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NUMERICAL INVESTIGATION OF ENDPLATES INFLUENCE ON THE WING IN GROUND EFFECT LIFT FORCE

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Abstract

The article presents a comparison of the wing in ground effect magnitude of conceptual WIG craft model main characteristics for a wing with and without endplates which are also known as winglets in regular aircraft. In article, the author describes WIG effect with and WIG craft, which operates on low altitude, smaller than the length of wing chord, mostly above the water reservoir. WIG effect phenomenon is simple. The first aircraft needs to fly at adequate altitude, with a smaller distance between lower airfoil surface and ground static pressure rises, leading to rising of lift force. The main advantage of the wing in ground effect craft on regular aircraft is a much higher lift to drag ratio, also this phenomenon provides to drop in specific fuel consumption of aircraft and allows flying with heavier cargo due to higher lift force. Characteristics present in the article were designated from simulations, which were conducted in Ansys Fluent software. Results obtained for a wing with endplate in numerical analysis shows the superiority of this approach. Endplates provide to increase WIG effect by a decrease in induced drag through the move out vertices from the wing tips, which are made by differential pressure above and under the wing. As winglets in regular aircraft, endplates provide to save fuel. WIG craft does not need airports so it could be a cheap alternative for modern aircraft.

Keywords: *endplates, ekranoplan, numerical analysis, wing in ground effect, airfoil*

1. Introduction

Most pilots experienced the phenomenon of the closeness of land during landing. Additional lifting force was created before the landing gear contact with the landing field caused the phenomenon of gliding over the belt until the appropriate loss of speed. Thanks to this, the air cushion that was created ceased to affect the wage carrier.

In addition, the surface effect reduces the speed of air flowing from the lower surface of the wings upwards, thus reducing the losses caused by the formation of vortices behind the wing. This phenomenon also has a positive effect on increasing the so-called effective wingspan. In free flight, vortices, by omitting the tips of the wings, lead to a loss of lift at their ends. They cause the loss of lift force by moving the vortexes of the wing ends [6, 7], as well as reducing the induced resistance (Fig. 1).

It can be concluded that the decrease in the effect of the resistance phenomenon induced on airframe resistance is the most important factor characterizing the attributive effect. At the same time, due to the possibility of the use of the dynamic airbag phenomenon by the airfoil, we can additionally increase the strength by the appropriate shape of the hull. The air entering the hull cannot get out of the way. It should be closed with a backflow e.g. with a flap. The second way to increase the lifting force is to limit the outflow of air from the wings, e.g. using flaps or additional elements, walls at the ends of the wings limiting the escape of air at their ends.

A dynamic air cushion is created during a progressive flight. If the lift is generated by exhaust gases of the turbine engine or by an additional propeller, this is a static airbag phenomenon. This phenomenon occurs when the wing in ground craft moves slowly over water or stands. It works then like a classic hovercraft.

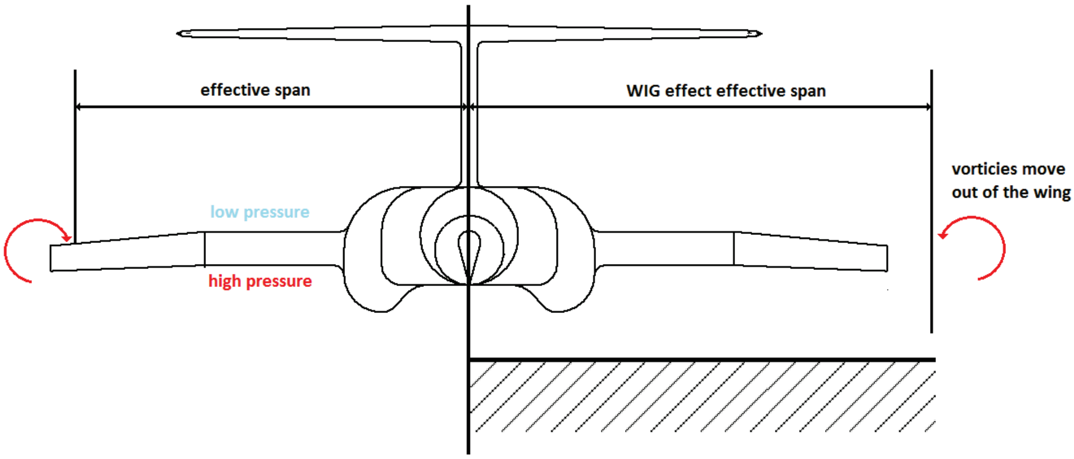

Fig. 1. Mechanism of WIG effect creation [2]

At the same time, it seems obvious to look for new solutions in the field of transport. The number of travellers increases year by year, and the import or export of goods (Fig. 2) is growing. The vision that, with time, there may be space in the sky for more aircraft is unlikely. The fact is, however, to increase the use of air corridors, which hinders air traffic, increases flight time and fuel consumption.

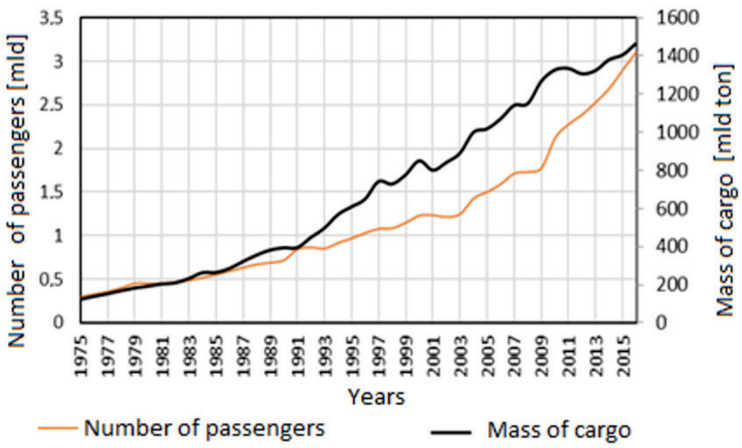

Fig. 2. Number of passengers in air transport in the years 1975-2016 [1]

The answer to this growing demand in the field of transport can be wing in ground crafts. These are special purpose airplanes. By using the wing in ground effect to increase the lift of the entire aircraft, we could move people and loads at high speed over the surface of the ground or water. The surface effect can be divided into a positive surface effect, desired in airplanes, which leads to an increase in wing lift, observed for positive angles of attack, and a negative surface effect leading to reduction of lift, i.e. to increase the downforce. This phenomenon is used in the automotive industry, especially in Formula 1. In the front of the car there is a characteristic “wing” maximizing the aerodynamic downforce.

The construction solutions found in screens over time are promising, and the effect of the near-surface effect on the characteristics of the airframe itself on parameters such as fuel consumption, is positive.

2. Ansys Fluent simulations

All simulations were prosecuted in Ansys Fluent 18.2 academic research. Simulation conditions for all cases:

– solver set as density-based because velocity in this simulation is set almost 0.3 of Mach number, and above this value, there is need to consider flow as compressible,
– speed set as 100 m/s,
– pressure value set as 1 atm. (101325 Pa),
– energy equation set on,
– turbulence model set as k-epsilon, and it contains two equations in it, first the turbulent kinetic energy k, and second dissipation rate equation,
– gas property set as ideal-gas, because the air in density based solver does not work with constant air density,
– there is a dependency, determine by K. V. Rozhdestvensky [2] which is the height of flight to chord length ratio, called height coefficient (1). Altitude above ground set as 0.1 of wing chord length,
– wing angle of attack equal to 6º.

Concept aircraft characteristics [3]:
– length of aircraft: 54.7 m,
– wing span: 31 m,
– aircraft height: 10.3 m,
– hull height and width: 4,5 m and 9 m,
– wing surface area: 180 m².

In every simulation as the main condition of results, convergence is recognized by stabilization of lift (vertical axis on Fig. 3) and drag (vertical axis on Fig. 4) coefficients in numerical analysis. When lift coefficient and drag coefficient remains still, as in Fig. 3 and 4, numerical analysis is succeeded. On both figures, on the horizontal axis the number of iterations is placed, it means number of steps it means the number of steps in which the convergence of calculations has been achieved.

In simulation as expected, aircraft with endplates produce higher lifter force. The increase in lift force in the simulations performed in the ANSYS Fluent program is almost 30% (Tab. 1), which significantly improves the characteristics of such aircraft. Higher lift force allows taking much more passengers or more cargo. So wing in ground effect provides to decrease in fuel consumption per passenger.

Tab. 1. Lift force of wing in the ground craft for different kind of wings

Type of wings	Lift force [kN]
Regular wings	1214
Wings with endplates	1570

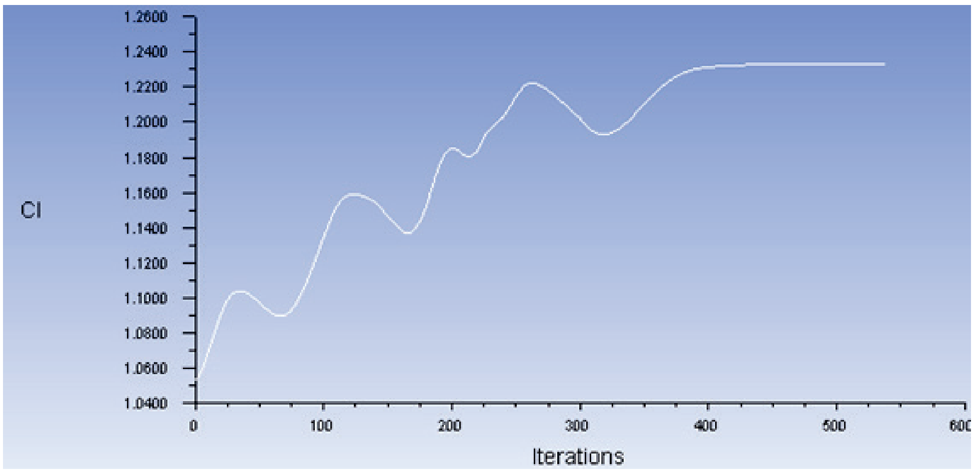

Fig. 3. Convergence of lift coefficient [3]

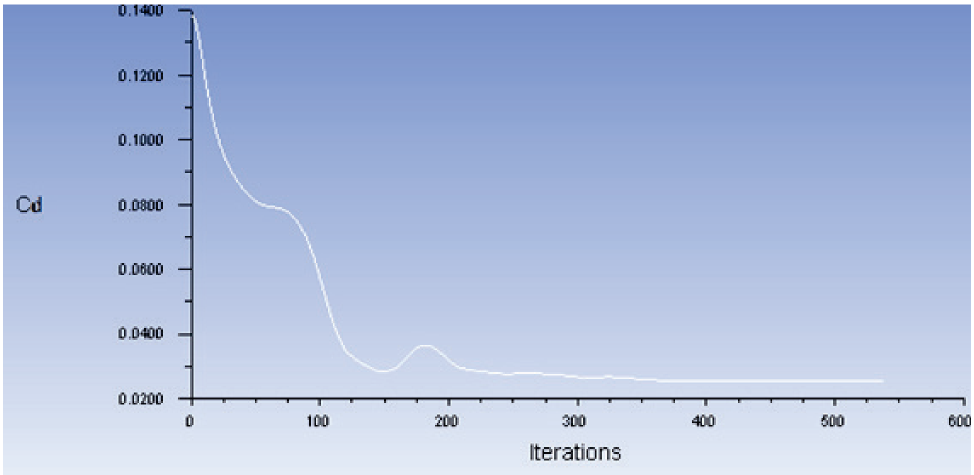

Fig. 4. Convergence of drag coefficient [3]

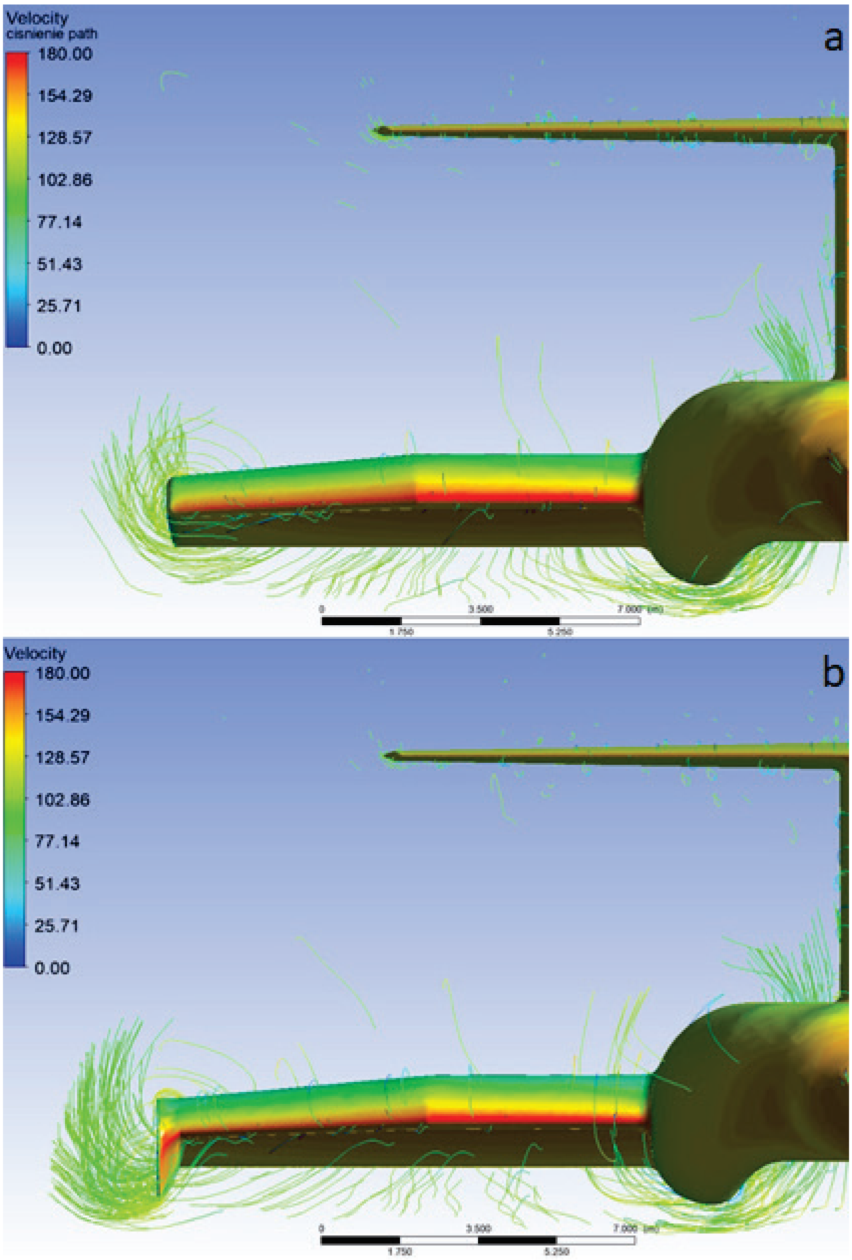

Fig. 5. Different wing kinds with velocity pathlines [m/s]

Figure 5 shows airstream path lines for two investigated cases. On the top (Fig. 5a), there is wing without endplates. As on Fig. 1, the vertices creation starts under the wing in almost 25% of wing length. This phenomenon provides to decrease in lift force by generating induced drag. On the bottom (Fig. 5b), vertices are moved out to the wing tip, and decrease the aircraft drag. Wing in ground effect flight with wings equipped with endplates provides to increase the effective span of the wing.

Figure 6 shows pressure distribution under two kind of wing. On the left, there is wing without endplates (Fig. 6a). There is an area on the wing tip with lower pressure (blue colour). This is the place on the wing where induced drag provides to decline in lift force. On the right (Fig. 6b), there is a wing with endplates. Pressure under this wing has almost equal distribution on the entire surface, and the pressure is higher. This is a consequence of the use of wings with endplates.

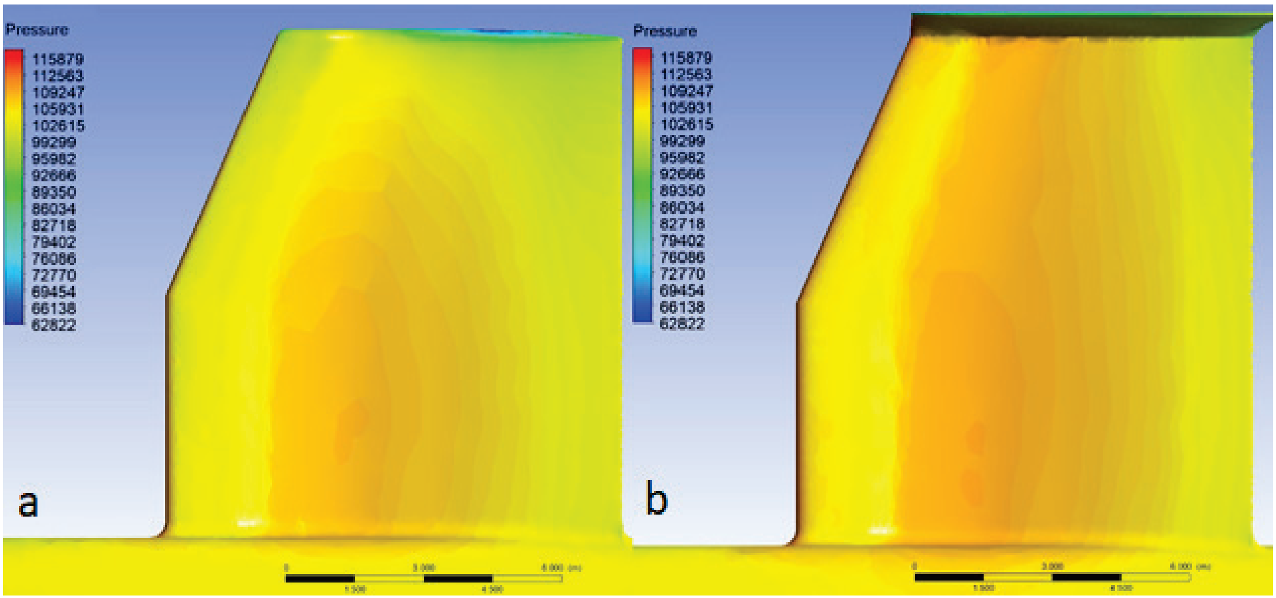

Fig. 6. Pressure distribution under the different kinds of the wing [Pa]

3. Conclusions

With obtained results, it is obvious that wing in ground effect flight with use of endplates on the wing tips generates much higher lift force than with the use of regular wings. Wing in ground effect has some features, which provide to increase in lift force, and in a decrease in drag force. With lower fuel consumption [5] and without the need of regular airports, wing in ground effect crafts could be future of aviation. Due to the low altitude of the flight, the choice of this kind of transport may be suitable for people who are afraid of flying aircraft. Therefore, it is a chance to increase the availability of fast transport around the world. The aircraft concept assumes the use of all systems that allow increasing the lift and subsequent optimizations under relative to the reduction of aerodynamic drag. The airframe with the maximum level of safety is to ensure the most environment-friendly operation.

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