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THE EXPERIMENTAL AND NUMERICAL ANALYSIS OF HELICOPTER PERFORMANCE IN URBAN AREAS AND IN SAR OPERATIONS

ANALIZA EKSPERYMENTALNA ORAZ NUMERYCZNA EKSPLOATACJI ŚMIGŁOWCÓW W AGLOMERACJACH MIEJSKICH ORAZ W AKCJACH RATOWNICZYCH*

The paper discusses the methods of experimental and numerical analysis of helicopter performance in urban areas and search and rescue operations. The phenomenon of aerodynamic interference between the helicopter and the object located in its immediate vicinity was examined. The main focus was on the impact of interference on helicopter loading, airflow around the helicopter and helicopter properties in these specific cases. The paper provides a set of research results using the FLUENT software on the dynamic response to the disturbed simulation model of the helicopter rotor including the deformation of helicopter blades as well as the results of laboratory research on physical helicopter models.

Keywords: *numerical modeling, helicopter, aerodynamic interference, maintenance in town.*

Praca przedstawia sposoby analizy eksperymentalnej oraz numerycznej użytkowania śmigłowca w aglomeracjach miejskich oraz akcjach ratowniczych. Rozpatrzono zjawisko interferencji aerodynamicznej pomiędzy śmigłowcem a obiektem znajdującym się w jego bezpośredniej bliskości. Analizie poddano wpływ zjawiska interferencji na obciążenia, opływ i własności śmigłowca w szczególnych przypadkach jego użytkowania. Przedstawiono wyniki obliczeń wykorzystujących program FLUENT, odpowiedzi dynamicznych na zaburzenia symulacyjnego modelu wirnika śmigłowca uwzględniającego deformacje łopat oraz rezultaty laboratoryjnych badań eksperymentalnych na modelach fizycznych śmigłowca.

Słowa kluczowe: *modelowanie numeryczne, śmigłowiec, interferencja aerodynamiczna, użytkowanie w mieście.*

1. Introduction

Typically, helicopters are capable of major aircraft maneuvers like take-off, landing, vertical ascending and descending with no cruising speed. Hence, helicopters are often used for special tasks and operations such as high-altitude rescue, military operations, mountain rescue, and other air operations in urban areas with tall buildings. Such incidents occur during high-altitude rescue around multi-storey buildings, at heliports as well as during mountain and medical rescue (Tatrzańskie Ochotnicze Pogotowie Ratunkowe (TOPR) - Tatra Volunteer Search and Rescue, Lotnicze Pogotowie Ratunkowe (LPR) - Air Emergency Medical Services). Similar incidents can happen when crane operating, military operations in cities and helicopter operations by media workers and the police to control cities. The use of helicopters in urban areas results in aerodynamic interference of the helicopter - object airflow [6, 7, 8]. Consequently, the pilot needs to be attentive if this phenomenon occurs during flight, particularly if there is turbulence due to wind flow around buildings and convection due to a temperature discrepancy between buildings and the ground, e.g. local areas of fire [10, 11]. Interference at a lee side of a building during special operations is regarded as one of the most dangerous helicopter - object interference incidents.

These incidents are intensively studied in the global leading helicopter centers, which is supported by a rapidly improved computing capacity, special software to visualise complex helicopter flow disturbance fields and improved computational methods. This theoretical examination is verified by wind-tunnel and flight experimental studies. As this subject develops fast, the latest accomplishments can be found only in conference proceedings, mostly of the American Helicopter Society Annual Forum and Technology Display (e.g. [1, 2, 3]) or the European Rotorcraft Forum. Although books and papers published in principal journals provide basic methodological knowledge, they are significantly behind the rapidly developing applications mentioned in the above conference proceedings.

2. Numerical analysing urban-area helicopter operation study cases

Numerical calculations refer to the assumed pressure distribution in the rotor. The airflow including objects in its close proximity was calculated with the FLUENT software [4]. The determined velocity field of airflow across the rotor plane enabled the characteristics of the basic parameters of load (developed at the Institute of Aviation, the OBCWN software was modified to analyse aerodynamic interference). This new airflow across the rotor blade enabled rotor load parameters and a new rotor surface pressure distribution. This new pressure distribution was introduced to correct and re-calculate airflow around a helicopter using the FLUENT. Iteration was carried out until the values obtained were convergent. To accelerate the convergence, a velocity field of the arithmetic average of the field from the previous and current iterations was entered into the next iteration. Such an approach was necessary for a highly flexible blade due to its significant sensitivity to the disorder and its response as a function of twisting the blade. Consequently, a satisfactory convergence of the calculations was already achieved in the second calculation step.

Figure 1 shows a helicopter model developed on the real geometry of helicopter W3-A SOKÓŁ. This geometry employs triangular and quadrilateral cells, and the size of the divisions was specified at the edges of the surface or adopted a constant length of element edges.

(*) Tekst artykułu w polskiej wersji językowej dostępny w elektronicznym wydaniu kwartalnika na stronie ***www.ein.org.pl***

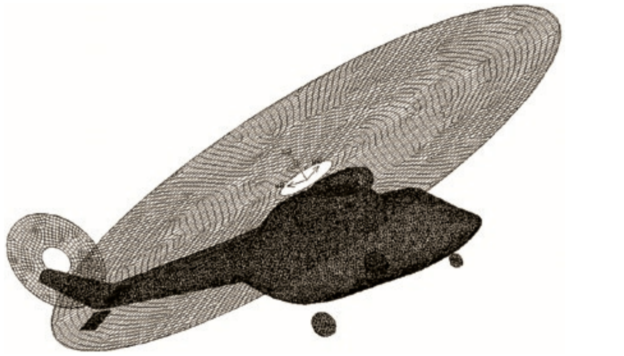

Fig. 1. Helicopter calculating grid (non-structural – triangular cells in the fuselage (edge is 0.05m), quadrilateral cells in the master and tail rotors (edge is 0.2m))

Figure 2 shows the distribution of measurement points generated by the FLUENT input file. File Journal is a list of commands to be entered manually using a graphical environment. The input file speeds and automates the creation of measurement points.

Vertical velocity values at the measurement points were collected in a table applied later as a source of information about the rotor induced speed in special software to calculate strength.

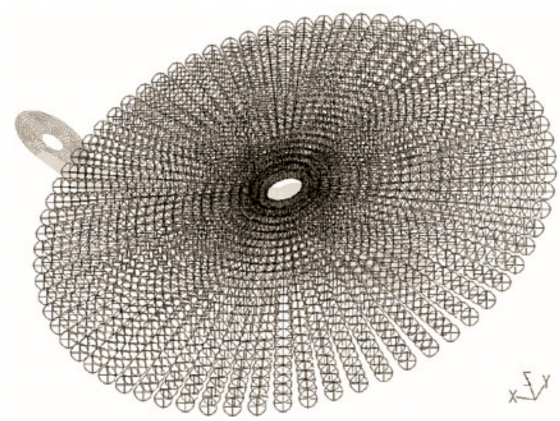

Fig. 2. Schematic of the arrangement of measurement points on the rotor

In addition, the calculations are based on the following assumptions: unsteady airflow calculations; helicopter free movement was simulated and modeled using a static mesh; calculations were done for compressible and viscous fluids; and a k-ε turbulence model was applied [5, 9]. The parameter distributions for the rotor model were defined by means of the velocity profiles developed (Fig. 3).

The strength calculation resulted in the table to provide the changes in rotor pressure distribution. This distribution can be used to define a real initial condition for a rotor pitch pressure model. It was entered by means of the profile file compatible with the previously measurement point distribution.

2.1. Numerical calculation results

One of the methods of numerical analysis of aerodynamic interference between the helicopter and the object located in its immediate vicinity was examined. The impact of interference on helicopter aerodynamic load, flow and properties in specific use was studied. The results of FLUENT calculations, dynamic response to the simulated disturbed rotor model including the deformation of helicopter rotor blades and the results of laboratory experimental tests on aircraft physical models are provided in this paper. Figure 4 shows this method of analysing the phenomenon, depicting the method of analysis of aerodynamic interference if helicopters are used in urban areas or for rescue. This method was applied to analyse the use of the helicopter in hover for the cases in Figure 5 –7.

Several characteristics and values were determined for the cases depicted in Figure 5 – 7. The most reliable parameters to prove aerodynamic interference are the values of power needed to manoeuvre and torque coefficient as in Table 2.1.

The values in Table. 2.1 confirm the growing demand for power to be delivered to the rotor to hover in the vicinity of the well object relative to other cases.

Table 2.1. Thrust and power in low hover

Case	Thrust - N	Power - kW	Cz	Cmz
Fig. A	61000	913.26	0.1632	0.01163
Fig. B	61000	810.48	0.1632	0.0103
Fig. C	61000	619.51	0.1632	0.0079

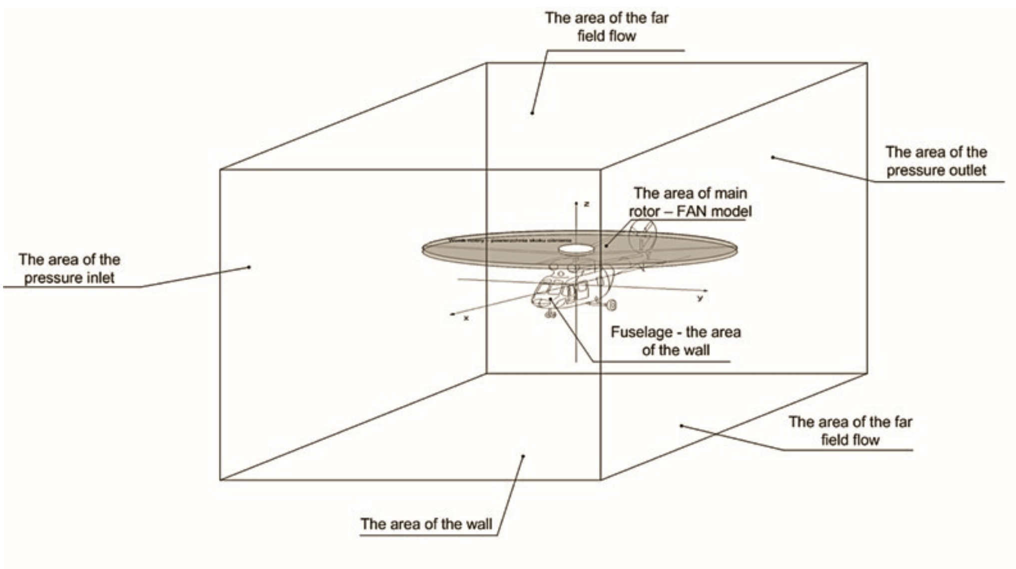

Fig. 3. Geometric assumptions for the calculation model and structure of the airflow area

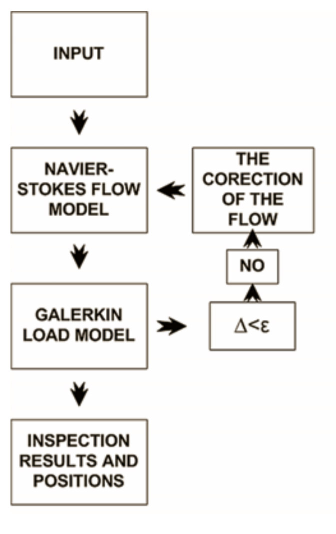

Fig. 4. Diagram with one of the methods used to deal with aerodynamic interference

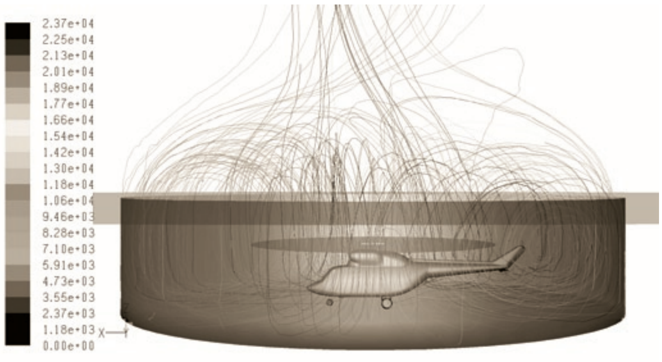

Fig. 5. Streamline distribution in hover in the well object

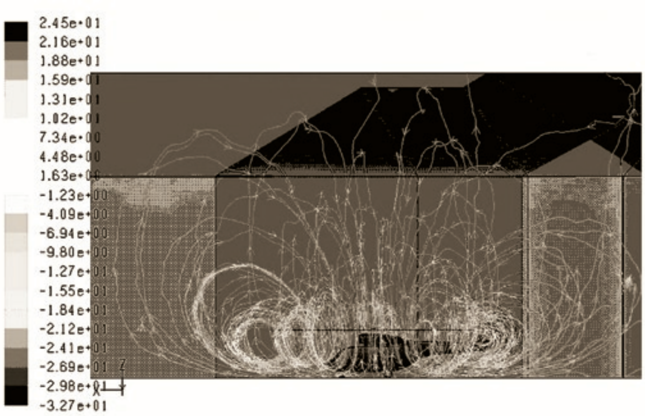

Fig. 6. Streamline distribution in hover in object "Royal Castle in Warsaw"

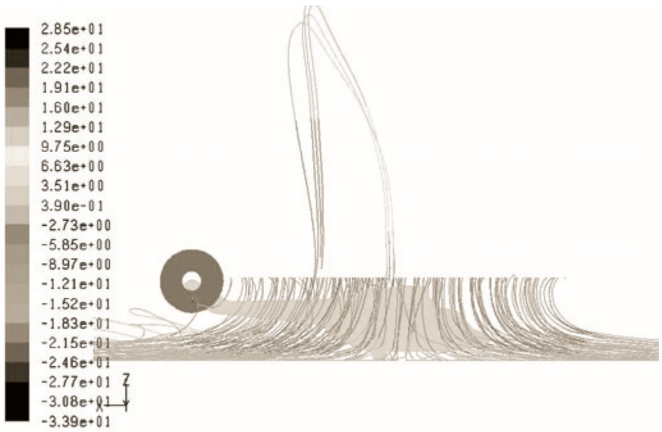

Fig. 7. Streamline distribution in hover with no nearby objects

Rotor-hull interference including the impact of the near ground was examined (Fig. 8). A Navier and Stokes model was applied to calculate airflow for three cases of hover by helicopter W3 - SOKÓŁ (Fig. 9): 1 – hover with the landing gear (wheels) very close to the ground, 2 – hover at the height of the landing gear 16 m above the ground, and 3 – hover at 32 m above the ground.

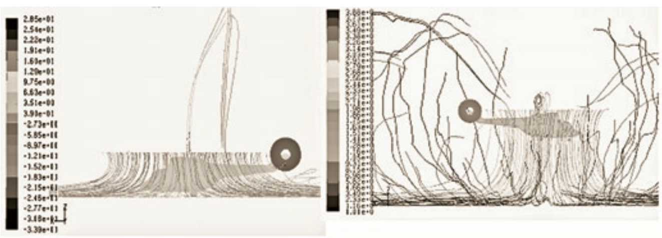

Fig. 8. Streamlines: a – hover, the landing gear in contact with the surface, b – hover, the landing gear at 16m

For the calculation of the charges for the analysis of interference phenomena and blade uses OBCWN program calculates the load on the rotor of the helicopter carrier with the ability to podczytywania any field disturbance in the speed box, speed disturbed fuselage in the vicinity of the substrate. The results of the analyses are illustrated in Figure 1. 9.

On the basis of the analysis, it was found the impact of proximity to Earth on the parameters characterizing accident carrier rotor helicopter. A significant impact was noted the presence of ground motion

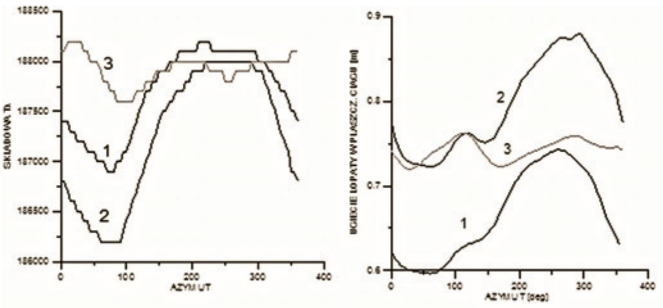

Fig. 9. The impact of the hull and on the ground: a-horizontal component of the Tx, b-swing shovel

and dynamics of loads asymmetry caller blades even in this State, which is zawis. In perfect for insulated, rotor zawisie notes to significant changes to the parameters of its work.

3. Experimental analysis of helicopters' exploitation cases in urban agglomerations

In order perform a verification of some of the results of computer simulation of interference phenomena taking place during the helicopter's operation in the urban area experimental studies corresponding to the cases analyzed numerically (Fig. 10) were carried out.

Fig. 10. The structure of the behind-rotor stream during experimental tests on the real helicopter W3-A FALCON

During a low hovering flight maneuver of the helicopter performed close to the ground at insufficient excess of the engine power an acceleration of the craft is possible. This may be realized by the use of kinetic energy of the carrying-rotors' inert system, in order to overcome the area, where the drive's required power is greater, than the disposable one. The result is a decrease of the carrying-rotor's speed. The limit condition of the permissible ratio of the rotor's kinetic energy utilization is non-crossing of the speed limit due to a possibility of the rotor blades' streams detachment. The possibility of reducing the minimal excess of the starting power by using the above mentioned take-off technique strongly increases the helicopter's usability. Namely, an operational payload increases, as well as the starting ceiling at a given load. Fig. 11 shows a schematic diagram of the distribution of forces acting on the helicopter during the maneuver of the low hovering flight.

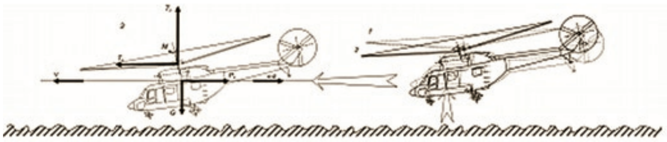

Fig. 11. Schematic diagram of the distribution of forces acting on the helicopter during the low hovering flight

Fig. 12 shows a comparative analysis of the Effective Translation Lift (ETL) phenomenon (instantaneous power demand growth necessary during the spin-on-the-fly low to the ground) obtained by a numerical analysis and compared with the results obtained from the experimental tests carried out on the real object W3-FALCON [11].

Interference analysis of rotor-induced flow with a horizontal influx of the stream and the method used for the determination of the temporary power demand (ETL) phenomenon influence on the helicopter's load allows to specify the effective loads, as well as the required power during the spin-up maneuver. This analysis may be useful in a preparation of the special take-off techniques of helicopters at their limit operational use.

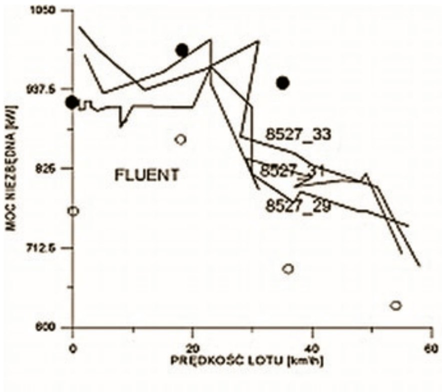

Fig. 12. The necessary power change along with the airspeed increase. Solid lines: the subsequent flight tests with a sample number; the indication of the results of the calculations of the FLUENT software: "o" is a helicopter without a draft, "•"- a helicopter with draft (adding power to accelerate and the "air bag" escape along with the tilt and the speed of flight increase)

4. Conclusions

The conclusions coming out from the study of the phenomenon of interference can be useful in the process of operational use of helicopters among buildings on heliports, particularly with regard to the assessment of dangerous zones due to the presence of an intense aerodynamic interference. This also applies to the use of marine helicopters based on the helidecks (ships' boards or drilling platforms' aerodromes). The usefulness of such knowledge also applies to the designers of the air strips located on the roofs of tall buildings. Investigations were carried out due to the occurrence of operational problems encountered by the users such as the State Fire Department (SFD) and the Polish Air Ambulance Service (PAAS) during the relief operations carried out by these services in towns and due to the fact of building the elevated helipads for sanitary helicopters.

On the basis of the performed numerical and experimental studies of the aerodynamic interference of the helicopter's flow around a conclusion comes out, that the pilot and other users should be warned against the situations, when the vicinity of an obstruction causes danger and that the minimal separation areas should be specified, for which the interference phenomenon between the helicopter and the other object may trouble the operational task.

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