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Rotorcraft Aerodynamic

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1. Introduction

A lot of currently research tasks contributing to the quality of conventional helicopter control are focused on the helicopter cabin environment. At the same time, the technogenic environment of the helicopter is emphasized more on the cognitive system flight situational ascent in front of the helicopter. It causes the helicopter systems to operate with at least probability of failure. The autonomy of the helicopter control in the future will be close to drone control. Such for example, self-service navigation systems will solve their decisions according to a priori calculations, which will be controlled by a helicopter according to command and predicted information from control centre. Based on these considerations, it is possible to include the problems in the following solution that is associated with the control of the helicopter in different modes and phases of flight, which can be expressed by mathematical models. However, it is also necessary to know the knowledge of helicopter control with a degree of intelligence and to intuitively create a possible hypothesis of the information usability about the control of on-board systems using built-in algorithms Fig.
1. Applicable solutions of the mentioned mathematical models are possible to use by differential equations, which implicitly give solutions to the complexity of controlling on-board information systems (Kaňuk, 2015; Lazar, 2011).

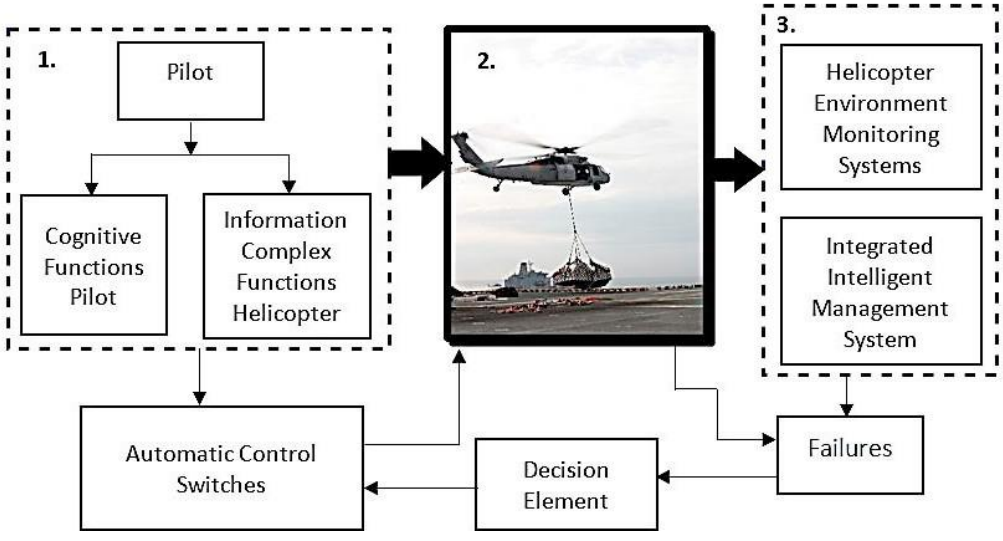

Fig. 1. Conventional helicopter configuration with predictive decision element.

The stabilization of the helicopter by autopilot and stabilization systems of helicopter in its specific hanging mode is solved. In this mode, the consideration of the control itself is the highest, ie with the highest value of the probability of failure. In the process of finding the quality of pilot control of a helicopter, these differential equations are taken as applicable constants and the responses to them are in the way of change of helicopter control according to the type and danger of failure during flight or complex manoeuvre (Beňo et al., 2005; Škvareková et al., 2020b). In this moment are used statistical models on the possibility of finding the quality of helicopter control, which are explain in the paper. In the most complex "hanging" mode, each helicopter propulsion and fuselage part, is stressed to a high probability of failure. This is one of the reasons why this mode is often used for the helicopter as a moment to detect a hidden failure before the

actual helicopter flight. The pilot verifies the stability of the helicopter with his observation skills and by checking the information systems in this mode. Any failure that occurs at this moment could reach a pre-critical or critical mode that can result in an air incident. Therefore, each failure causes a non-standard situation, which unlike the aircraft, is characteristic of disaster in this mode. A possible non-standard situation is also changing the doctrine of the entire continuous control of a conventional helicopter. If a non-standard situation arises due to a failure, we can also mean a change in the state of the entire aeronautical ergatic system (AES) of the helicopter as Fig. 1 -1,2,3 (Ižaríková & Lacáková, 2017; Kurdel, 2016)). In the moment, when it is possible to correct the failure by the helicopter

control systems and the pilot's skill itself, according to the established procedures, the ability to maintain the stability of the helicopter in such a mode, is only a thirty percent success.

1.1 Literature review

For currently research, the previous research in the field of UAV and human factor, where were very important. The prediction of UAV flights with the control system of modern helicopter (Novák Sedláčková et al., 2020), the monitoring and dynamic simulation of the UAV flight phases as in the way of simulation of UAV flights close to the mountain orographic terrain (Kurdel et al., 2019) in combination with Škvareková et al. (2020b) and reducing of mental load and lack of pilot training. The landing procedure simulation via applying nonlinear optimal control method in the form of performance index as a demonstration of landing with failure (YU et al., 220) and the safe landing trajectories obtained by formulating a nonlinear optimal control problem based on a nonlinear helicopter dynamic model and geometry constraints due to actuator failure (Wang et al., 2020). One of the research methods in the field of helicopter control and learning is based on the principles of the theory of asymptotic learning. In the event of a failure in non-standard situations or its local parts according to these standards, the pilot can solve tasks together with the help of a decision-maker. The occurrence of any failure (subjective or objective) requires a change in the system of principles (control doctrine) of control of the entire helicopter (Ižaríková & Lacáková, 2017). The above consideration points to the assumption of a change in the reliability of the observed object (faulty helicopter system) in achieving the required area of successful completion of the helicopter control by the pilot (safe landing with failure). Any decrease in helicopter reliability (caused by a failure) will cause a limited condition that will affect the pilot's control operations to successfully achieve safe landing (Kelemen, 2009).

2. Applicable Research Methods

The ability to operate helicopter by pilot in non-standard situations is understand as intellectual property and is important to find a way to adapt pilot skills to eliminate the failure when the problem occurred (Ižaríková & Lacáková, 2017; Kurdel, 2016).When changing the flight mode caused by the failure, a non-standard condition arises, where the manifestation of the helicopter doctrine indicates changes in the position of the helicopter itself and estimates that the pilot must solve without a prediction system to reach the required (unspecified) time of successful solution (Škvareková et al., 2020a). Apriori estimates for changes in the management of the helicopter are caused by:

- feeling the need to align pilot skill with the properties of the current state of the helicopter in which it is located.
- to change the helicopter control in the conditions of the cause of the failure by correct estimates.
- This type of estimation of a successful landing of a failed helicopter is performed by monitoring the convergence of the entire aeronautical ergatic system (AES) with the helicopter metasystem using the following aspects of thesearch:
- the mean position of the cyclic control of the helicopter,
- the corresponding position of the collective control without inertial AES affected by the fault,
- the required value of the probability of performing the tasks of the helicopter metasystem to complete a successful landing (Khatwa & Helmreich, 1999)

When monitoring the effectiveness of estimating the local quality of conventional helicopter control, we accept the principle of asymptotic learning, which was observed on the simulation system of helicopter control in Slovak Training Academy. The mathematical model Rayleigh distribution [MATLAB] was used for the solution as Fig. 2.

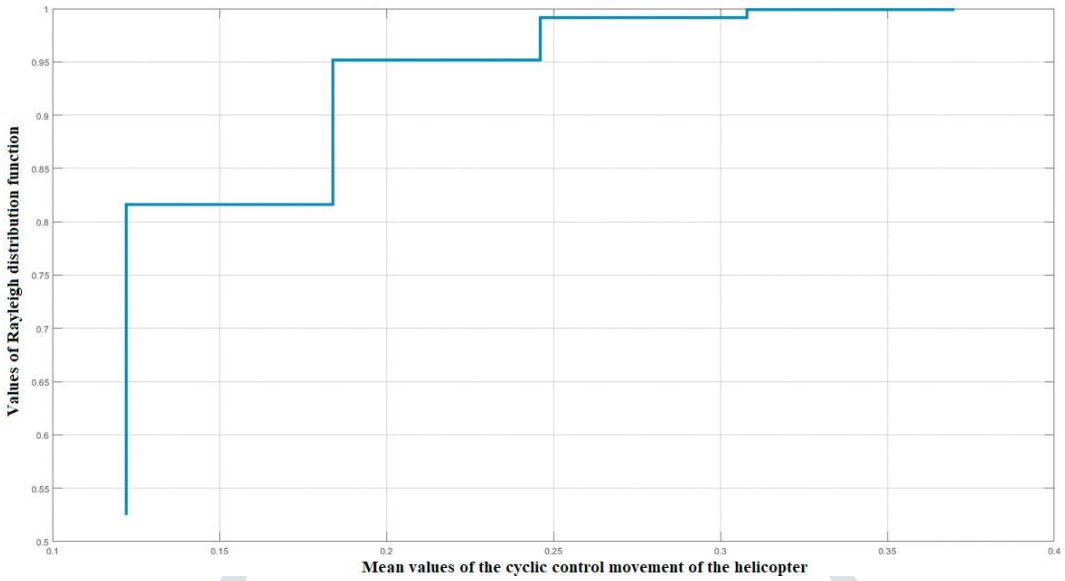

Fig. 2. Rayleigh's probability function of a successful landing with a failure.

Another transformation is to achieve a function that shows us the probability that in the event of a random change in the control of the helicopter, the positioning value of the cyclic control will decrease compared to the entered value (learned) and is defined by the helicopter control conditions. We determine the conditions using the distribution function: cdf = 1-pi; Convergence condition: cdf = 1 - pi; if = 1, then cdf = 0.

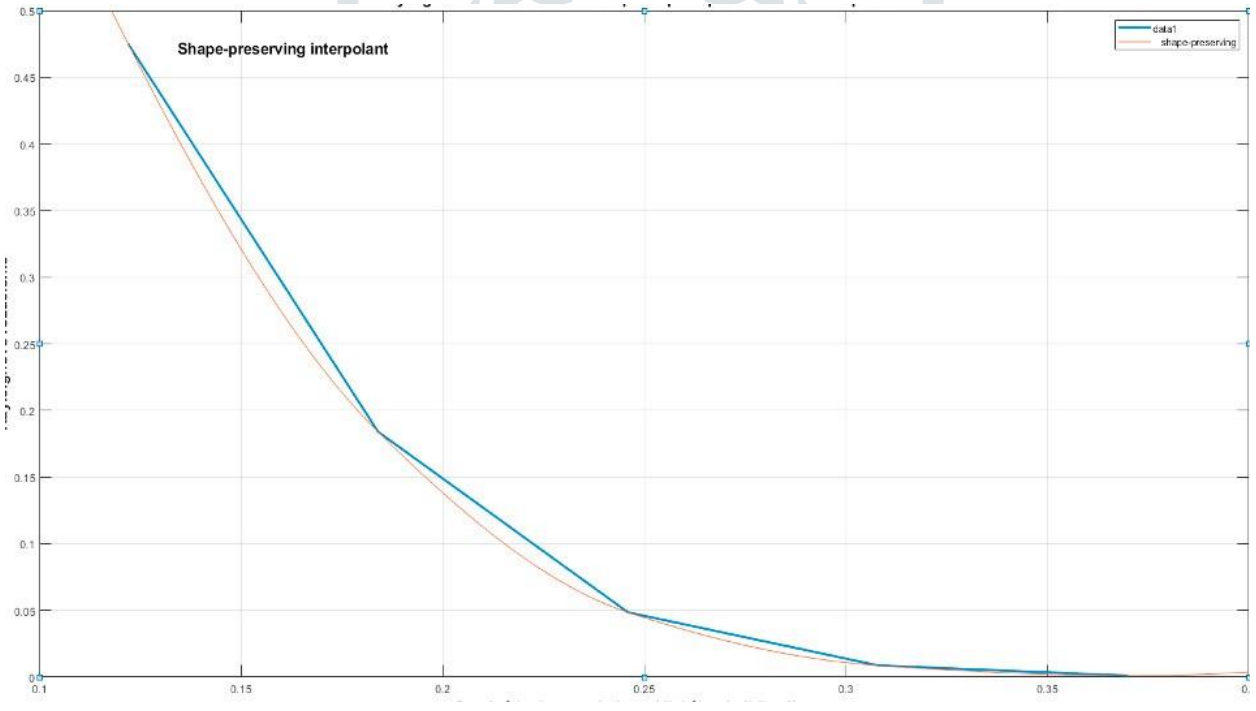

Fig. 3. Rayleigh's distribution of pilot skills on successful landing.

E=(x.*pi); the median values of the decision elements of the Rayleigh distribution.

D=(x.^2.*pi)-E.^2; dispersion, the extent to which the distribution is stretched or compressed. The defined dispersion that arises when operating a failing helicopter are determined by the standard deviation and the interquartile range by which the helicopter can be maintained on the specified route.

ES=sum(x.*pi); the summary median value.

DS=sum(x.^2.*pi)-E.^2; total dispersion. The resulting graph as an estimate of the helicopter dispersion during a sudden landing at a complex failure of Fig. 4.

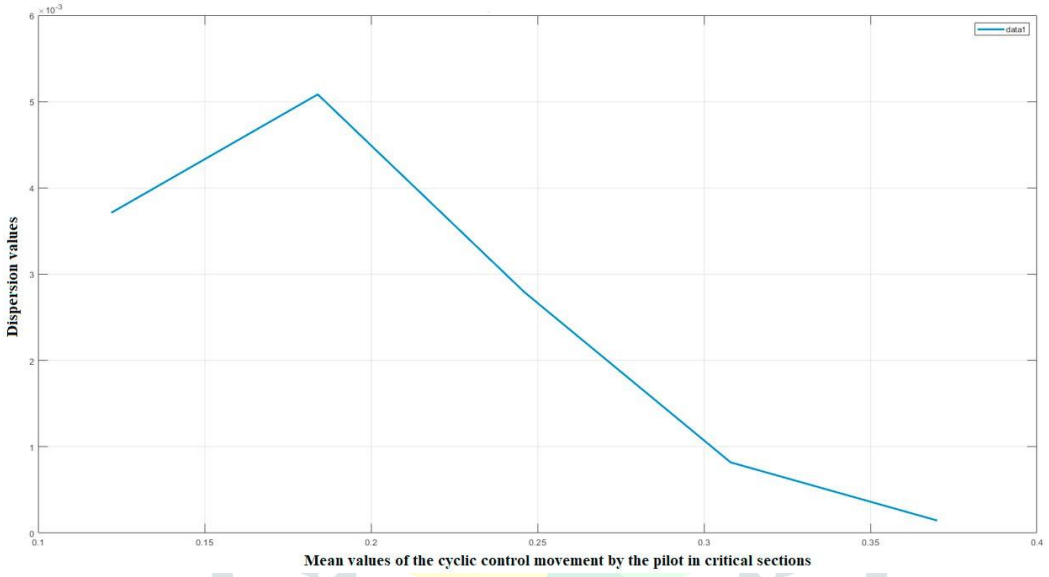

Fig. 4. Estimation of the dispersion of the failure on helicopter reaction.

At the same time, another graph (Fig. 5) shows the growth of the pilot's skills in perfect landing manoeuvre and comprehensively declares the effectiveness of the method of local estimation of the quality of helicopter control.

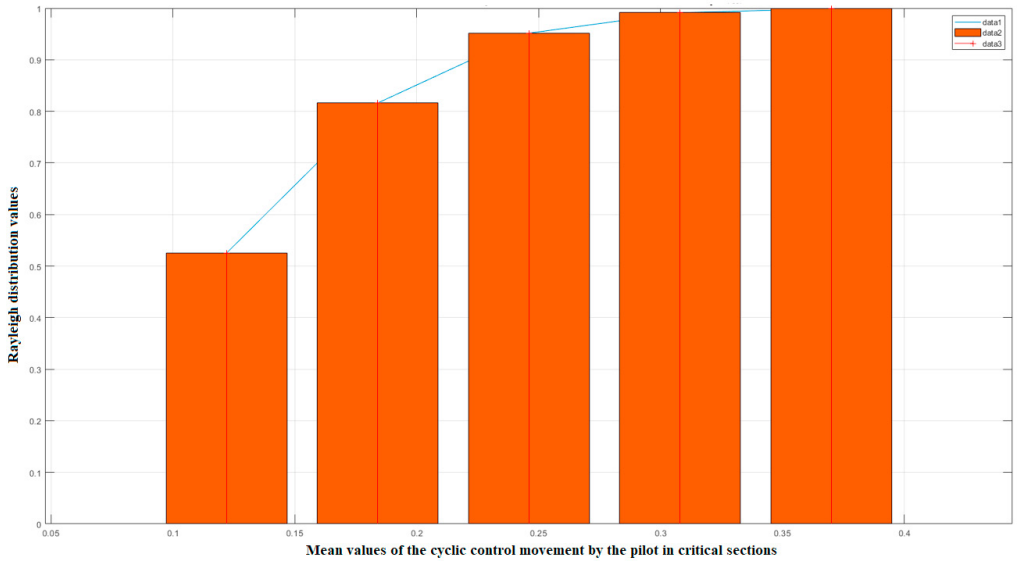

Fig. 5. Rayleighś distribution function of the probability increase of a pilot's ability to overcome a failure.

3. Time variability of the delay of AES helicopter control by the pilot

While maintaining all flight parameters and managing the landing manoeuvre of a helicopter with a failure and a shortening of time, based on predisposing estimates, there is a discrepancy with the prescribed measured actual altitude (Lazar et al., 2011; Češkovič, 2012). These estimates were applied to a simulated emergency landing of a Black Hawk UH-60 helicopter. The given landing simulation was performed with the failure of one engine so that the ASS (Area Successful Solution) was achieved as accurately as possible with the greatest possible maintenance of control stability of this helicopter. The landing manoeuvre was performed at the selected altitude and in a time duration of 35 s (period). The movements of the helicopter handlebar were (Fig. 5), n = [0 1 5: 5: 35], in cycles. N = 0: 9.

The mean values of the position of the cyclic pilot control are:

y=[0 0.2225 0.4338 0.4598 0.0823 0.0392 0.0360 0.0345 0.0119 0.012];

Achieving the control skills by AES proficiency has an asymptotic character, the mathematical model of which is:

$$x = [(1 - \frac{1}{e^{yN}})] \quad (1)$$

The selected value of time delay is the tenth of cycle as Fig. 6.

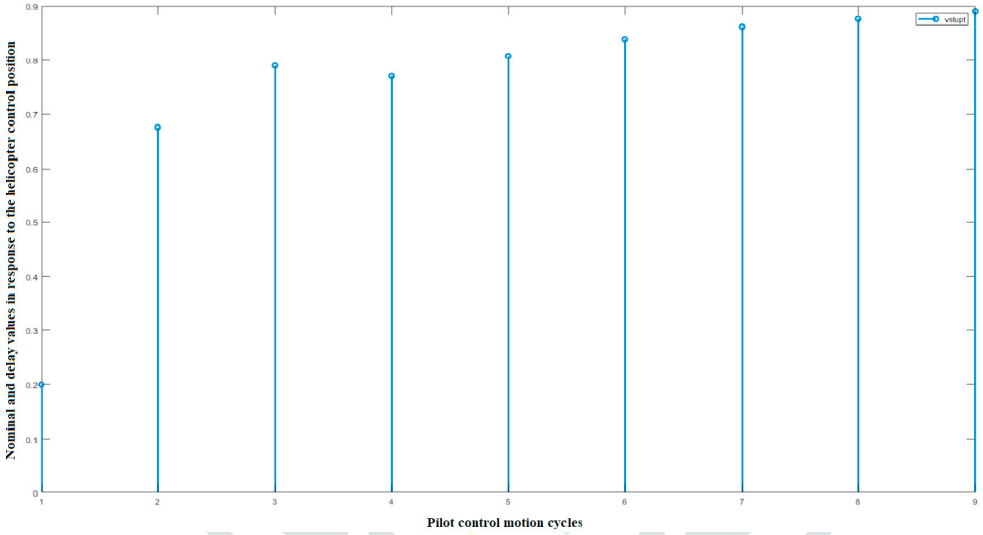

Fig. 6. The variable delay of pilot control of helicopter with a failure.

4. Analytical solution of a decision member function while changes in control of conventional helicopter

For analyse of the asymptotic learning process in the process of helicopter control we used the Butterworth filter and standard frequencies on response of the helicopter pilot control. The filter is a part of the decision element as on Fig. 1. The input to solution is frequencies of the deflected cyclic control by the helicopter pilot on the STA training simulator (Adamčík et al., 2015). 35s is a period of the frequency range measurement; the number 10 represents the measured frequency in the ASS section of the helicopter. [L, M] = rat (35/10); L-interpolation factor, M-decimation factor.

f = fdesign.polysrc (L, M, 'Fractional Delay', 'Np', 1); the number 1-represents the upper limit of the helicopter control deviation, Np-program determined by the order of the Butterworth polynomial.

Hm = design (f, 'lagrange');

t = [0 1 5: 5: 35]; conversion of the frequency of movement of the cyclic control into the time relation of the manifestation of a failure.

Y = [0 0.2225 0.4338 0.4598 0.0823 0.0392 0.0360 0.0345 0.0119]; helicopter pilot.

Asymptotic learning of the pilot to manage failure control expressed as:

x= [1- (1/e^((Yt))]. (2)

The course of this learning based on the measured data of the responses from the control of the helicopter is expressedin Fig. 7.

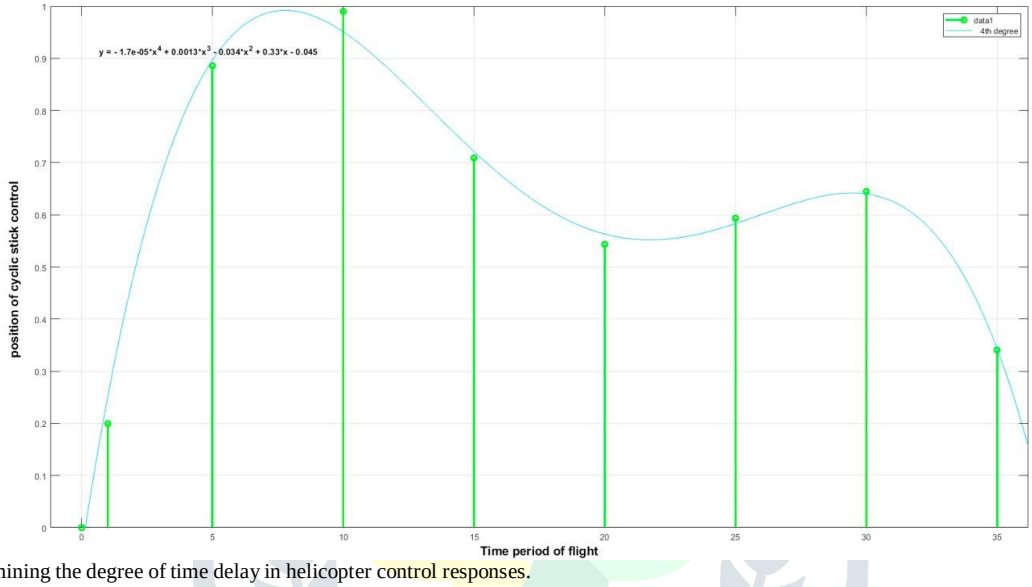

Fig. 7. Determining the degree of time delay in helicopter control responses.

5. Creating the level of pilot skills in dichotomous pilot control of the helicopter in the final phase ofcorrections

The premise of the analysis is the transformation of the number of cyclic control positions determined into dichotomous states. We determine the degree of skill of the helicopter pilot whose content is determined by the modelof the exponential function. Learning as well as skill is procedurally evaluated by dichotomous states: successful and unsuccessful in the pilot's decision-making (Adamčík et al., 2015). The development of skills and learning will have an asymptotic character (Ghosh & Lee, 2010). The aim of the analysis is the characteristics of the pilot: YN = [0 0.2225 0.012] and the cycle with period T, with the section [0 1 5: 5: 35] formally assign time standardised by
regulation:
t = 0: 9; where the periods are Ti = [0 2 2.5 2.5 2 1 0.5 2 1], i = 1,2 ..... , 9.

The skill of the pilot, expressed by the period T:

YT = Yi / Ti, where i = 0,1,....., 9;

YT = [0 0.1112 0.1735 0.1839 0.04160 0.0392 0.0720 0.01725 0.0119 0.012];

The criterion function of achieving ASS is determined by the method of asymptotic learning, where the exponentialterm dominates:

$$x = \left(\frac{1}{e^{(YYT}} \right) . t. (3)$$

The numeric form is:
x = [1 0.8948 0.7068 0.576 0.8467 0.6492 0.8863 0.9092 0.8976];
The representative points had to be determined from the calculated values of x. The first three periods represent the pilot's decision to choose the tactics for achieving ASS (Češkovič, 2012). For this reason, the final stage of asymptote development is subjected to this analysis, the ordered numbers of which form a matrix:
F = [0.5760 0.6492 0.8220 0.8863 0.8976 0.9092]. A vector meaning "margin". Helicopter control positions [0.5760 0.6492] represents the quality of the pilot's decision to increase the skill with the weight [1 1] as "success". In the end part of the asymptote pilot moves the pilot stick with at least the weight [0 0 0 0], where was created a matrix:
A = [1 1 0 0 0 0], where A is an asymptotic dichotomous measure (oscillation vector).
The described emergency situation shows that only the development of the pilot's skill has a discontinuous (discrete) character in terms of a fast landing with the above-mentioned failure. The continuous control function also satisfies this idea of implementing an emergency landing with responsible skill quality. The basis is the essence of helicopter control - so the pilot does not chaotically interfere in the control of helicopter, which could cause uncontrollable responses of the entire helicopter structure. Based on these results, it is possible to design control assistance circuits. For their basis, it is necessary to create appropriate models that must first be regularly transformed into the shape of the Chebyshev polynomial (Ižaríková & Lacáková, 2017), which has unit coefficients. Then, we will use the Chebyshev polynomial to construct an impulse (weight) filter to emphasize or suppress some aspects of helicopter control in comparison with other responses from chaotic pilot control. We use the weight function (Zítek, 2016) to create for pairs of symbols the rows of vectors 'F', 'A' where: W = [2 1 1]; will respond to the command to perform impulse response.).

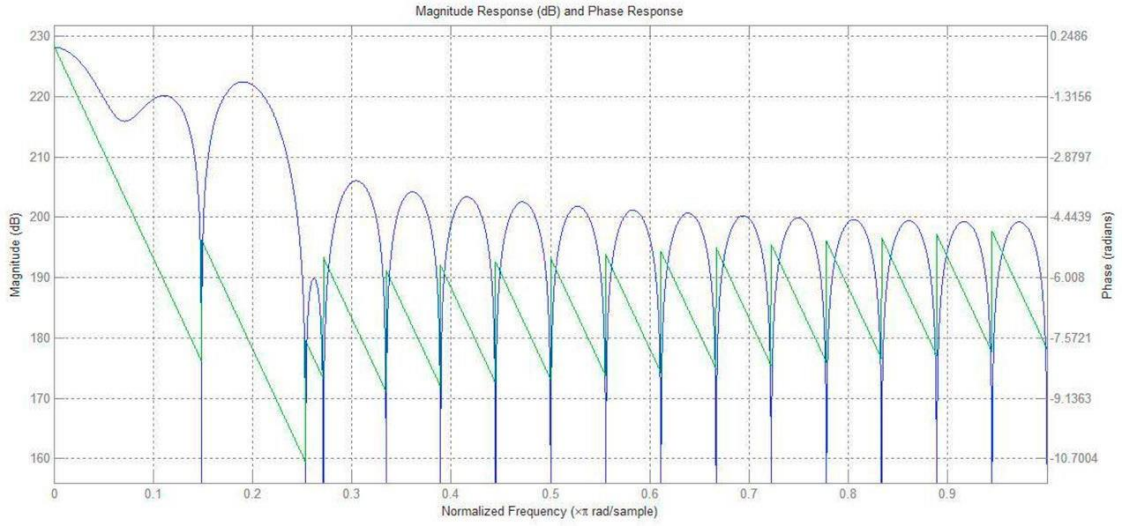

Fig. 8. Magnitude and phase response of the helicopter control according to pilot's intervention in the control.

Fig. 8 shows that early interventions of the control assistance circuits can filter unexpected intervention of the pilot (x-axis, stage 0 ÷ 0.25). The presented complex phase of flight during emergency landing and stabilization of the helicopter and all its deviations to the ASS point was measured within 35 s. This interval was evaluated and measured by us during the simulated flight, where the interval was suitable for the analysis of measurements. The process of experiment is outgoing from theoretical assumptions and the theory of helicopter control. During the experiment, we paid attention to each control component of the helicopter.
The effectiveness of using control estimation in practice, in determining the quality of pilot skill, increases in the analysis of outputs in which the mean values of the amplitudes of weight functions and their interventions in control machines were used. For this purpose, the digital filter has been applied to the value of the time period is N = 35.

he order of the filter was proportional to the number of samples of the cyclic control motion of the helicopter. Existing commands in the MATLAB environment can accept pilot errors (err) and the corresponding coefficients. Subsequently, we gradually obtain records that can be qualitatively and quantitatively analyzed with using of other functions according to MATLAB: [b,err] = firgr (N,F,A,W); hfvt = fvtool(b). The result can be a complex indeterminate control model of a failed helicopter control to stabilize it to the landing point (ASS).).

Conclusion

The dichotomous measure method is suitable for monitoring and classifying pilot skills in a non-standard flight situation.

The condition for its usability is the knowledge of the flight characteristics of AES, which controllability is especially important. The prerequisite for this method is to estimate the quality of readiness of the helicopter pilot under certain conditions when a failure occurs, which results in stabilization of its control to the phase of safe landing. The transformation of helicopter control deflections into dichotomous states leads to accelerated oscillations, which, however, result in delays in pilot responses to this control for the helicopter control itself. Based on this, it is necessary for the pilot to have knowledge-skill-experience that these changes can occur while at the same time acquiring the skills needed to deal with them. We assumed that the pilot's skill is controlled according to an exponential mathematical model (1), which expresses the way to enter the problem area of helicopter control, which is part of the metasystem in the field of complex helicopter control. The premise of this research was the transformation of the number of determined positions of the control parts of the helicopter into dichotomous states. The analysis of the quality of the acquired pilot's skills and their development was also determined by the model of the exponential function (2), which can be processed into simulation models of a conventional helicopter.

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