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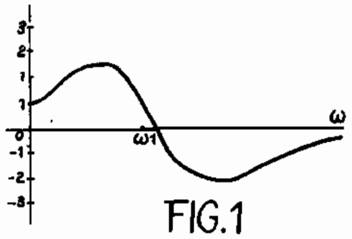

FIG.1

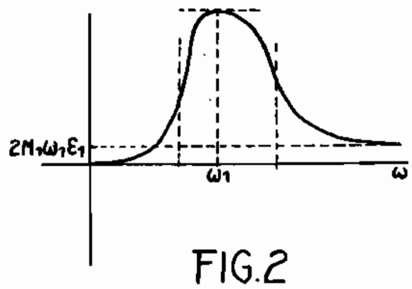

FIG.2

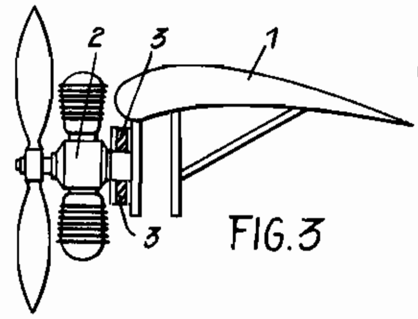

FIG.3

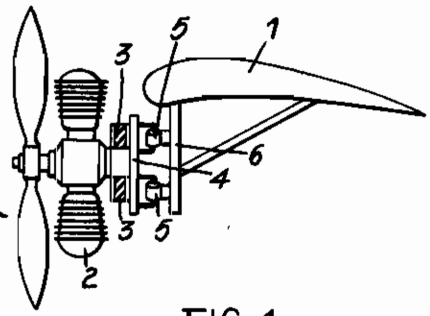

FIG.4

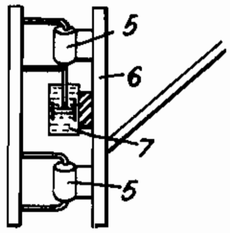

FIG.5

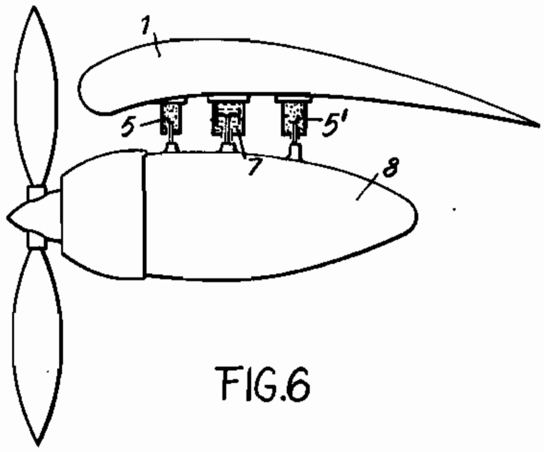

FIG.6

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ALIEN PROPERTY CUSTODIAN

SUSPENSION DEVICES

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This invention relates to the suspension of aeroplane engines and other members on supports subjected to reciprocating movements and more particularly the wings.

Resilient suspensions have already been employed for engines and more particularly for the engines of aeroplanes for the purpose of protecting their frames from the vibrations due to the irregularities of the torque of the said engines.

It has also been proposed (French Patent No. 798,631 of the 28th November, 1935) to construct resilient elements giving also a radial elasticity so that if, for example, the engine has a dynamic want of balance in its rotary movement the frame is automatically protected from the vibrations due to this dynamic want of balance, provided that the resilient elements are suitably calculated.

The present invention envisages the case in which the frame of the engine itself cannot be considered as fixed but is on the contrary rigid with a body which has certain reciprocating movements damped or maintained.

The presence of the engine provided with its suspension then modifies the movements of the body in question in a complex manner by its reactions and it is desirable in such a case to determine the suspension while taking into account not only the vibrations of the engine which must be prevented from being transmitted to the body but also the characteristic movements of the body which it is necessary to avoid making self-maintained and which must be even more damped if possible.

To attain these results the invention proposes to employ a suspension system having torsional elasticity and also radial elasticity, characterised in that the radial elasticity is not the same in the various radial directions and that it is adjusted at least in the most important radial direction (generally the vertical direction) under quite definite conditions, which will be indicated below.

In addition to this definite elasticity it is again proposed according to the invention to introduce suitably proportioned damping means in order to damp the vibrations of the engine relatively to the body which supports it.

An important particular application of the invention is that of an engine mounted on a wing capable of entering into flexion torsion vibrations for example.

It is known that in certain cases these vibrations are self-maintained by the aerodynamic forces. If there are more degrees of freedom (wing with aileron for example) the possible cases of vibrations are still more frequent. These vibrations naturally present great dangers and it is of the highest importance to make the engine and its suspension contribute towards damping them.

Under these conditions the engine only takes part through its mass and all the other masses attached to the wing, such as the landing gear for example, can advantageously be mounted according to the same principles. In such a case the torsional elasticity no longer takes any part and the invention consists solely in a suspension to the supporting mass with an elasticity in the vertical direction, that is to say the characteristic vibrations of the support, accompanied by damping, and such that it allows the maximum damping effect according to the principles which will be explained below.

In a general manner it can be said that the invention is characterised by the fact of mounting in absorbers of vibrations the masses which are necessarily fixed to the wing proper and which do not take part in the wing profile for creating the lift.

The effects of a mass supported resiliently and with viscous damping on the vibrations of an aeroplane wing can be expressed in figures as follows—

Let M_1 be the value of the suspended mass. If ω_1 is the pulsation of resonance of the said mass on its resilient support of the point of suspension fixed in space and if the movement of the said mass is effected with a coefficient of damping $M_1\ \omega_1\ \epsilon$ so that the equation of this movement is:

$$M_1\omega^2_1 z+2M_1\omega_1\frac{dz}{dt}+M_1\frac{d2z}{d_{t2}}=0 \qquad (1)$$

it is found that at each pulsation ω everything happens as regards the wing as if there had been fixed to the point of suspension a mass m rigidly connected to it such that

$$m=M_1\frac{1-\left(\frac{\omega}{\omega_1}\right)^2+4\epsilon^2\left(\frac{\omega}{\omega_1}\right)^2}{\left(1-\left(\frac{\omega}{\omega_1}\right)^2\right)^2+4\epsilon^2\left(\frac{\omega}{\omega_1}\right)^2} \qquad (2)$$

and as if, on the other hand, there had been attached between the same ordinate point z_1 of the vibrating wing and a point fixed in space a viscous damper creating the damping force

$$F=2M_1\omega_1\epsilon\frac{\left(\frac{\omega}{\omega_1}\right)^4}{\left(1-\left(\frac{\omega}{\omega_1}\right)^2\right)^2+4\epsilon^2\left(\frac{\omega}{\omega_1}\right)^2}\frac{dz_1}{dt}$$

If it is desired to study in detail the effects of the said mass m added to the wing and of the said damping force, it is naturally necessary to observe the repercussions which they involve on the movements of flexion and torsion of the wing.

The effect of the mass m is to modify also in a rather important manner the principal coefficients of inertia in the equations of their movement, to modify much more the terms of coupling by inertia which can even change sign. The effect of the force F is to add everywhere, at all the degrees of freedom of the deformable wing a proportional damping independent of the speed of the aeroplane and which can compensate incompletely or superabundantly the negative damper of aerodynamic origin due to the effects of torsion. In the case in which the compensation is superabundant the placing of the wing in self-vibration starting from a certain critical speed becomes impossible.

It must now be explained how the factors vary with the pulsation ω.

Figure 1 shows the variations of the ratio m/M_1 as a function of ω. This figure shows that at very slow pulsations the mass brought back is equal to M_1. For a certain value of ω in the neighbourhood of but less than ω_1 it passes a maximum which will attain for example the value of 2.2 M_1 if we give to ϵ the value 0.11. For a value of ω scarcely greater than ω_1 m disappears and then changes sign.

It is thus seen that for all the values of ω less than ω_1 the wing has an inertia which is greater than in the absence of mass M and its characteristic frequencies are reduced but that for all greater values of ω everything takes place as if there had been added to the wing a negative mass, that is to say, a kind of resilient return dependent on the frequency, that is to say again that its characteristic frequencies of torsion and flexion will be increased.

This latter circumstance is a priori favourable to the disappearance of the critical speeds for the aeroplane but the most important phenomenon resides in the fact that the distribution of weight relatively to the elastic axis changes very much on account of the positive mass m.

Figure 2 shows in the same way the variations in the coefficient of the force F as a function of ω. From the course of this variation it results that owing to the resonance an extremely large damping force is brought back on the wing for all the frequencies of vibration in the region of $\mp$ 30% around ω_1. All the dampings which result therefrom increase in proportion.

The Applicants have found more particularly that if the suspension of the engine is of the adhering rubber type which has a sufficiently high damping factor ϵ the damping of the flexion and the torsion of the wing resulting from placing the engine in resonance at about $\mp$30%, is about six times greater than the damping of structure of the wing itself supposed of metallic construction: this number six increasing to twenty in the case of the strict resonance $\omega=\omega_1$.

The mathematical theory of the putting into vibration of a wing having flexion-torsion provided with an engine suspended in this way has shown the Applicants that the critical speeds completely disappear owing to the damping.

These explanations having been given the effect of the devices which form part of the invention will be better understood.

Figure 3 shows a suspension according to the invention but in which separate means are not used for ensuring the necessary vertical freedom. It shows the wing 1 in section, the engine 2, the rubber blocks 3 of the suspension. The invention thus consists in constructing and arranging the said blocks 3 so that the resonance of the engine on the suspension in the up-and-down movement has a pulsation ω_1 comprised between the characteristic pulsation of flexion and the characteristic pulsation of torsion of the wing or less than these two values.

This can quite well be a feature of the invention in view of the fact that in all the suspensions hitherto known the said pulsation ω_1 is very much greater than these values.

The other characteristic frequencies of the engine in the other degrees of freedom will be determined, for example, to satisfy the conditions set forth in the French Patent No. 798,631 already mentioned.

Figure 4 shows a more characteristic arrangement of the invention. The engine 2 is mounted by means of elastic joints 3 calculated according to the conditions of the French Patent No. 798,631 fixed on a plate or frame 4 which is itself mounted with large freedom for up-and-down movements by means of new elastic supports 3 preferably of the type giving a single degree of axial freedom, on the engine frame proper 6 rigidly fixed to the wing 1. The elasticity of the flexible devices 5 or similar devices is then chosen so that in the vertical up-and-down movement, taking into account the elasticities in series 3 and 5, has a resonance ω_1 equal to or greater than the characteristic pulsations of the wings.

Figure 5 shows an improved arrangement in which there is provided between the mounting 4 and the frame 6 real dampers, preferably hydraulic, and giving the desired degree of damping, for example to bring the coefficient ϵ of the equation (1) to the value $\epsilon=0.4$, which corresponds to a weakening in the ratio of 10 to 1 from one amplitude to the next in a movement of free oscillation.

Figure 6 shows an arrangement of the same order in which there is an engine fuselage 8 comprising engine, cover, fuselage proper covering a retractible gear etc. and, if necessary, tanks, which is suspended according to the principles of the invention on the resilient supports 5 and 5′ working in parallel with the hydraulic damper 7 actuated by the relative movements of the assembly 8 in relation to the wing 1.

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