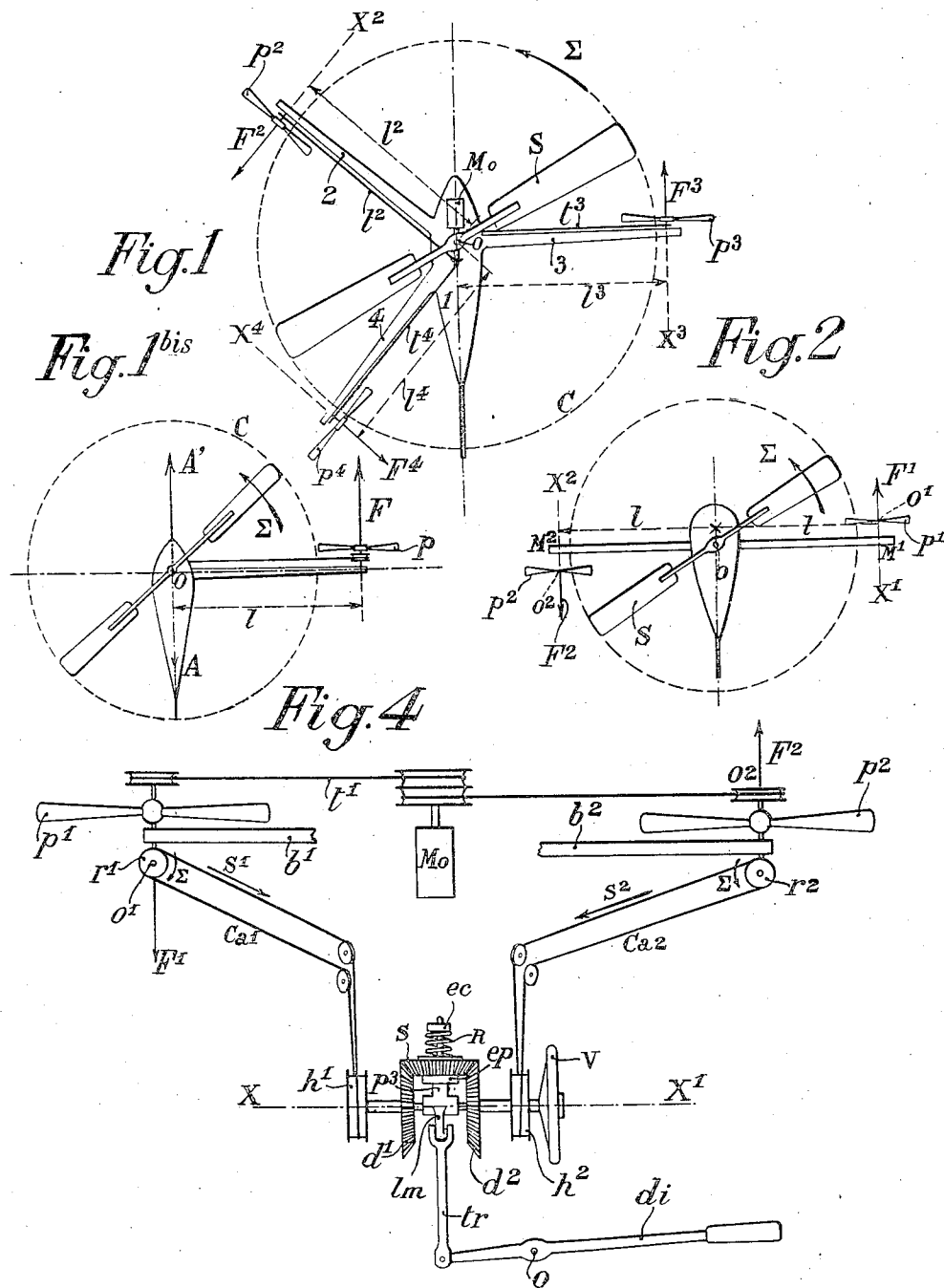
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STEERING AND PROPELLING DEVICE FOR HELICOPTERS

Filed June 28, 1929

2 Sheets-Sheet 1



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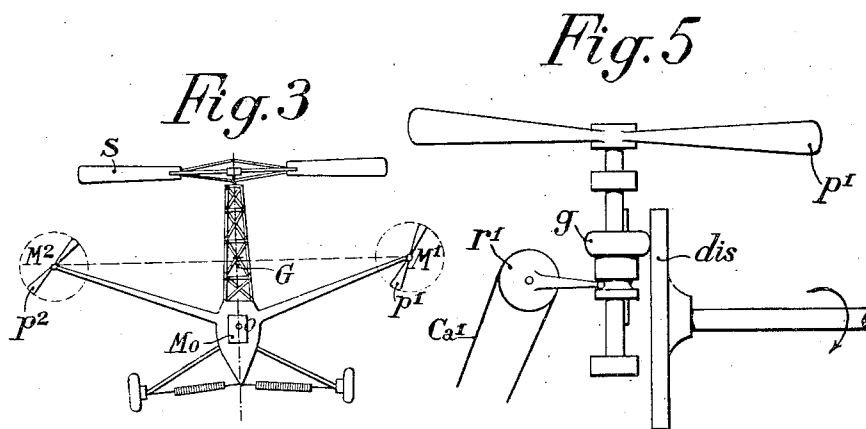
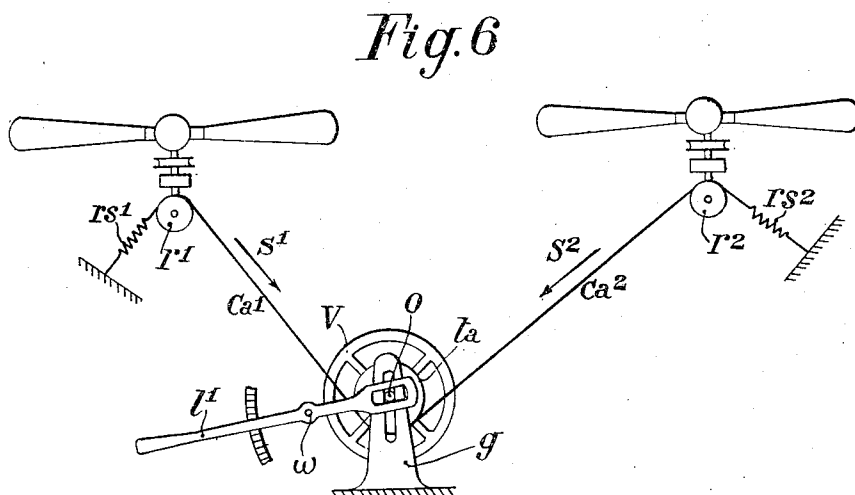
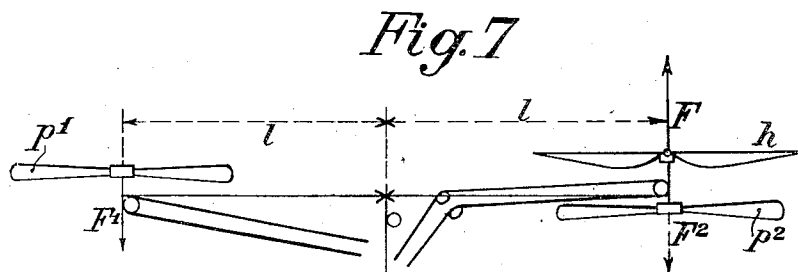
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STEERING AND PROPELLING DEVICE FOR HELICOPTERS

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2 Sheets-Sheet 2



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## UNITED STATES PATENT OFFICE

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## STEERING AND PROPELLING DEVICE FOR HELICOPTERS

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The present invention has for object a steering and propelling device for machines of the helicopter type.

$p^4$ , the axes of rotation  $X^2, X^3, X^4$  of which are located in the plane of the figure which is assumed to contain the center of gravity of the machine projected at O.

More particularly applicable to machines having a single lifting or supporting propeller set in motion by an engine integral with the cock-pit. The invention is also applicable to machines having several noncompensated lifting propellers, that is to say for which the algebraic sum of the moments of the torques opposed by the air to the rotation of each of the lifting elements is different from zero, the said moment being considered relatively to any axis parallel to the axes of the various lifting elements.

The auxiliary propelling elements are mechanically actuated in any manner whatever, for instance by means of transmissions such as  $t^2, t^3, t^4$  actuated by the main engine or engines of the cock-pit.

If we designate by M the driving torque absorbed by the rotation of the lifting element S at a given moment, it is necessary, in order that the cock-pit should not tend to rotate on itself, that the forces such as F and the leverages such as l, should be related by the condition

$$(1) \quad F^2 \times l^2 + F^3 \times l^3 + F^4 \times l^4 \text{ etc. } \dots = M$$

If, on the other hand, the forces  $F^2, F^3, F^4$  etc. do not admit a general resultant, the machine tends to remain on the spot, the anti-rotation torque being simply destroyed by the action of the propelling elements.

If now the condition (1) ( $\Sigma F^i = M$ ) is realized, and that, on the other hand, the forces  $F^2, F^3, F^4$  etc. admit a general resultant F, the machine will tend to enter in transmission in the direction of F; the propelling stress being precisely equal to this force F.

The simplest case in which these two conditions are realized is that of Fig. 1 bis, in which a single propelling element b is used, this propelling element acting at the end of a leverage l and developing a stress F, such as  $F^1 = M$ . The machine then tends to enter in translation and the cock-pit has, at the same time, no tendency whatever to rotate of itself. This may be very easily understood by assuming, as one has always the right to do, that at point O have been applied two equal and directly opposed forces OA and OA', parallel to the forces F and equal to the said force. The forces F and OA determine a torque having a moment equal to  $F^1$ ; that is to say to M, this torque is transportable in its plane and exactly opposes itself to the anti-rotation. Relating to the forces OA' equal and parallel to F, it drives the machine in its direction without any unbalancing since it acts at the center of gravity.

For greater clearness, the case of a machine having a single lifting propeller will be considered, the reasoning remaining rigorously the same in case of machines having several noncompensated propellers.

In the particular case of an helicopter having a single lifting propeller which is caused to rotate by an engine integral with the cock-pit, the said cock-pit tends to rotate about the axis of the lifting element under the influence of a torque equal to the torque opposed by the resistance of the air to the rotation of the lifting propeller.

The principle of the invention rests on the application, at suitable chosen points of the cock-pit, of aerodynamic forces suitable chosen and moreover, adjustable according to a special method. These forces are obtained by the action of the auxiliary propelling elements the axes of which are located in a plane passing through the center of gravity of the machine and at right angles to the axis of rotation of the lifting element.

Fig. 1 shows by way of example an arrangement of these forces; S designates the lifting element, C the circumference described in the direction  $\Sigma$  by the ends of the said lifting element, O the projection on the plane of the figure of the axis of rotation.

The cock-pit in which the main engine Mo is assumed to be secured, is indicated at 1. At 2, 3, 4, etc. . . . , are shown beams or girders rigid with the cock-pit 1.

$F^2, F^3, F^4$ , etc. . . . are the stresses created by the auxiliary propelling elements  $p^2, p^3$ ,

The principle of the invention is not limited to this particular case, but comprises the use of any number of eccentric forces, such as  $F^2$ ,  $F^3$ , etc. . . ., the intensity of which can be controlled at will, so that the condition (1) be always fulfilled, whilst leaving the possibility of making provision in order that the said forces admit or not a general resultant such as  $F$ .

For simplifying the description, the case of a machine having a single lifting propeller will be considered.

Figs. 2 and 3, of which 2 is a diagrammatic plan view and 3 a diagrammatic elevation, relate to this case.  $S$  is a lifting propeller rotating in the direction  $\Sigma$ ; the propelling elements are reduced to two, shown at  $p^1$  and  $p^2$ ; they rotate about two parallel axes  $X^1$  and  $X^2$  by means of any transmission connected, for instance, to the engine  $Mo$  of the cock-pit  $c$ . The propelling elements are symmetrically arranged relatively to the axis  $OG$ .

The line  $O^1$ ,  $O^2$  joining the centers of the propelling-elements, passes through the center of gravity  $G$  of the machine. The forces  $F^1$  and  $F^2$  created by the propelling-elements  $p^1$  and  $p^2$  must, at every instant, be such that:

$$F^1 \times M^1 G + F^2 \times M^2 G = M \quad (2)$$

in which  $M$  always designates the driving torque absorbed by the lifting member  $S$ .

This driving torque  $M$  varies relatively slightly during flight. It is subjected to really important variations only when the machine is climbing, is coming down, or again during a particularly rapid translation.

This torque  $M$  will be assumed to be constant, for simplifying the description, but the reasoning remains the same if such is not the case.

Assuming the condition (2) is realized, if, by means of a suitable device, the forces  $F^1$  and  $F^2$  are subjected to diminutions equal to each other, the entire cock-pit will be driven in a movement, of rotation in a direction  $-\Sigma$ . If both forces  $F^1$  and  $F^2$  are, on the contrary, subjected to a simultaneous increase, the cock-pit will rotate in the direction  $+\Sigma$ .

By causing the forces  $F^1$  and  $F^2$  to simultaneously vary in the same direction, the cock-pit can be set in any desired direction, the rotation of the said cock-pit ceasing only when the forces will have been brought back to the value for which the condition (2) is fulfilled.

For obtaining this result, it suffices, for instance, to use as propelling elements  $p^1$  and  $p^2$ , variable pitch propellers, the incidence of which is adjustable at will.

The pilot, by acting on the incidence control of these two propelling elements can cause the cock-pit to rotate in one direction or the other.

Assuming this hypothesis is realized, the immobility of the propeller in the space will

be obtained if the forces  $F^1$  and  $F^2$  are equal to each other. Their common value is then designated by  $F$ .

If now the force  $F^1$  is diminished according to a pretermined amount and that the force  $F^2$  increases exactly to the same amount, the condition (2) will always be fulfilled since  $\Sigma FR$  will remain constant, but the system will then admit a general resultant equal to  $F^2 - F^1$ . The machine will enter in translation under the effect of a tractive stress included between  $O$  and  $2F$ .

For completely obtaining the result sought for, that is to say the control of the steering and of the translation, it must therefore be possible to operate the propelling elements so as to:

(1) Simultaneously increase or diminish their propelling stresses for causing the machine to rotate on itself in one direction or the other;

(2) Cause the stresses of the propelling elements  $p^1$  and  $p^2$  to differentially vary so that their sum remains constant, and this for causing the translation stress to vary from zero to its maximum  $2F$ .

This result can be obtained in various ways, the simplest of which consists in regulating the angles of incidence of the propelling elements, or their speeds of rotation.

Fig. 4 shows a particular form of carrying out the invention, in the case of two propelling elements  $p^1$  and  $p^2$ , constituted by variable pitch propellers.

This Fig. 4 illustrates a diagrammatic plan view of the machine:  $t^1$  is the transmission actuating the propelling elements, the center of gravity of the machine is in the plane of the figure. The cock-pit is not shown  $b^1$  and  $b^2$  are two arms rigidly secured on the cock-pit and, generally speaking, all the elements of the figure are also secured on the said cock-pit;  $r^1$  and  $r^2$  are two pulleys supported by the arms  $b^1$  and  $b^2$ . The rotation of these pulleys in one direction or the other allows, during the operation of the propelling elements, of modifying the mean incidence of their blades between given limits  $+i$  and  $-i$ .

$\Sigma$  is the direction of rotation of the pulleys which corresponds, for instance; to an increase of incidence of the propelling elements they control.

The propelling air-screws  $p^1$  and  $p^2$  create stresses  $O^1 F^1$  and  $O^2 F^2$ .

$Ca^1$  and  $Ca^2$  are cables winding on drums  $h^1$  and  $h^2$ . When these drums rotate in the same direction, the cables are simultaneously urged in the directions  $S^1$  and  $S^2$ , or in the directions  $-S^1$  and  $-S^2$ , and the simultaneous rotation of both pulleys  $r^1$  and  $r^2$  is effected either in the direction  $\Sigma$ , or in the direction  $-\Sigma$ , that is to say that an increase or a diminution of the incidence of the propelling elements is produced.

If the cables  $Ca^1$  and  $Ca^2$  are operated in

reverse direction relatively to each other,  $S^1$  for instance for the cable  $Ca^1$  and  $-S^2$  for the cable  $Ca^2$ , the incidence of one of the propelling elements increases, whilst that of the other diminishes according to the same amount.

The drums  $h^1$  and  $h^2$  are respectively rigid with toothed crowns  $d^1$  and  $d^2$  of a differential gear, the planet wheel  $s$  of which is mounted on a planet wheel-carrying shaft  $ps$ . The planet wheel-carrying shaft is provided with a shoulder  $ep$  on which the planet wheel fits by means of a spring  $R$  held by a nut  $ec$ , so that the planet wheel  $s$  frictionally rotates about its shaft  $ps$ . On the same shaft is rigidly secured a lever the projection of which is seen at  $lm$  (represented somewhat obliquely in the figure for greater clearness) and on which is pivoted another lever  $tr$  leading to a last steering lever  $di$ , pivoted about a point  $o$ .

On the drum  $h^2$  is secured a hand wheel  $v$ . The operation is as follows:

If the lever  $di$ , usually actuated by the pilot's foot, acts on the lever  $lm$ , it causes the rotation of the planet wheel-carrying shaft  $ps$  about the axis  $XX'$ .

Owing to the friction existing between the planet wheel and its shaft, the said planet wheel does not rotate on itself and simultaneously drives both toothed crowns  $d^1$  and  $d^2$  and, consequently, the drums  $h^1$  and  $h^2$ . These drums determine the simultaneous operation of the cables, either in the directions  $S^1$  and  $S^2$ , or in the directions  $-S^1$  and  $-S^2$ , according to the direction of rotation of  $di$ .

There is therefore simultaneous increase or diminution of the incidence of the propelling elements, this allowing to set or orient the cock-pit at will.

If now the lever  $di$  is held stationary by the pilot and that the latter operates at the same time the hand wheel  $v$  in any direction, the planet wheel-carrying shaft  $ps$ , held stationary, can no longer rotate about the axis  $XX'$ . The planet wheel therefore rotates on itself by overcoming the resistance of the friction and acts, between the crowns  $d^1$  and  $d^2$ , as an intermediate pinion.

The crowns  $d^1$  and  $d^2$  then rotate in reverse direction, this having for effect to determine an increase of incidence of one of the propelling elements and an equal diminution of the incidence of the other. There is then variation of the general resultant parallel with the lines of action of the propelling elements and equal to the difference of the stresses they create. This variation allows to vary the general translation stress between zero and its maximum value.

The anti-rotation torque has remained very approximately the same, as variations of incidence determine approximately proportional variations of the thrusts of the propelling elements  $p^1$  and  $p^2$ . It suffices more-

over if there is a material variation of the torque, to act on the lever  $di$  for maintaining the direction of the machine in the chosen direction. This action of the lever  $di$  can take place during the operation of the hand wheel  $v$ .

As will be seen, this device allows to realize the previously mentioned conditions.

The principle of the invention is not in any way modified if, instead of causing the incidence of the propelling elements to vary, their speed is caused to vary. It suffices to assume (Fig. 5) that the pulleys such as  $r^1$  instead of acting on the incidence of the propelling elements, move for instance friction rollers  $g$  on rotating discs  $dis$  actuated by the engine and that the whole is combined in such a manner that the operations of the pulleys  $r^1$  and  $r^2$  produce a simultaneous increase or diminution of the speed of the propelling elements when the cables are pulled in the directions  $S^1$  or  $S^2$  or  $-S^1$  and  $-S^2$ , or on the contrary, an increase of the speed of one of the propelling elements and a diminution of the speed of the other, when they are operated in the directions  $S^1$  and  $-S^2$  and  $-S^1$ .

It can even be imagined that the operation of these cables acts in such a way as to vary the speed of two independent engines, respectively actuating the propelling elements  $p^1$  and  $p^2$  and the cables of which control for instance the admission, the principle of the invention still consisting in utilizing the torque created by auxiliary propelling elements, balancing the anti-rotation torque of the cock-pit, with the exception of the differences necessitated by the orientation or steering movements of the latter, with or without production of a general resultant of translation.

Numerous modifications of the device described may be considered and the use of a differential gear is not in any way necessary. The controls themselves are of any type and may be pneumatic, electric, link or like controls.

Fig. 6 shows by way of example a modification without differential gear, in which  $r^1$  and  $r^2$  still represent operating pulleys capable of varying the stress of the propelling element, either by variation of their incidence, or by variation of their speed; the said pulleys can moreover, be replaced by levers, rocks, etc. . . . and the cables by any transmission members. The pulley system and the cable are simply maintained by way of example.  $rs^1$  and  $rs^2$  are returning springs tending to pull the cables in the directions  $-S^1$  and  $-S^2$ .  $ta$  is a drum about which passes the cable  $Ca^1 Ca^2$ . It is movable about its center  $O$  and braked on its axis, which latter can be moved in the guideway of a slide  $g$ .

To the drum  $ta$  is connected a hand wheel  $v$  and the axis  $O$  is itself urged by a forked

lever  $l^1$  pivoting about the point  $\omega$  and serving for steering purposes.

If the lever  $l^1$  is angularly moved, the drum  $ta$  moves down without rotating on itself; the cables are urged in the directions  $S^1$   $S^2$  and there is for instance simultaneous increase of the effect produced by both propelling elements, resulting in an orientation or steering movement.

If now the lever  $l^1$  being held stationary, the hand wheel  $v$  is acted upon for causing the drum  $ta$  to rotate, the cables  $Ca^1$  and  $Ca^2$  are urged either in the directions  $S^1$  and  $-S^2$ , or in the directions  $-S^1$  or  $+S^2$  and the same effect as above is obtained.

It will thus be seen that it is easy to imagine as many driving devices as desired, without departing from the principle of the invention.

To the device may be conveniently added a movable surface acting as a rudder and mechanically connected to the lever  $dz$ . Useless when the machine is at rest, this rudder acts as soon as the helicopter is in translation. It contributes by its orientation to facilitate the changes of direction and to improve the stability during flight.

The device can, on the other hand, be provided with one or more fixed pitch propellers adapted to realize totally or partially the anti-rotation torque.

Fig. 7 shows by way of example such an arrangement with a single fixed pitch propeller.

$p^1$  and  $p^2$  illustrate the variable pitch propelling elements. Here, the forces they create are of the same direction and are indicated at  $F^1$  and  $F^2$ .

The fixed pitch propeller  $h$  creates the stress  $F$ . The leverages are assumed to be equal, if the propelling elements are so adjusted as to each create a stress  $F^2$  and there is no general resultant. The resulting torque is  $F^1$ . It remains the same if the stresses  $F^1$  and  $F^2$  are simultaneously varied. There is then a general resultant directed in one direction or the other and which can be used for dragging the machine or on the contrary for braking it.

The differential control of the propelling elements  $p^1$  and  $p^2$  produces the steering, so that the manipulations of the preceding hand wheel and lever produce reverse effects.

This arrangement has the advantage, in translation with full tractive power  $F$ , or really utilizing the propeller  $h$  only, the efficiency of which is always greater than that of the variable pitch propelling elements. It shows, on the other hand, the multiplication of the method of realization or of application of the invention.

Claims:

1. In a helicopter, the combination of a lifting system comprising one or more rotary lifting elements, auxiliary propelling ele-

ments, the axes of rotation of which are situated at a certain distance from the center of gravity of the machine in a plane passing through the said center of gravity at right angles to the axis or axes of rotation of the lifting elements and means for controlling the stresses created by the said propelling elements, said means being such that the said auxiliary propelling elements create constantly a torque equal and oppositely directed to the antirotation couple of the frame, due to the reactions of the air upon the lifting element or elements and, at the will of the pilot, an horizontal propelling stress.

2. In a helicopter, the combination of a lifting system comprising one or more rotary lifting elements, auxiliary propelling elements, the axes of rotation of which are situated at a certain distance from the center of gravity of the machine in a plane passing through the said center of gravity, at right angles to the axis or axes of rotation of the lifting elements and means controlled by the pilot and adapted to render unequal the stresses created respectively by the said auxiliary propelling elements.

3. In a helicopter, the combination of a lifting system comprising one or more rotary lifting elements, auxiliary propelling elements the axes of rotation of which are situated at a certain distance from the center of gravity of the machine in a plane passing through the said center of gravity, at right angles to the axis or axes of rotation of the lifting elements and means controlled by the pilot and adapted to render unequal the stresses created respectively by the said auxiliary propelling elements whilst maintaining substantially constant the sum of their moments relatively to the center of gravity of the machine.

4. In a helicopter, the combination of a lifting system comprising one or more rotary lifting elements and auxiliary propellers, whose incidence is variable and the axes of rotation of which are situated at a certain distance from the center of gravity of the machine in a plane passing through the said center of gravity, at right angles to the axis or axes of rotation of the lifting elements and means for controlling the incidence of the said propelling elements, the said means being such that the said auxiliary propelling elements create constantly an equal torque oppositely directed to the torque of anti-rotation of the frame, due to the reactions of the air upon the lifting element or elements, and at the will of the pilot, an horizontal propelling stress.

5. In a helicopter, the combination of a lifting system comprising one or more rotary lifting elements and auxiliary propellers whose incidence is variable and the axes of rotation of which are situated at a certain distance from the center of gravity of the

machine in a plane passing through the said center of gravity, at right angles to the axis or axes of rotation of the lifting elements and means for modifying in the reverse directions the angles of incidence of the blades of the said auxiliary propelling elements.

6. In a helicopter, the combination of a lifting system comprising one or more rotary lifting elements and auxiliary propelling elements the axes of rotation of which are situated at a certain distance from the center of gravity of the machine in a plane passing through the said center of gravity, at right angles to the axis or axes of rotation of the lifting elements, pulleys controlling the adjustment of the incidence of the blades of the propelling elements, pulleys connected to these first pulleys by cables, driving wheels rigid with these second pulleys, a pinion gearing with the said driving wheels, a shaft on which this pinion is coupled by friction, a control lever adapted to cause the shaft carrying the said pinion to rotate about the axis of the driving wheels and a hand wheel rigid with one of the driving wheels.

In testimony whereof I have hereunto affixed my signature.

ETIENNE OEHMICHEN.

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