

FLIGHT TESTS OF UPGRADED HELICOPTERS

Mirosław Nowakowski

*Air Force Institute of Technology
Księcia Bolesława Street 6, 01-494 Warsaw, Poland
tel.: +48 22 6851036
e-mail: mirosław.nowakowski@itwl.pl*

Abstract

In-flight tests and measurements are usually performed for newly built or modernised aircraft utilised by the Polish Armed Forces. In the course of the in-flight tests the airborne equipment is investigated also. The main goal of the performed tests is to verify the tactical performance and to identify the technical parameters of the investigated aircraft or equipment.

New aeronautical designs are subjected to flight test prior to being introduced into production and service. It is why ITWL was involved in both functional tests of equipment /systems installed on-board of helicopters as well as tests intended to determine flying qualities and performance thereof. Numerous test flights have been carried out in conformance to the newly developed methodology that takes account of the Joint Airworthiness Requirements - JAR 29 - Large Rotorcraft.

Helicopter flight data and control parameters have been recorded in the course of experimental test flights by means of the measuring and recording equipment. The post-flight analyses of the recorded data made it possible to assess longitudinal static stability and directional stability, manoeuvrability and agility as well as performances of the upgraded helicopter Mi-17-IV.

Keywords: *transport, helicopter flight, flight tests, flying qualities, performances*

1. Introduction

The objective of flight tests carried out for the upgraded Mi-17-1V helicopter and then described in this paper was to find out how additional equipment installed on-board of the rotorcraft affect its performance characteristics (including operational limits) and flying qualities. The additional components that may potentially affect the performance and flying qualities of the Mi-17-1V helicopter after its upgrade comprise its armouring and dispersers of exhaust gases. Overall weight of the additional equipment much exceeds 1000 kg and substantially decreases the machine payload, whilst its location moves the gravity centre of the helicopter forwards to the position very close to the maximum allowed displacement that may lead to worsening of such flying qualities as stability or manoeuvrability of the helicopter. In turn, dispersers of exhaust gases cause power drop of the rotorcraft engines and increased fuel consumption, which entails decline of the helicopter performance, chiefly related to the ascending velocity, maximum ceiling as well as flying range and flight duration.

With consideration to the foregoing remarks, tests of performance parameters related predominantly to determination of the following:

- polar curves for ascending as well as the practical ceiling,
- maximum, cost-effective and optimum speed values
- flying ranges and flight durations

Flying qualities that were subjected to tests included:

- longitudinal static stability and directional stability,
- Manoeuvrability and agility of the helicopter.

The tests of the foregoing flying qualities and helicopter performances were carried out and

evaluated in accordance with standardized regulations included in Joint Aircraft Requirement Part 29 (JAR-29).

2. Tests of performance characteristics

2.1. Polar curves for ascending

One of the tests dedicated to determination of performance characteristics consisted in drawing up polar curves for ascending that, in turn, enable to find out maximum vertical velocities of ascending w of the rotorcraft under test and corresponding velocities V_Y for best ascending. Experimental tests for the scope in question were carried out at the barometric altitudes H_b for various manufacturing options of the helicopter. For each altitude the tests consisted in execution of predefined cycles including no-slip ascending with the rated power N_{NO} of the driving unit at the instrumental speed values V_P of flights, where V_P was incremented by 10-15 km/h for each cycle with the speed ranging from 60 km/h to nearly maximum values. The recorded set of measuring points made it possible to plot the desired polar curves for ascending $w=f(V_P)$, whilst the condition $dw/dV_P=0$ was used to find out the instrumental velocity V_Y for best ascending and maximum ascending velocity for the altitudes and helicopter weight values covered by the test scope. Examples of test results with regard to polar curves of ascending for the Mi-17-1V helicopter are presented in the graphic form in Fig. 1. Moreover, the graph shows values of velocities V_Y for best ascending and maximum ascending velocities w determined from the polar curve on the basis of information from the reference studies [3] and marked with the symbol of \otimes . The presented graph demonstrates that additional equipment installed on the helicopter board had no practical effect onto the velocities for best ascending whilst the maximum ascending velocities dropped down by 3-5%.

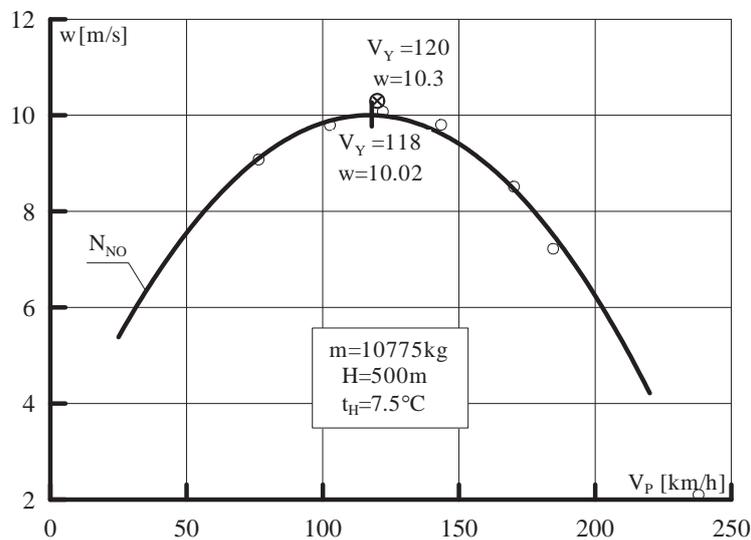


Fig. 1. The relationship between ascending velocities of the aircraft and the instrumental speed values V_P of flights with the rated power N_{NO} of the driving unit operation

2.2. Practical ceiling

To find out characteristics of the practical ceiling of the helicopter under tests, i.e. the ceiling range, the time necessary to reach the predefined ceiling and fuel consumption during such climbing operations it was necessary to execute test flights. Climbing to the predefined ceiling values were executed for the maximum takeoff weights and for the range of rated power N_{NO} of the rotorcraft driving unit. Climbing to the flight altitudes were carried out at the climbing speed of

$w=0.5\text{m/s}$, with the attempt to maintain the predefined, optimum profile of speed and elevation values, already determined of the basis off take-off and climbing tests.

Results from tests performed with the Mi-17-1V helicopter and intended to check climbing performance to the required ceiling are shown in Fig. 2. The graph presents the relationship between the climbing time τ and the barometric elevation H_b for climbing and was plotted on the basis of data recorded during execution of the tests. The presented results demonstrate that the Mi-17-1V helicopter reached the practical ceiling of $H_p=4700\text{m}$ under conditions that correspond to the standard ones at that altitude, whereas it is the ceiling that is less by 100 m than the one specified in reference literature [3] when the system for heating the inlet channels of air was inactivated.

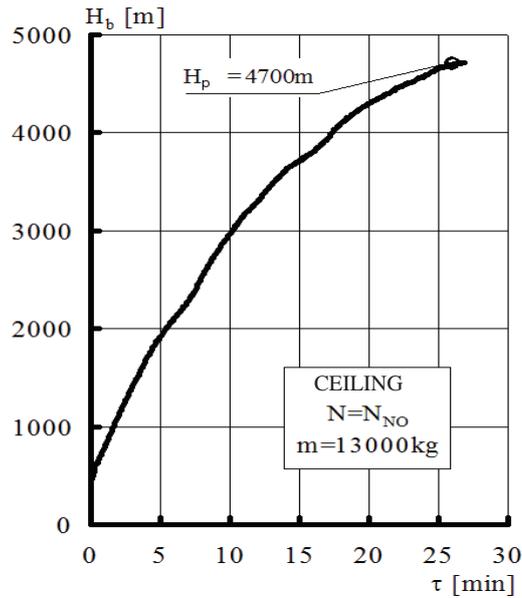


Fig.2. Relationship between the climbing time τ and the function of barometric altitude H_b

2.3. Fuel consumption. Maximum, cost-effective and optimum speed values

Tests of fuel consumption were carried out as a series of test flights dedicated to each specific altitude and weight values and executed at the instrumental speed values of V_P incremented by 10-15 km/h for each flight series and ranging from 60 km/h to nearly maximum values. The mentioned test flights were performed at the altitudes of H_b for each weight option of the helicopter and with activation or inactivation of the ice-melting system for air inlets to the engines.

The completed tests made it possible to obtain the desired characteristics of fuel consumption per unit weight of the rotorcraft with specification of fuel consumption per hour $Q=f(V_P)$ and per kilometre $q=f(V_P)$ for the barometric altitudes covered by the test scope and respective weight options. Examination of inflexion points on the obtained graphs for fuel consumptions enabled to determine cost-effective speed values V_{EK} and optimum (travelling) speed values V_{OP} , for which the respective minimum fuel consumption per hour (Q_{min}) and per kilometre (q_{min}) are achieved.

Examples of test results for the Mi-17-1V helicopter are presented graphically in Fig. 3. Dot and square points correspond to data acquired from the recorded of flight parameters whilst the solid and dashed lines are obtained as interpolation of the acquired information and represent the desired characteristic curves for fuel consumption, respectively for active and inactive ice-melting system for air inlets. Moreover the graph indicates the values of cost-effective V_{EK} and optimum V_{OP} speed values determined on the basis of the plotted characteristic curves with corresponding values of minimum fuel consumption. The symbol of '⊗' stands for characteristics of speeds and fuel consumption specified in literature sources [3] concerning the helicopter without additional equipment.

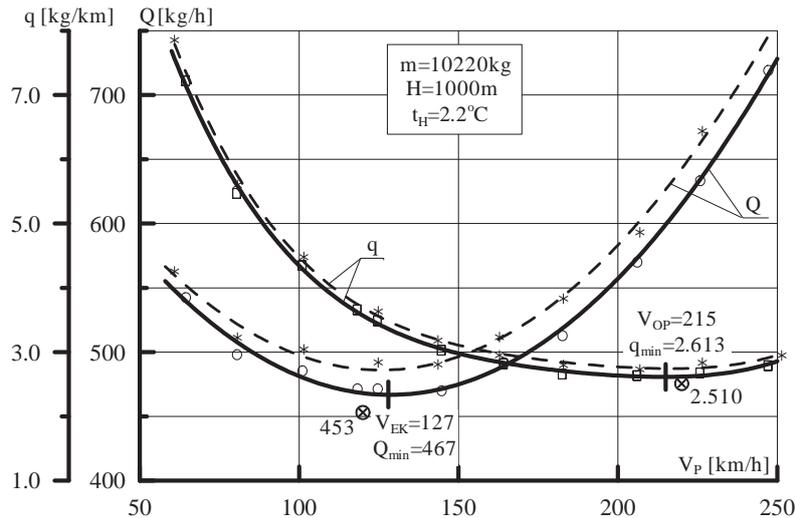


Fig. 3. Relationships between the fuel amount consumed by the helicopter per hour (Q and per kilometre (q) of flight and the speed V_P of the horizontal flight indicated by the cockpit instruments

The presented information makes it possible to state that activation of the ice-melting system for air inlets increases the minimum fuel consumption per kilometre. The growth of q_{min} by 3-4% corresponds to the information from the reference studies [3] that specify the increase to 3%. Secondly, the minimum fuel consumption per kilometre q_{min} determined from tests with the active ice-melting system is by 8 - 10% higher than the corresponding reference values for Mi-17-1V helicopters but with no additional equipment (for inactive ice-melting system). One should expect that the mentioned growth of fuel consumption is basically associated with furnishing of the helicopter version under test with dispersers of exhaust gases.

3. Examination of flying qualities

3.1. Longitudinal static stability

Examinations of the longitudinal static stability of the helicopter were carried out in accordance with requirements of the JAR-29 regulations and covered the phases of climbing, horizontal flights, autorotation descent and approaching to the landing point as well as forward and backward flights at low altitudes with the effect of ground relief. Test flights intended to find out characteristics for longitudinal static stability were carried out with the power of the driving unit (rated power N_{NO} or indispensable power) that correspond to specific phases of flights at the barometric altitudes H_b with various range of flight speed V_P indicated by instruments and for various options of the helicopter weight.

The values recorded for the inclination angle χ of the steering disk (leaning angle d_χ of flying controls for longitudinal steering), stroke angle ϕ_{WN} for the helicopter rotor and the travel speed V_P made it possible to determine sets of measuring points and to obtain curves $\chi=f(V_P)$ and $d_\chi=f(V_P)$ for longitudinal balance of the helicopter as these are the curves that determine longitudinal static stability of the rotorcraft.

The example results from the dedicated tests of the Mi-17-1V helicopter for the ascending and travel phases are shown in the graphic form in Fig. 4 and Fig. 5. The test data obtained from test flights are marked on the graphs with respective symbols. The solid lines represent the desired curves for longitudinal balance of the helicopter, whilst the vertical dashed lines stand for speed limits required by appropriate regulations. The balance curves plotted on graphs feature with negative values of the $\delta\chi/\delta V_P$ derivatives and respective positive values of the $\delta d_\chi/\delta V_P$ derivatives within the ranges of desired speed V_P . For the conventional signs of directions as assumed for the

measuring system the foregoing means that is necessary to move the flying controls forward (outward) to speed the rotorcraft up to the speed value exceeding the speed of balance. Reverse movements are for the opposite effect. According to JAR-29 demonstration of the foregoing helicopter behaviour serves as a proof of its static longitudinal stability.

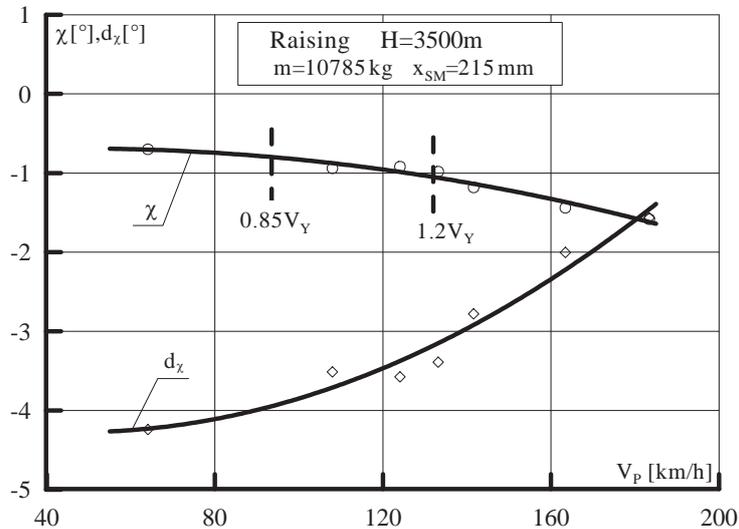


Fig. 4. Relationship between the inclination angle χ of the steering disk and leaning $d\chi$ of the control stick versus the instrumental flight speed V_P for the ascending phase.

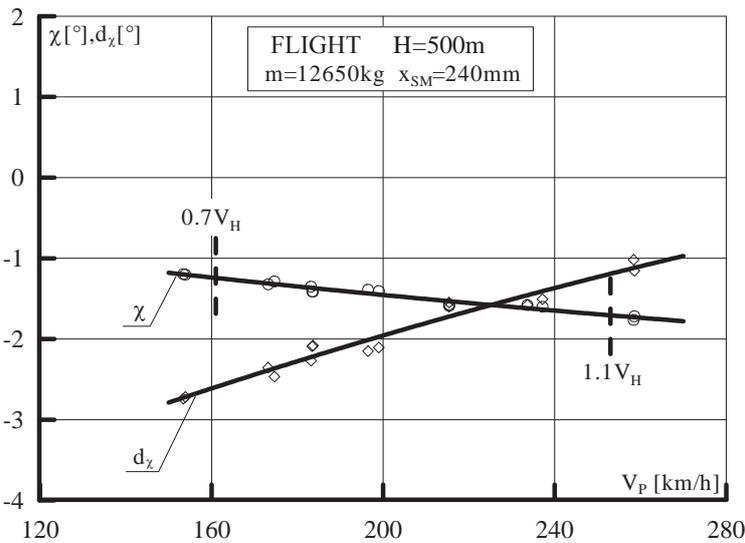


Fig. 5. Relationship between the inclination angle χ of the steering disk and leaning $d\chi$ of the control stick versus the instrumental flight speed V_P for the travel phase

3.2. Static directional stability

Test of static directional stability of the helicopter were carried out at several altitudes H_b for the following phases of flights:

- climbing at the flight speed of V_P that corresponds to the speed of best climbing V_Y and with application of the maximum continuous power,
- travel at the speed of $0.9V_H$ (V_H – the maximum speed with application of the maximum continuous power),
- autorotation or the travel speed of V_Y and under conditions of the apparent autorotation (DRP at the position of ‘mgz’),

- descending with the working engine, for the flight speed of $0.8V_H$, the vertical speed of descending equal to -1000 ft/min.

The examination consisted in execution of a series of test flights, with defined values of altitudes and, steady flights with the values of slip angles of β incremented by $\sim 5^\circ$ for each test until the slip values that correspond to deviation of the turn indicator ball by its full diameter to the left or right.

Examples of test results for flights of the Mi-17-1V helicopter at the altitude of $H_b = 500$ m are shown in Fig. 6. The test data obtained from test flights are marked on the graphs with respective symbols. The solid line stands for the curve $\varphi_{SO}=f(\beta)$ of the helicopter directional balance whereas the dashed line presents the relationship between deviation X_{PED} of the left pedal and the slip angle. It must be added that positive values of β angle correspond to the direction of air stream flow from the left side of the helicopter whilst positive values of the X_{PED} parameter correspond to forward deviation of the left pedal for direction control.

The plotted graphs indicate that the left slip is possible only after pushing the right pedal forward and vice versa and deviations of control pedals lead to nearly linear increase of the helicopter slip angle. According to JAR-29, such behaviour of the rotorcraft serves as a proof for static directional stability of the helicopter under tests.

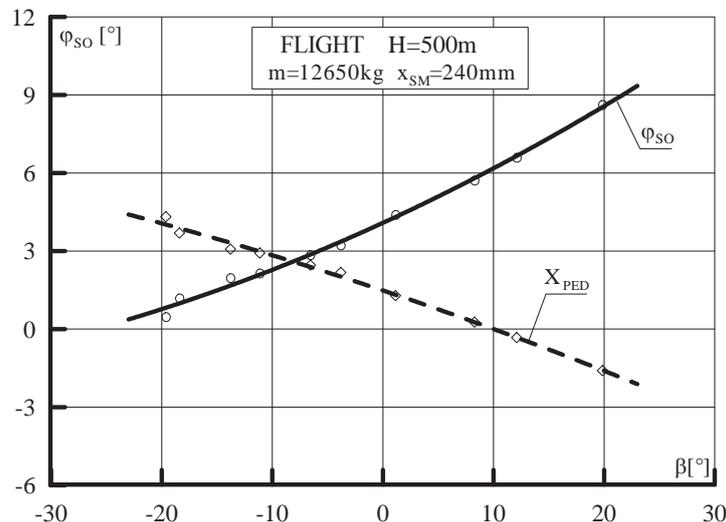


Fig.6. Relationship between the stroke φ_{SO} of the tail rotor and deviation X_{PED} of pedals versus the β slip angle during the travel phase

3.3. Manoeuvrability and agility

The plan of examinations for manoeuvrability and agility was in line with requirements of the JAR-29 regulations and covered all the phases of flights anticipated for the helicopter under tests. These included:

- turns with bank angles up to $\pm 30^\circ$ during horizontal flights and up to $\pm 20^\circ$ during ascending and autorotation manoeuvres, all these turns for various speeds and altitudes of flights,
- longitudinal and transverse displacements of the helicopter within the range of permissible values of flight speed at the following geometrical altitudes $H=1.5$ m with the effect of ground relief, $H=8$ m with partial consideration to the effect of ground relief and $H=15$ m with no consideration to the effect of ground relief,
- takeoff and landing operations with various values of own weight and payload, various position x_{SM} of the gravity centre, at various directions and velocities of wind gusts,
- entering the autorotation flight mode by the helicopter and termination of the autorotation descend,
- flights with great number of manoeuvres.

Examples of test results with regard to manoeuvrability at turns are presented in Fig. 7 and 8 as waveforms for the tilt angle η of the control disk and the pitch φ_{SO} of the tail rotor. The both parameters are the functions of the helicopter bank angle when turns were made during horizontal flights at the altitude of $H_b=3000\text{m}$. The test data obtained from test flights are marked on the graphs with respective symbols, whereas the lines depict approximated waveforms for steering parameters at individual speed values.

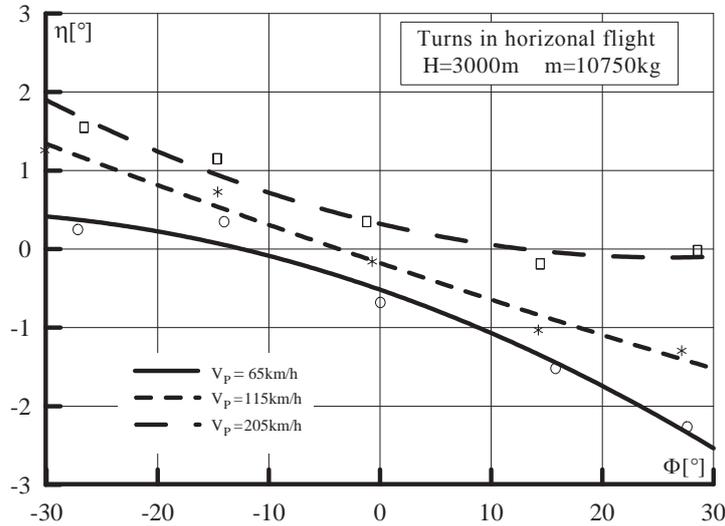


Fig. 7. Relationship between the tilt angle η of the steering disk and the bank angle Φ of the helicopter. The relationships are shown for various values of the flights speed V_P with turns during horizontal flights

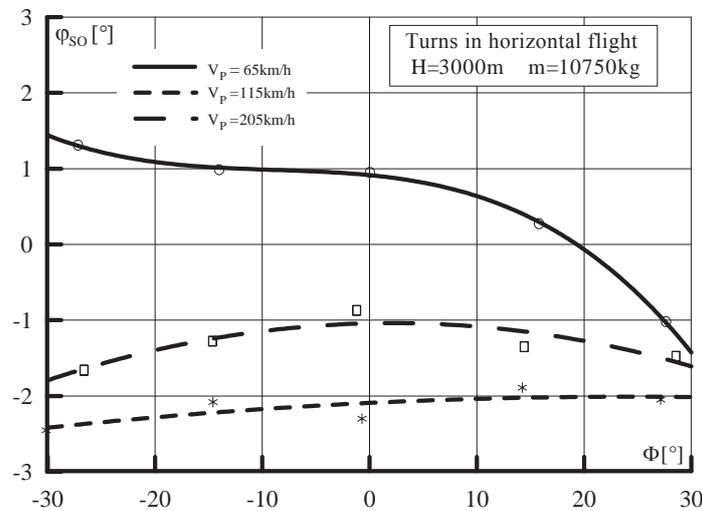


Fig. 8. Relationship between the pitch angle φ_{SO} of the tail rotor and the bank angle Φ of the helicopter. The relationships are shown for various values of the flights speed V_P with turns during horizontal flights

The completed tests allow making conclusions about manoeuvrability of the helicopter. It was found out that for all the flight phases that are permitted for the helicopter operation, the examined helicopter offers sufficient reserves of manoeuvrability for every, even for the most unfavourable position of the gravity centre for the specific manoeuvre and extremely adverse ambient conditions (position of the gravity centre direction and velocity of wind, turbulences, etc.).

In addition it was confirmed that manoeuvres with the helicopter under tests is rather easy within the all range of flight phases that are anticipated for the rotorcraft. Attention of the pilot is not overburdened and flying the helicopter needs no extraordinary skills from the pilot. All in all – the helicopter guarantees sufficient reserves of safety and navigation properties.

4. Conclusions

The completed investigations and flight tests made it possible to find out updated (resulting from the effect of additional equipment) performance parameters and flying qualities required by future users.

References

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