Session Subjects Authors Index Back to Index

27TH EUROPEAN ROTORCRAFT FORUM

HELICOPTER EXTREME MANOEUVRES AT LOW FLIGHT SPEEDS

Kazimierz SZUMANSKI Warsaw Institute of Aviation, Warsaw, Poland, e-mail: kszu@il.ilot.edu.pl
Jerzy BEREZANSKI Warsaw Institute of Aviation, Warsaw, Poland, e-mail: ber@il.ilot.edu.pl
Andrzej SZUMANSKI Warsaw Institute of Aviation, Warsaw, Poland, e-mail: aszu@il.ilot.edu.pl

The paper deals with the problem of helicopter flight mechanics at low flight speeds. The purpose of performed analysis is to achieve possibility of helicopter angular position control within wide range of angular displacements. This is performed by linear and centrifugal acceleration control. Rotor thrust vector control makes those accelerations appear.

1.Introduction

The possibility of the pointing fuselage axis at target direction and holding helicopter position for given but relatively short time, is a necessary requirement in modern military helicopter applications. During flights at higher speeds it is easier to control fuselage axis position making use of helicopter kinetic energy, what allows flight path change and, as a result, fuselage axis position change. Low kinetic energy level at low flight speeds enforces searching of other ways to control helicopter angular position independently from actual flight path.

Sample manoeuvres performed with the use of such a technique, not frequently applied in helicopter practice, are low radius deep turns (with helicopter nose aiming at any direction), flight condition with the use of linear acceleration for keeping helicopter fuselage axis at given angle and diving or jump manoeuvre elements (also with direction change), started and finished with close-to-hovering phases. Manoeuvres performed this way are particularly useful in military applications. Keeping the target in aiming cone independently from flight direction allows more effective attack or defense. Linear or centrifugal acceleration control allows precise fuselage pitch angle stabilization so that aiming could last longer. Both accelerations combination uncovers, as a result, a little known area of manoeuvres performing possibilities (also for helicopters with articulated rotors) from “supermanoeuvreability” field of interest. Include of vertical accelerations (climb, descent), and/or high angles of helicopter fuselage axis position in space widen helicopter manoeuvre possibilities. One can say it is important problem also from possibilities of helicopter flight envelope extending point of view. It is also essential to consider introduction of those techniques into helicopter training programmes.

2. Extreme manoeuvres at low flight speeds.

2.1 Types of manoeuvres.

One can list a number of manoeuvres performed at low flight speed range, which is useful on battlefields. They enable to keeping the target in targeting cone for the time long enough to shoot, or enable a helicopter to aim at the target by manoeuvre with height or/and direction change. These kinds of manoeuvres include: symmetrical diving (“same direction”, “hit the deck”(2)), diving with direction change at exit (“sideslip” – according to airplane nomenclature), jump to hovering: static (from hovering) or dynamic (from level flight), aiming in upper or lower semi-sphere – with the appropriate use of centrifugal and/or linear acceleration to reach necessary fuselage pitch angle, manoeuvre with the use of active direction control during flight with slip to get given fuselage yaw angle disconnected with flight direction to keep fuselage axis in target direction independently from flight path.

The necessity of performing manoeuvres mentioned above is mostly a result of accepted standards of modern military helicopter applications – in defense or ground/air targets attack (Figs. 1 and 2) (2).

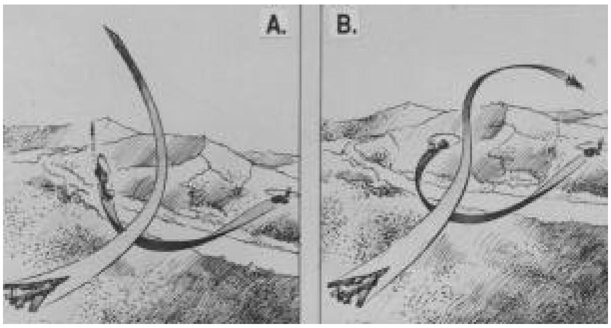

FIG.1. Helicopter manoeuvres during air fight: helicopter vs. airplane(2). A – tasks switch – helicopter performs sharp turn to attack position;
B- fly away of an airplane - helicopter attacks.

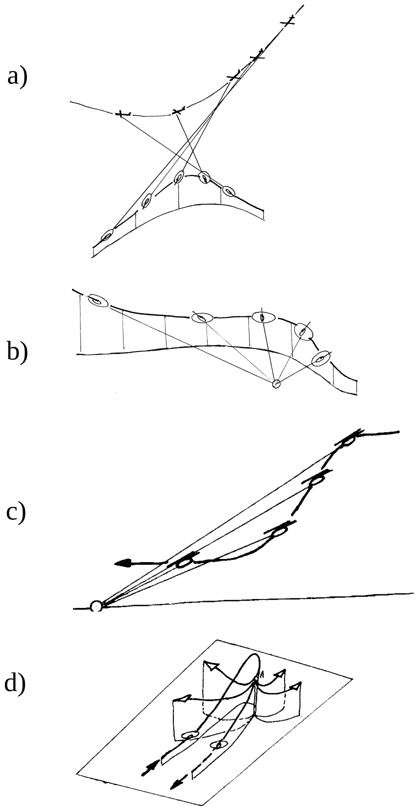

FIG.2. Possibilities of keeping helicopter axis in the target direction by thrust vector control what causes acceleration along flight path and flight path curvature: a) – for aerial mobile target; b) – for ground target; c) - fuselage axis kept in the direction of the target in entry into a contour flight; d) - counterattack by reverse (hammerhead or mod hammerhead) - with helicopter aiming in arbitrary direction in returning part of the reverse. This type of manoeuvre is commonly used in “helicopter vs. helicopter” type of fight.

2.2 Mechanics of low speed manoeuvres.

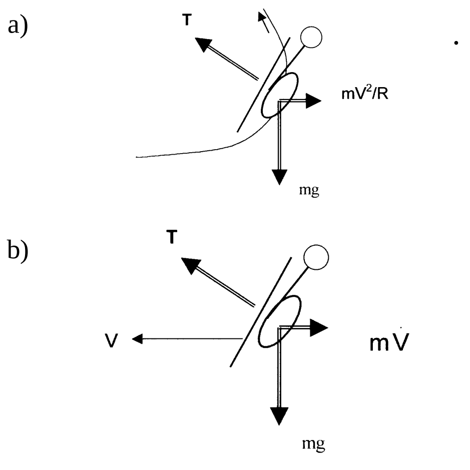

FIG.3. Application of accelerations for keeping determined helicopter pitch (or flare out). a)-centrifugal acceleration; b)-linear acceleration.

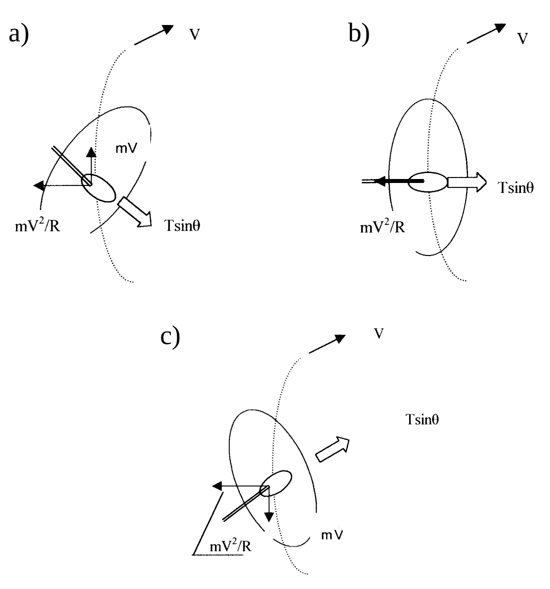

FIG.4. Application of accelerations combination to increase fuselage angular position control possibilities. a)- deceleration in turn; b)- steady flight; c)- acceleration in turn.

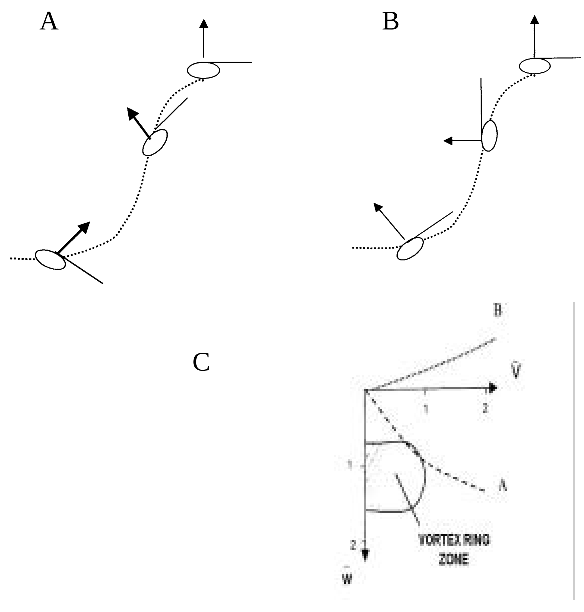

FIG.5. Two methods of performing “entry into a contour flight” manoeuvre: A- levelling out with the use of “aircraft technique” with more intensive cyclic pitch operating; B-levelling out with the use of “helicopter technique” with more intensive collective pitch operating, C- vortex ring area and rotor flow polar curve, which signal flight through vortex ring area hazard.

On figures 3-5 the essence of pilotage techniques used to widen helicopter manoeuvrability at low flight velocities was shown. Combination of centrifugal and linear acceleration shown on fig.4 allows manoeuvre needs to be realised during ground or air targets attack. The essence of control leading to quick entry into contour flight and pass by vortex ring is shown on fig. 5. In this case more intensive collective pitch control during recovery from dive decreases opposite to induced velocity direction stream flow component. This way the danger of approach to vortex zone decreases and energy-consumption of whole system increases in this flight phase (levelling-out may cause rotor overspeed).

3. Flight tests

The tests were conducted with the use of Mi-2 helicopter in Warsaw Institute of Aviation and W-3 Sokol (Falcon) helicopter in WSK-PZL Swidnik S.A. Few dozens of engineers were involved in the project. During tests, NOE (Nap-Of-the-Earth) manoeuvres were performed according to the test programme similar to one for military helicopters (including detailed requirements for flight path and other parameters). Particular manoeuvres performed during tests were determined according to ADS-33 standards. Flight parameters, helicopter loads, control runs, flight path were recorded the use of Global Positioning System and video recorders.

3.1. Tests with the use of advanced GPS system.

In order to obtain flight path geometry and flight parameters at low flight velocities and various angles of fuselage flow round, a Global Positioning System have been adapted. To increase measurement accuracy, an advanced, high-precision receivers has been used. Positions recorded by GPS (mounted on board) were corrected with the help of file recorded by on-ground reference station placed in test area. This ensured higher reliability of measurements (high accuracy) what enable to perform mathematical analysis of better quality.

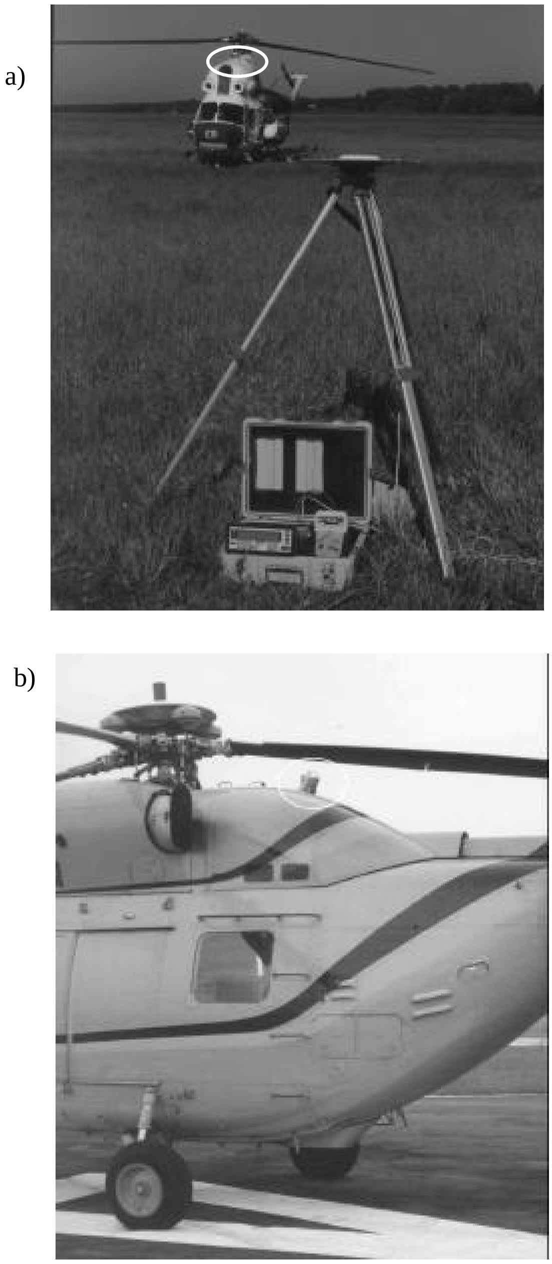

FIG.6. Introduction of GPS systems into helicopter testing. a) – Trimble 4000 reference station. On the Mi-2 helicopter antenna position of GPS ProXRS receiver is marked; b) – ProXRS receiver antenna location on PZL Sokol helicopter.

A Trimble model ProXRS GPS receiver, has been used as a mobile device. As an on-ground receiver, Trimble 4000 reference station has been used. Sampling frequency of position recording was 1Hz, but there is possibility of increasing this feature to 5Hz with the use of radio modems. Because of equipment difficulties the possibilities of increased sampling frequency have not been applied. Photographs of reference station and GPS antennas mounted on helicopters Mi-2 and Sokol are shown on fig. 6. Accuracy of corrected positions was equal ca.

20 cm applying to geographical position and ca. 60 cm applying to altitude (uncorrected accuracies averaged adequately 50 and 75 meters).

A complete flight path has been recorded into ProXRS receiver memory (receiver file was created) and corrections have been recorded by reference station (base file). After the flight, both files were copied onto computer hard disk and receiver file has been corrected with the use of corrections from base file (Pathfinder Office software was used). Then the manoeuvres were identified (common time base) and flight path recordings were divided into fragments corresponding to performed manoeuvres. For identification purposes software worked out for PZL Swidnik S.A. was used. Sokol helicopter was equipped with a telemetric apparatus enabling on-line monitoring of flight parameters, control parameters, helicopter loads. Every manoeuvre was marked with a number and additionally with time marks – hour, minute and second of beginning and ending. Before the flight, the time was synchronised both for ProXRS receiver and helicopter apparatus. After the flight, with the use of PZL Swidnik software, time of beginning and ending of each manoeuvre (marked with known number) was identified. Next, flight path recording from GPS receiver for this time interval was identified. Rows with positions between time of beginning and ending of each manoeuvre were used for analysis purposes. Positions were corrected for the whole flight recording, and the manoeuvres identification was performed on corrected file.

3.2 Results of the tests

Sample test results according to manoeuvres at low flight velocities, measurable only with the use of GPS (helicopters were not equipped with low flight velocities measurement apparatus) are shown below. There are examples included: jump to hovering – manoeuvre that begins and mid flight velocity and ends with hovering or hovering with direction change; accel – decel – manoeuvre that begins and ends with hovering; aiming in turn – with fuselage axis pointed up or down at the direction of upper or lower semisphere targets; entry into contour flight from hovering with direction change (“sideslip”).

Results, shown on fig. 8-12 include flight paths and velocities resulting from flight path analysis, selected flight parameters from on-board apparatus (helicopter bank and pitch angles) and photographs.

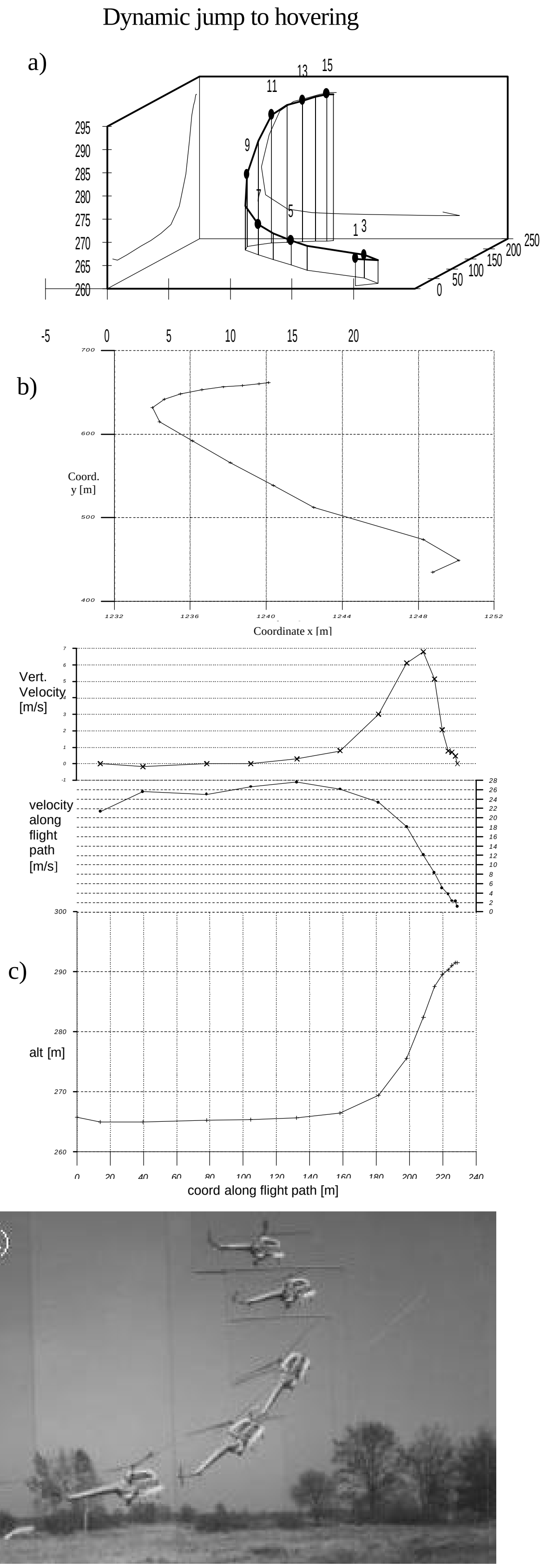

FIG.8. Dynamic jump to hovering – with flight direction change. a) – 3D plot of flight path; b) – flight path projection onto x-y plane; c) – flight speed and height recording; d) – picture of dynamic jump to hovering.

Accel – decel

FIG.9. Initial (top) and final (bottom) part of "acceleration-deceleration" manoeuvre.

For "accel-decel" manoeuvre 3D flight path and altitude change vs. coordinate along flight path is shown. Results of further analysis are vertical velocity and velocity along flight path as a function of position on flight path.

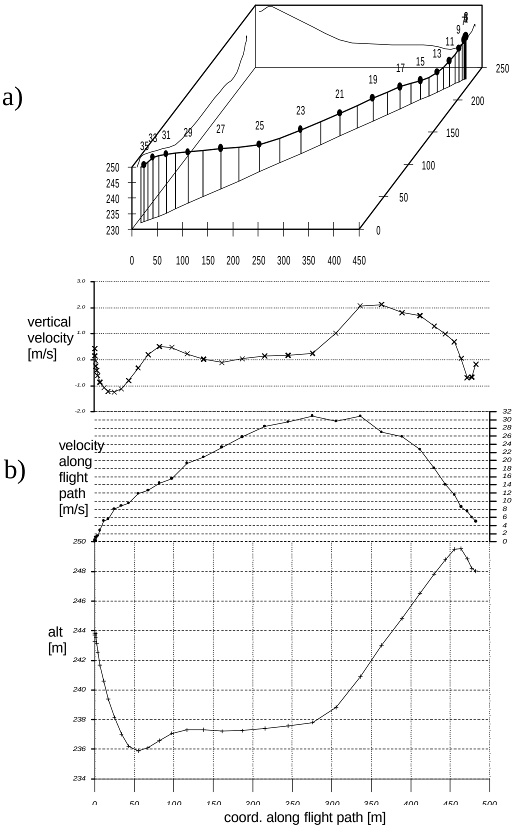

FIG.10. "Acceleration-deceleration" manoeuvre. a) – 3D flight path; b) – flight parameters. Flight speed and altitude recordings.

Aiming in turn – lower semisphere

For "aiming in turn – lower semisphere" manoeuvre there are shown – perspective view of flight path, flight path projected onto x-y plane, calculated vertical velocity and velocity along flight path as a function of position on flight path, distribution of fuselage bank and pitch angles.

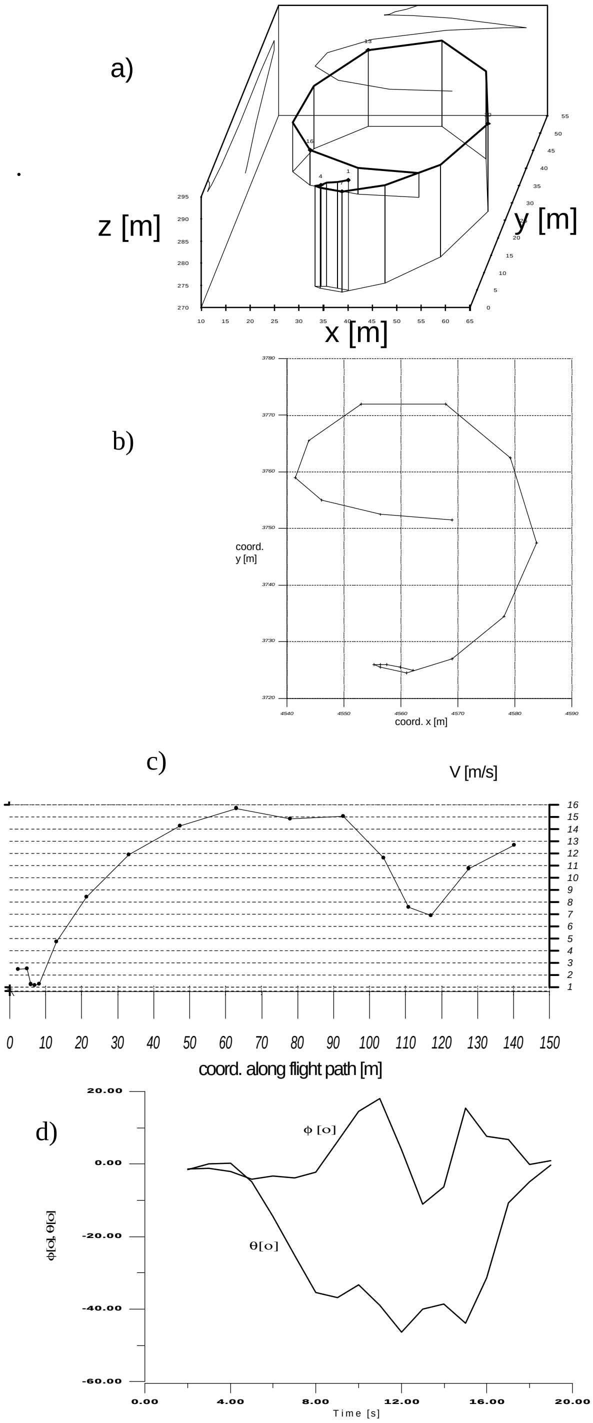

FIG.11. "Aiming in turn – lower semi-sphere" manoeuvre. a) – 3D flight path, b) – flight path projection onto x-y plane, c) – flight speed and height recording along the flight path, d) – pitch (θ) and bank (φ) angles plot.

Entry into contour flight („sideslip") from hovering or flight at low velocity.

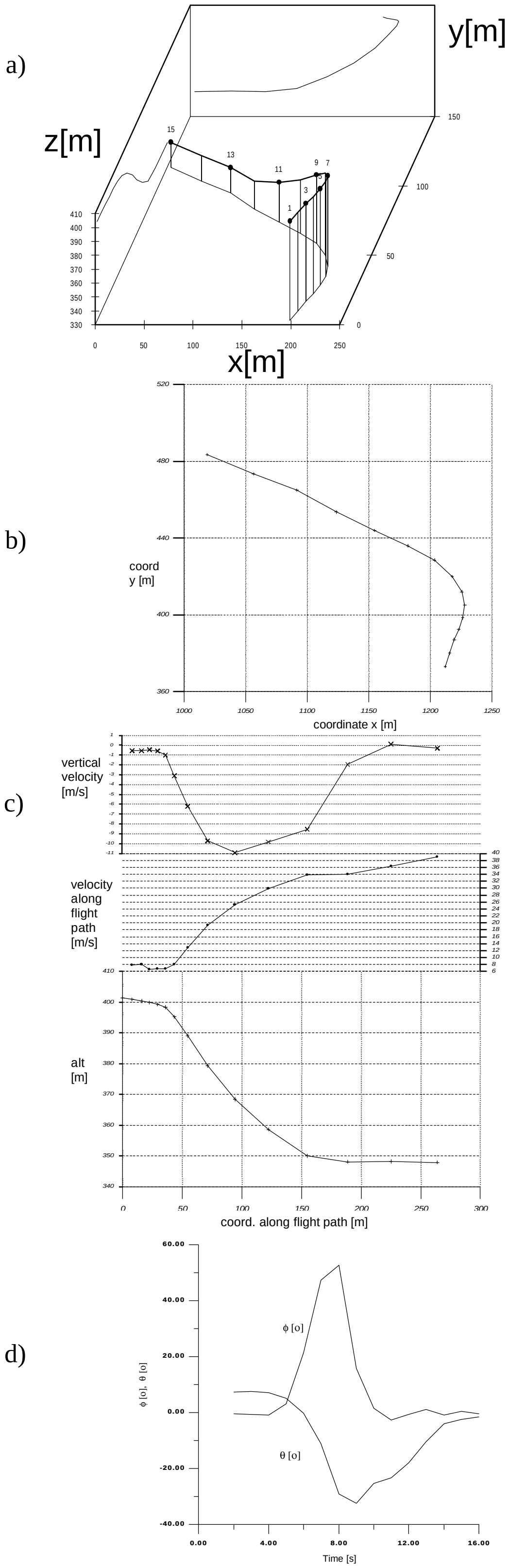

FIG 12. "Entry into contour flight" manoeuvre with bank and change of direction. a) – 3D flight path; b) – flight path projection onto x-y plane; c) flight speed and height recording; d) - pitch (θ) and bank (φ) angles plot.

4. Conclusions

Making use of thrust vector control at low flight velocities it is possible to perform spatial manoeuvres with considerable helicopter angular position changes, especially useful in military applications. Such flight conditions result from principles of helicopter flight mechanics and are included within allowable limits of structure loads. They also do not require pilot's unique skills. As a conclusion derived from tests one can say that safety level while performing this kind of manoeuvres does not exceed acceptable limits, there is only necessity of using pilotage techniques which enable to avoid vortex ring zone, keep proper blade-tail beam clearance and keep rotor overspeed below allowable limit.

References

1. *Aeronautical Design Standard. Handling Qualities Requirements for Military Aircraft.* US Army Aviation and Troop Command, St. Louis, ADS-33D, 1994.
2. Lamborn L.C., Lee R.A., Metzger M., *Apache Longbow Aerobatics.* AHS Forum 56, 2000r.

The work has been performed within Scientific Researches Committee research project number 9T12C04713