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Numerical simulation of the full-scale planting helicopter skid type chassis mode avtorotation

Michailov S.A., Doctor of of Science, Professor,
Kazan State Technical University named A.N. Tupolev
Karl Marx str., 10, Kazan, Russian Federation, 420111
Email: michailov@kai.ru
Nedel'ko D.V., Candidate of Science, Alimov S.A., Usol'tsev A.A., Shakirov M.Z.
J.S.C. «Kazan Helicopters Plant»,
Tetsevskaya str., 14, Kazan, Russian Federation, 420085
Email: samlabkaz@yandex.ru

The authors carried out a set of calculations for assessing the level of the forces generated by the main rotor light multipurpose helicopter with skid landing gear during the landing in autorotation.

Keywords: helicopter landing gear, testing.

As part of the certification procedure for compliance with the requirements of helicopter aviation regulations AP-29, one of the important points is to perform an emergency (forced) landing in autorotation. Freewheel landing is quite dangerous regime in terms of its performance, which entails the need to determine the most appropriate method of piloting a helicopter in the performance of this regime. It is necessary to determine magnitude of the forces arising on a helicopter rotor. The authors of this paper developed a method to determine the traction force and the longitudinal force helicopter, based on data from flight experiments on planting multipurpose helicopter with a skid type of chassis.

We considered two options freewheel multi-purpose helicopter landing:

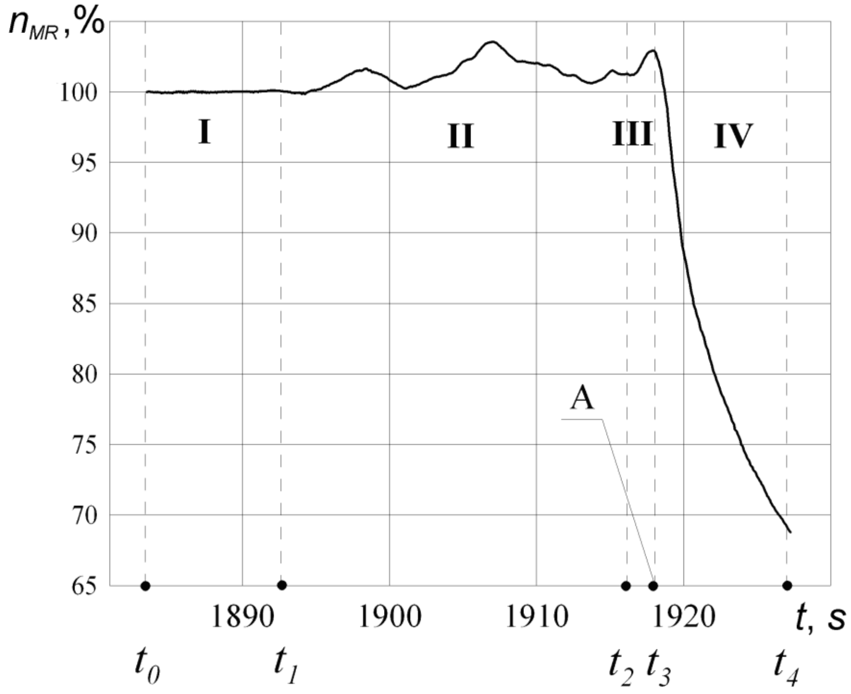
Option 1 – freewheel landing, in which at the time of touchdown implemented vertical airspeed helicopter 1.77 m/s at a pitch angle of 9,6 °;

Option 2 – freewheel landing, in which at the time of touchdown implemented vertical airspeed helicopter 1.25 m/s at a pitch angle of 4,1 °.

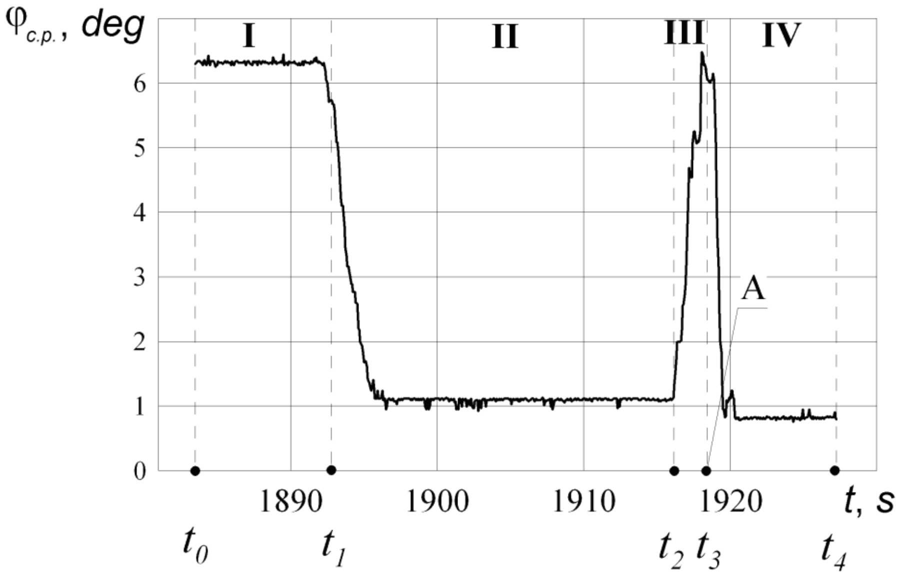
Selected for analysis freewheel helicopter landing were performed on a snow-covered concrete surface, which greatly simplifies the process of this analysis, because allows us to neglect the friction forces in the contact surface with the landing skids.

Freewheel landing with engine performed by the following procedure. Since the initial mode and level flight at an altitude $H = 300\,m$ and $V_{\text{пр}} = 110 \div 120\,km/h$ of the helicopter and supplied to autorotation of the main rotor (HB) by translation engines on the regime "flight low throttle" on the $H = 200\,m$ engines were transferred to the regime, "earthly low throttle." After a visual clarify the conditions for landing on the $H = 100 - 120\,m$ turned down both engines transfer mode switch to "STOP". Further on $H = 20 - 25\,m$ to satisfy the energetic braking helicopter to a speed $V_{\text{пр}} = 40 \div 50\,km/h$ increase of the pitch angle $\vartheta = 25...30^{\circ}$ and to increase collective pitch to $\varphi_{\text{c.p.}} = 4^{\circ}...4{,}5^{\circ}$. From the height $H = 6...8\,m$ began to decrease in pitch angle so that the height of $H = 1{,}5...2\,m$ a pitch was close to the maximum allowable planting corner, and the angular velocity of the helicopter – close to zero. From the height $H = 1{,}5...2\,m$ produced a further increase in the collective pitch with the pace necessary to quench the rate of descent at the time of landing.

The main parameters measured in the course of flight tests, consider the following quantities: the rotor speed n_{MR}, longitudinal ground speed V_{x}, collective pitch $\varphi_{\text{c.p.}}$, the angle of the swash plate in the longitudinal direction κ. An example of the change process parameters n_{MR}, $\varphi_{\text{c.p.}}$ when the landing is depicted in Figure 1 a, 1 b.



a



b

Figure 1. Flight parameters
a – the frequency of main rotor rotating, *b* – collective pitch.

A point on these figures marked the moment of contact helicopter landing pad, the Roman numerals I - IV are the main stages of the flight:

1) Zone I – the horizontal portion of the flight time t_0 to time t_1;

2) Zone II – lower portion of the time t_1 to time t_2;

3) Zone III – plot "to undermine MR" from time t_2 to time t_3;

4) Zone IV – landing site from time t_3 to time t_4.

At any given time on the flight parameters can be calculated T_{MR} of thrust and longitudinal force H_{MR} rotor. For an approximate calculation of the force used by the authors was the classical theory of the rotor [1]. Under this theory, used the average over the disc rotor speed inductive value, determined by the formula Glauert [2]:

$$u_{\mathrm{av}} = \frac{\mathrm{T}}{2\pi R^2 \rho V} \tag{1}$$

The average relative velocity inductive found by the formula:

$$\bar{\upsilon}_i = \frac{u_{\mathrm{av}}}{\omega R} = \frac{\mathrm{T}}{2\pi R^2 \rho V_x \omega R} \tag{2}$$

The values of traction T_{MR} and H_{MR} longitudinal forces are given by:

$$T = C_{\mathrm{T}} \frac{\rho}{2} \pi R^4 \omega^2 , \tag{3}$$

$$H = T\left(a_1 - \varphi_{\mathrm{Ç}}\right) , \tag{4}$$

where a_1 – the coefficient of the Fourier series expansion of the equation flapping blade, φ_3 – angle wedged MR, C_{T} – the coefficient of traction.

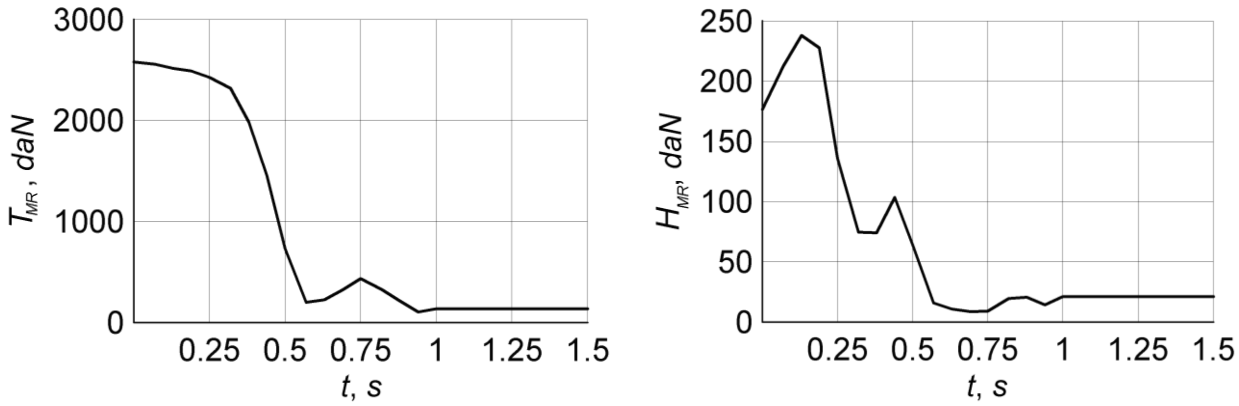
Technique of calculation of thrust T_{MR} and longitudinal force H_{MR} rotor is as follows:

1) take the values of the initial parameters in a certain moment of time t_i;

2) the amount of traction MR taken as corresponding to the take-off weight of the helicopter. Next, by (2) calculates the value of the average relative inductive speed. Then run the necessary calculations to determine the coefficient C_{T}, traction T_{MR}. The new value is compared with the initial thrust, and if the difference between them is more than 0.1%, the new value is taken as the traction original. Computation cycle repeats as long as the received condition (0.1%) is not fulfilled. So value is obtained traction MR at time t_i, and accordingly the longitudinal force H_{MR};

3) Items 1 and 2 are repeated for each time step.

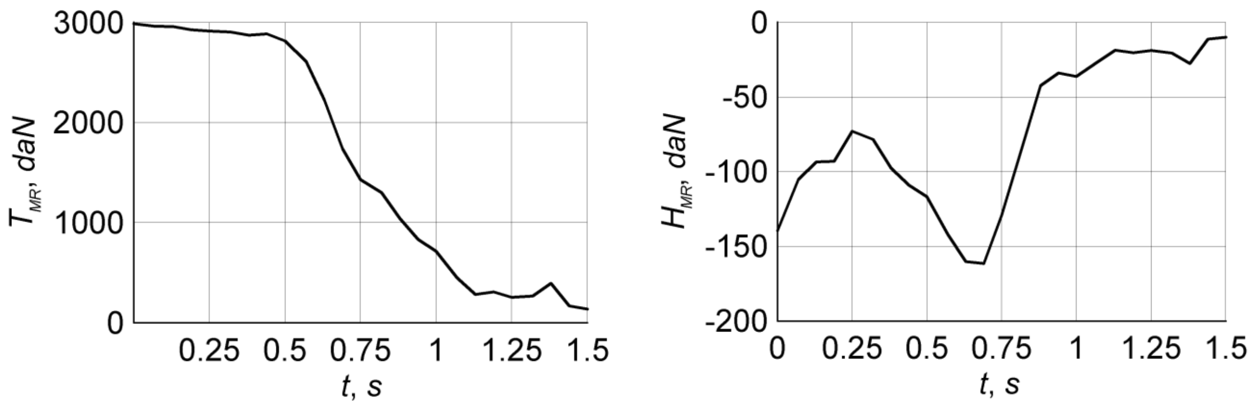
In Figures 2*a* and 2*b*, 3*a* and 3*b* shows the results of traction T_{MR} and longitudinal force H_{MR} rotor from the moment of touching the chassis of the landing area on the developed technique for two versions of the landing



a *b*

Figure 2. Option 1, the values of forces:
a – thrust MR, *b* – longitudinal force MR.

To check the correctness of the calculation model and the values obtained T_{MR} and H_{MR} used in calculating the dynamics of motion of the helicopter after touching them landing surface. The calculation is performed according to the method of [3]. The initial data for the vertical speed V_{y} helicopter when it touches the landing area used by the results of flight measurements. T_{MR} and H_{MR} forces were attached to the center of mass of the helicopter. Skid landing gear model used for calculation is set out in [4]. Comparison of the results of calculation and experiment for flight overload near the center of mass of the helicopter is shown in Figure 4 (Option 1). Figure 5 shows a comparison of the results of calculation and flight experiment for the helicopter pitch angle (also for option 1).



a *b*

Figure 3. Option 2, the values of forces:
a – thrust MR, *b* – longitudinal force MR.

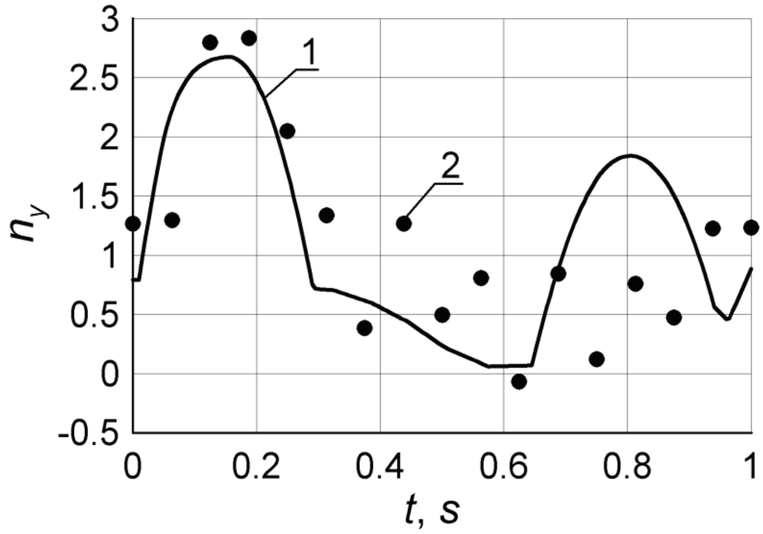


Figure 4. Overloading the center of mass (option 1):
1 – calculation; 2 – flight experiment.

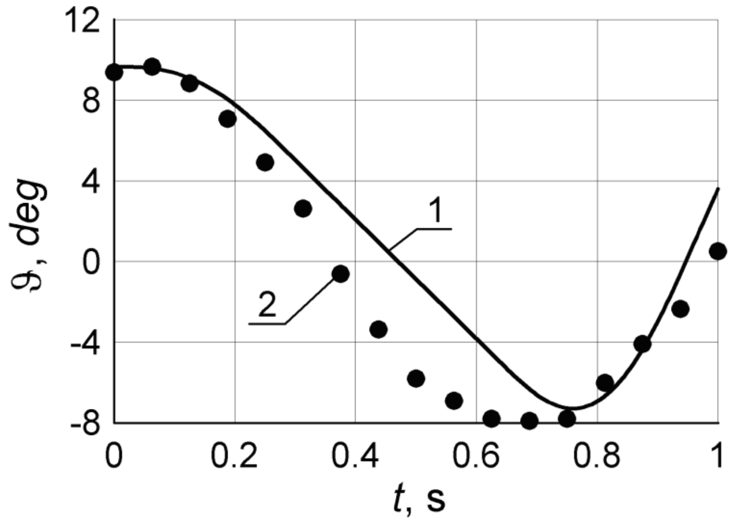


Figure 5. The pitch angle helicopter (option 1):
1 – calculation; 2 – flight experiment.

In accordance with the charts of figures 4 and 5, it can be argued about the positive verification technique for calculating the forces exerted by the main rotor helicopter, and suitability for reproduction parameters of motion of the helicopter during the performance of a freewheel landing. The method developed can be applied to analyze the results of flight tests in order to create the most appropriate technique to perform a helicopter landing skid type landing gear in autorotation.

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