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THE COAXIAL HELICOPTER VIBRATION REDUCTION.

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ABSTRACT

Theoretical and flight test results are presented. It is shown that substantial reduction of alternating forces acting on a helicopter structure and reduction of vibration level are achieved by selection of coaxial rotor optimum configuration.

1. INTRODUCTION

The problem of the helicopter vibration level reduction is most important today. A lot of technical approaches has been adopted for the same as:

- -aeroelastic blade design;
- -pendulum type vibration absorbers for the blade root section;
- -vibroisolating main rotor and reduction gear mounts;
- -active vibration level reduction systems (HHC ,IBC).

The results of investigation in the field of the vibration level reduction, HHC and IBC systems in particular, were published in many papers and contain analytical models, wind tunnel and flight test data [2-14].

The presented paper is devoted to the formulation and solution of the coaxial helicopter vibration level reduction problem.

2. THE FORMULATION OF THE PROBLEM

At fig.1 there are plotted alternating forces acting upon the coaxial rotors hubs, transmitted via the main rotors and the reductor gear shafts and causing the helicopter vibration. For the sake of simplicity let us examine only the vertical alternating forces upon the upper rotor hub (Fu) and lower rotor hub (FL) acting at the blade

frequency 3ω and corresponding phases Φ_U and Φ_L. At fig.1 there are presented the location of the blades in respect to each other, the direction of the upper and lower rotor rotation as well as the lower rotor No.1 blade azimuth $\Psi_{1U} = \omega t$ and the upper rotor No.1 azimuth $\Psi_{1U} = \omega t + \varphi$.

Some 25 years ago our engineers formulated a simple but rather goog idea : by changing the difference of the alternating forces phases ($\Phi_U - \Phi_L$) on the upper and lower rotors to make these forces act in a counterphase thus reducing the total alternating force and the helicopter vibration level.

This appoach was verified at the Ka-25 helicopter flight testing in 1968.

3. FLYING TEST BED

Flying test bed based on a helicopter was tested in different main rotors system configurations. Namely, φ angle determining the upper rotor blade lead over the corresponding lower rotor blade was set at different values (ref. fig.1).

At a zero lead angle φ=0 the corresponding lower and upper rotor blades "meet" at a zero azimuth at the back in the helicopter longitudinal plane. When the angle is not zero $\varphi > 0$ the blades of the upper and lower rotors come one over the other at the left from the helicopter symmetry plane at an azumuth $\varphi/2$ in the direction of the upper rotor rotation. At the change of the upper rotor blade position in respect to that of the lower rotor blade the difference of the alternating forces acting upon the upper and lower rotor is also changed.

The flight test results of the Ka-25 helicopter are presented at fig.2. It may be seen that the amplitude of the vertical vibrational accelerations considerably depends upon the lead angle value at the flight speed approaching the maximal and decreases by 3...4 times in comparision to that of the basic configuration.

4. MATHEMATICAL MODELLING

The results obtained by modelling the vertical alternating forces on the coaxial rotor hubs present some interest.

The ULYSS-6 general mathematical model of the coaxial rotor system has been used which was described by the autor in his paper presented at the 17th Europian Rotorcraft Forum in 1991 [1].

The model represents the following aeroelastic factors :

- nonlinear motion equations and boundary conditions for the 6-bladed coaxial rotor including the joint elastic blade root torsion at a flexible control linkage;

-coaxial rotor vortex blade model;

-aerodynamic data of the airfoil in a compressible air flow and a dynamic stall based on the results of testing in a stationary stream and testing of oscillating airfoil in the wind tunnels;

-rigid fuselage .

The results of vertical alternating forces calculation using the ULYSS-6 are shown at fig.3,4.

At the left side of fig.3 there are presented the calculated vector diagrams of the vertical alternating forces F_U and F_L acting at a blade frequency 3ω upon the coaxial rotor hubs. A set of vector pairs is presented where each pair corresponds to some definite value of the lead angle (φ). The vectors turn angle F_U , F_L is equal to the blade azimuth when the 3ω frequency vertical forces reaches its maximum value. The vector length is equal to the alternating load maximum value.

It may be seen that the upper rotor force F_U (Ψ_U) as an azimuth function depends little upon the location of blades in respect to each other (angle φ).

The lower rotor force F_L (Ψ_L) amplitude depends considerably upon φ . The Φ_L phase is changed too. The force vector turns in the direction of the upper rotor rotation approximately at an angle $\varphi/2$. The vector "follow" the points where the upper rotor blade tip vortexes meet with the lower rotor blades

The summary vertical force of the two rotors transmitted to the fuselago is shown at the right side of fig.3. The summing up takes account of the upper and lower rotor blades location in respect to each other determined by a φ angle. The summary calculated force has the least amplitude at φ =60 degrees. At flight testing the lowest vertical vibration level was observed at φ = 30 deg. (ref.fig.3).

Same calculations were done also for a simplitied nonvortex coaxial rotor system model i.e. with an inductive flow constant all over the disc. These results are presented at fig 4. It may be seen that 3ω frequency alternating forces values on the blades have grown by about 1.5 times, the force phases do not depend upon the location of the blades in respect to each other. However the summary forces the smallest also at φ =60 deg.

5. THE KA-50 HELICOPTER FLIGHT TEST RESULTS

An a real flight side and longitudinal alternating forces of 3ω frequency also act upon the helicopter along with the vertical forces which complicates the analysis. However we manage to achieve a low vibration level at Kamov helicopters. The blade aeroelastic design and the blade natural frequency are rather important factors in solving the vibration problem.

Fig.5 presents the vibration level of our lastest helicopter Ka-50 .It may be observed that the vibration level along all three axises-vertical, longitudinal and side-is rather low.

6. CONCLUSIONS

The investigations carried out in the field of aeroelasticity and vibrations at the Kamov Helicopter S&TCo. pemit to achieve a low level of our coaxial rotor helicopters

7. ACKNOWLEDGEMENTS

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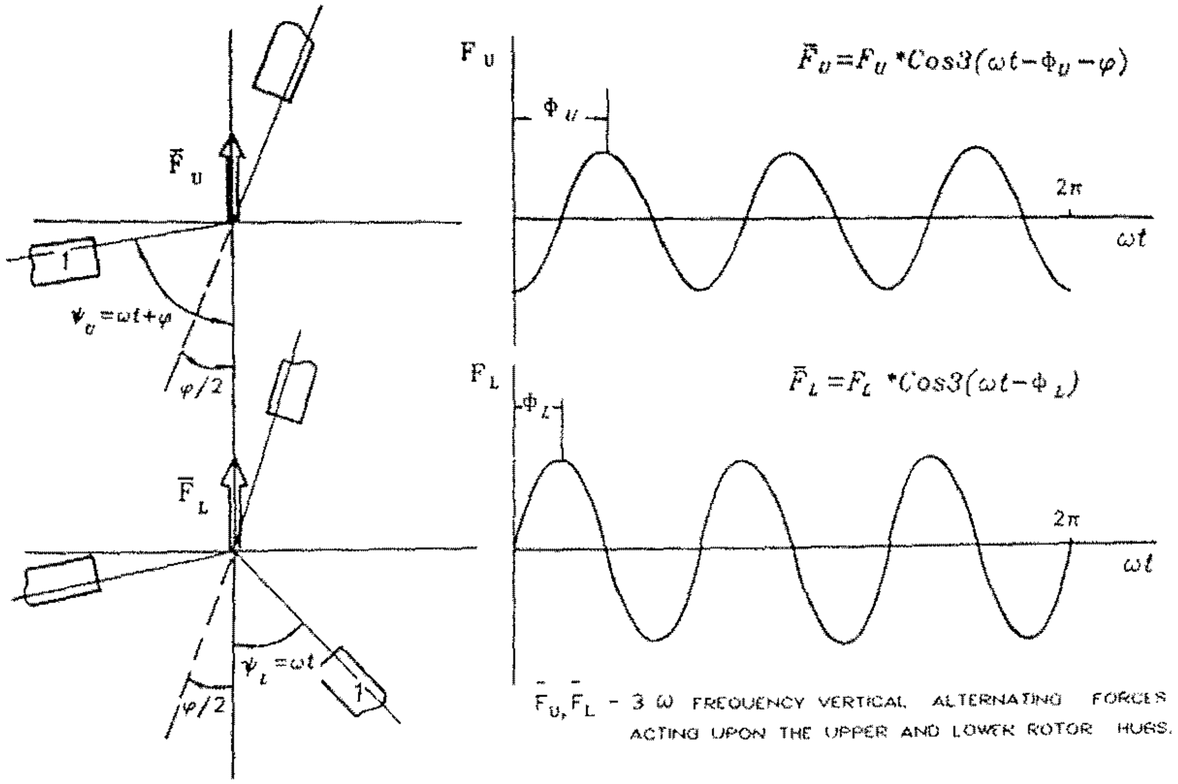
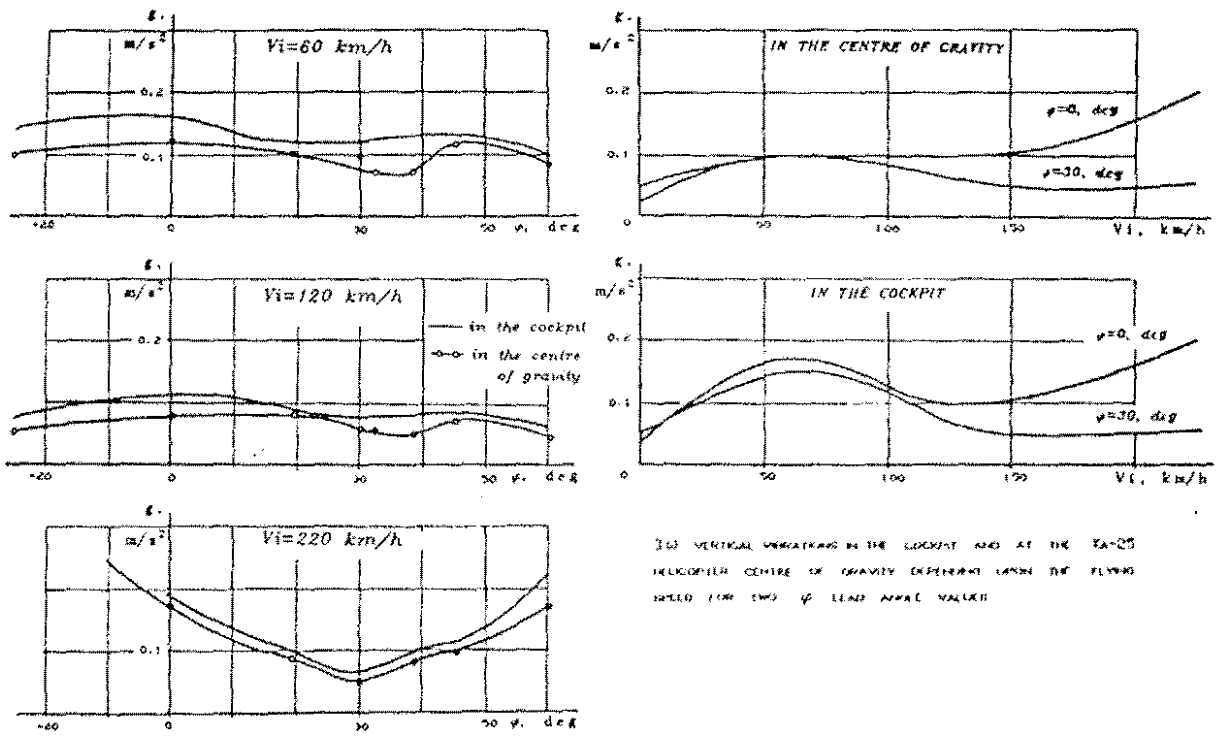


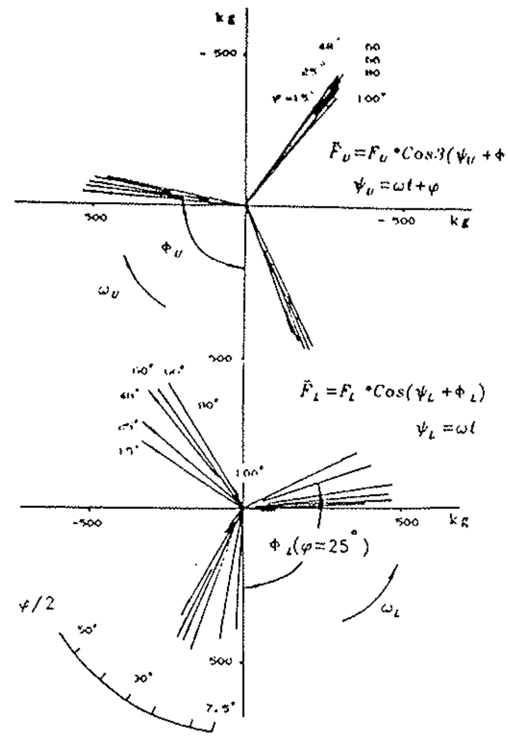
FIG.1 THE SIMPLEST DIAGRAM SHOWING THE ALTERNATING FORCES ON THE COAXIAL ROTOR HUBS.



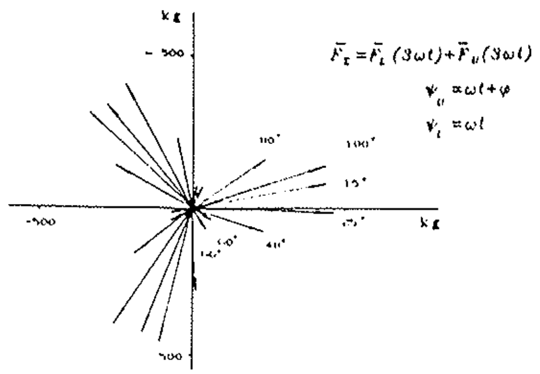
3ω VERTICAL VIBRATIONS IN THE COCKPIT AND AT THE Ka-25 HELICOPTER CENTRE OF GRAVITY DEPENDING UPON THE UPPER ROTOR BLADE LEAD ANGLE φ VALUE.

3ω VERTICAL VIBRATIONS IN THE COCKPIT AND AT THE Ka-25 HELICOPTER CENTRE OF GRAVITY DEPENDING UPON THE FLYING SPEED FOR TWO φ LEAD ANGLE VALUES.

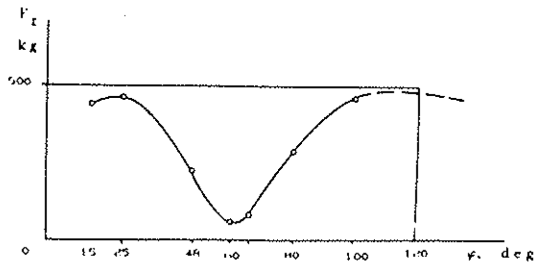
Fig.2



3 ω VERTICAL ALTERNATING FORCES VECTORS AT THE UPPER $\bar{F}_U$ ROTOR HUB AND LOWER $\bar{F}_L$ ROTOR HUB FOR VARIOUS φ (DEG) LEAD ANGLE VALUES (ULYSS-6 ANALYSIS RESULTS).

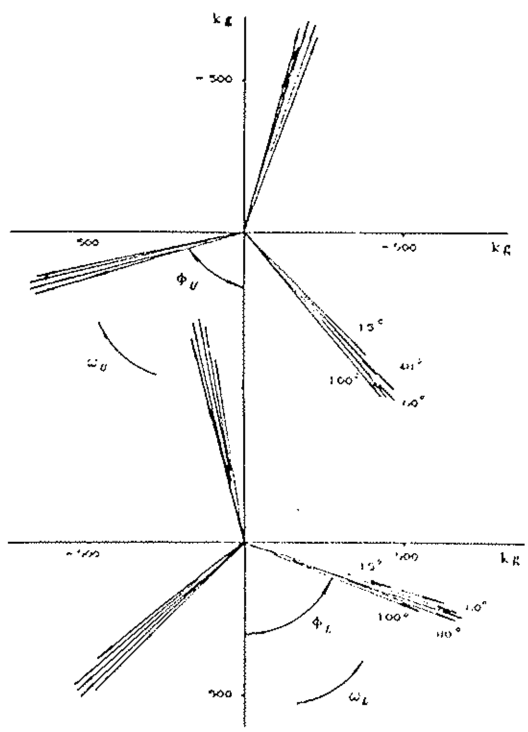


3 ω SUMMARY VERTICAL FORCES VECTORS FOR VARIOUS φ (DEG) LEAD ANGLE VALUES (ULYSS-6 ANALYSIS RESULTS)

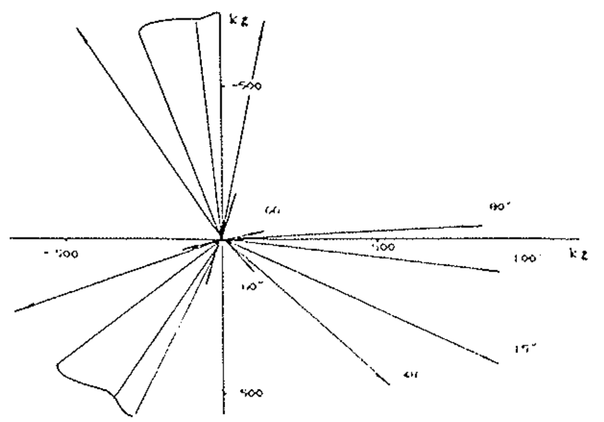


3 ω SUMMARY FORCE VALUE DEPENDING UPON THE φ (DEG) LEAD ANGLE VALUE (ULYSS-6 ANALYSIS RESULTS)

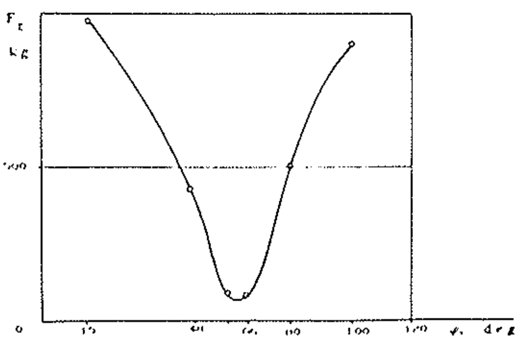
FIG 3



3 ω VERTICAL ALTERNATING FORCES VECTORS AT THE UPPER $\bar{F}_U$ ROTOR HUB AND LOWER $\bar{F}_L$ ROTOR HUB FOR VARIOUS φ (DEG) LEAD ANGLE VALUES (ULYSS-6 ANALYSIS RESULTS WITHOUT COAXIAL ROTOR VORTEX SYSTEM)

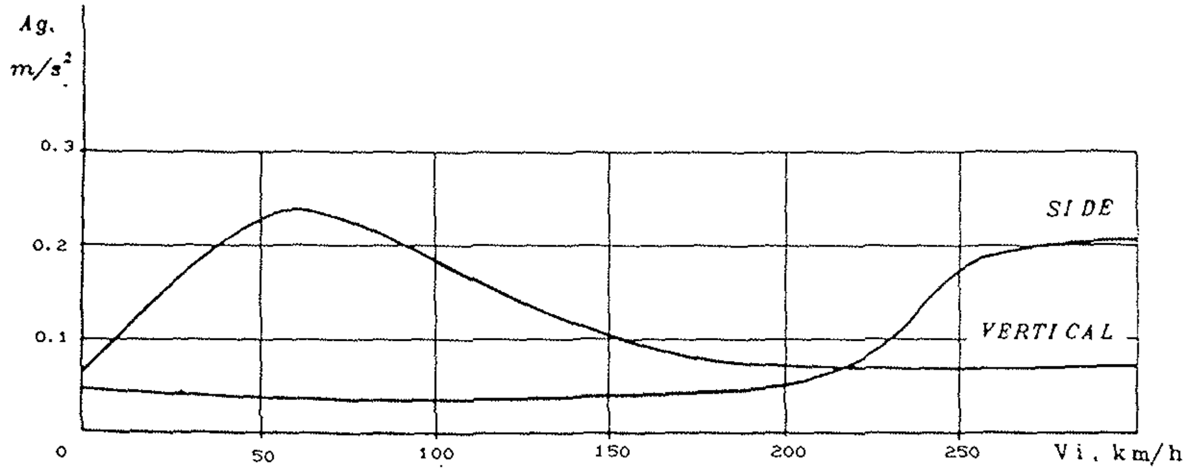


3 ω SUMMARY VERTICAL FORCES VECTORS FOR VARIOUS φ (DEG) LEAD ANGLE VALUES (ULYSS-6 ANALYSIS RESULTS WITHOUT COAXIAL ROTOR VORTEX SYSTEM)



3 ω SUMMARY FORCE VALUE DEPENDING UPON THE φ (DEG) LEAD ANGLE VALUE (ULYSS-6 ANALYSIS RESULTS WITHOUT COAXIAL ROTOR VORTEX SYSTEM)

FIG 4



VERTICAL AND SIDE VIBRATIONS DEPENDING UPON THE HELICOPTER KA-50 FLYING SPEED.

FIG.5