NON-LINEAR GROUND RESONANCE OF A HELICOPTER

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Abstract

A method of the ground resonance phenomenon analysis is described. It has been performed for a one-main rotor helicopter on the basis of a complete set of nonlinear differential equations taken from flight mechanics. It has been modified by taking into account forces and moments produced by a landing gear. Some results of numerical calculations for two models of landing gear–ground interactions are shown.

Introduction

A helicopter is a rotorcraft, which can be subjected during its motion, to various types of vibrations. For some of these vibrations there can appear self-excited oscillations caused by the interaction of the lagging motion of the rotor blades with other modes of the helicopter motion. The ground resonance is a specific case of vibrations where inertia forces react with the fuselage on its landing gear. For some values of the angular velocity of the main rotor, these interactions between lagging motions and motion of the fuselage are self-excited and they are responsible for unstable behaviour of the helicopters.

In the classical theory of the ground resonance [1, 2] only the following motions are usually considered: the lagging of the main rotor blades, the rolling of the fuselage about longitudinal axis and the displacement of its mass centre along lateral axis. Aerodynamic forces are not included into consideration. Many other simplifications are taken into account too.

Solution of the Problem

In this paper a specific nonlinear model of a helicopter has been implemented for investigation of the ground resonance phenomenon. *Specific* means that it has been adopted from flight mechanics [3]. Usually it is applied for the analysis of flight mechanics problems, for instance, manoeuvres with stall aerodynamics effects or flight in failure of the main rotor blade system. In this model any typical simplifications have not been taken into account.

For the analysis it is assumed that the helicopter fuselage is a rigid body and the main rotor consists of four rigid blades which are considered separately. Each blade performs motions about its horizontal flapping hinge and vertical lagging hinge.

Additionally, for analysing the ground resonance phenomenon, landing gear rigidity and damping have been taken into account [4]. Two models of interactions between landing gear and a ground surface have been applied – linear (LG-LM) and nonlinear (LG-NL) /Fig.1/.

Finally, the set of 28 nonlinear differential equations has been obtained:

$$A(t,X)\dot{X} + B(t,X) = f(t,X,S)$$

where X is the vector of flight parameters:

$$\boldsymbol{X} = (U,V,W,P,Q,R,\omega,\dot{\beta}_i,\dot{\zeta}_i,\beta_i,\zeta_i,\psi,\Theta,\Phi,\Psi)^T$$

The vector S is the vector of control parameters: $\mathbf{S} = (\theta_0,\kappa_s,\eta_s,\varphi_{tr})^T$

Two cases of the ground resonance phenomenon have been considered. The first one - for a staying helicopter. In this case the angular velocity of the main rotor was higher than nominal. An effect of the collective pitch increasing on the ground resonance has been analysed /Fig.2/. An influence of the landing gear model on this phenomenon has also been considered /Fig.3/.

In the second case it has been assumed that the helicopter was moving forward on an air strip. It is known that in this case the lateral stiffness depends on velocity and material characteristics of the landing gear. Effects of this phenomenon on the ground resonance has been analysed /Fig.4/ for different lateral stiffnesses. The angular velocity of the main rotor was equal to the nominal value.

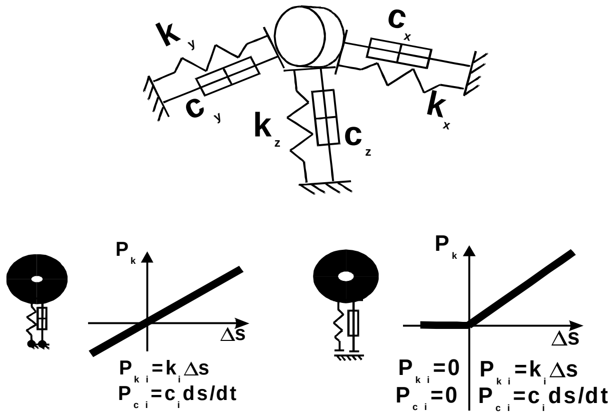

Fig.1. Linear and nonlinear models of the landing gear

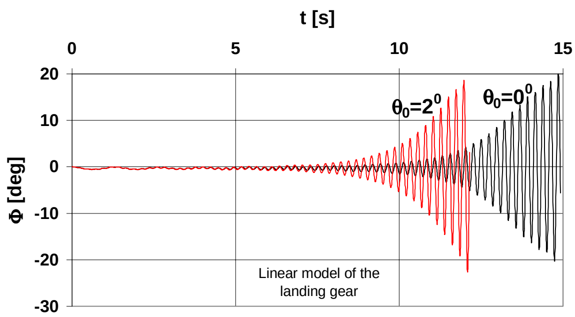

Fig.2. Rolling of the helicopter (LG-LM)

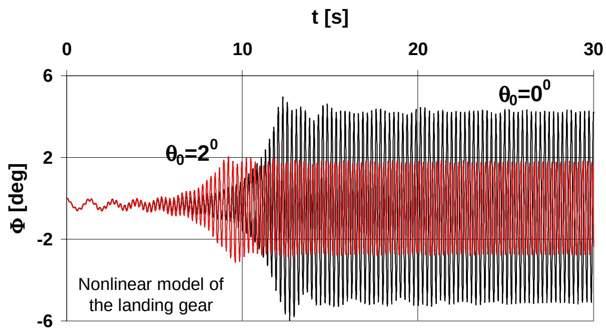

Fig.3. Rolling of the helicopter (LG-NM)

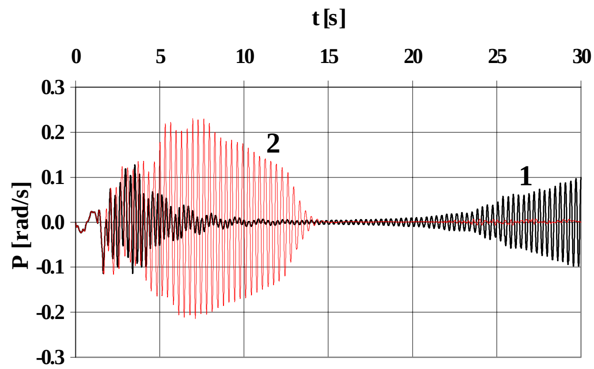

Fig.4. Ground resonance during "aeroplane take off" (LG-NL)

Concluding remarks

The proposed method of numerical analysing of the ground resonance allows to take into account all couplings between motions, nonlinearity of characteristics and a lot of aerodynamic phenomena. On the basis of performed simulations the following conclusions may be formulated:

- the ground resonance of staying helicopter arises at the angular velocity higher than nominal
- detachment of wheels from the ground surface imposes a limit of resonance oscillation amplitudes
- increasing of the collective pitch hastens while of oscillation appearance but for the case of described above detachments decreases amplitude of oscillations

the ground resonance phenomenon may occur during "an aeroplane" take off of the helicopter, even for nominal angular velocity of the main rotor, in the case when the lateral stiffness of landing gear decreases quickly.

References

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