Considerations of the Bird Strike on Aircraft Wing

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Abstract
Airborne bird strike are relatively common and are on an ascending trend, which is a serious economic and aeronautical security, which is related to the increase in the numbers of large bird populations. According to the specialist references, the number of collisions of this type increased ten times between 1990 and 2015, the most exposed being propulsion systems and aircraft wings. Pilots and operators can be informed about ornithological threats and flight crews use standard operating procedures for such events to reduce the potential and consequences of a bird incident. The article wants a software analysis of the bird strike with a lifting surface of the aircraft.

Key words
bird impact, XFLR5, aerodynamic coefficient, Clark Y

Symbols and acronyms

FAA	- Federal Aviation Administration	XFLR	- Xfoil Low Reynolds
AoA	- angle of attack	VLM	- Vortex Lattice Method
C_d	- drag coefficient	C_p	- pressure coefficient
C_m	- pitch coefficient	C_l	- lift coefficient
BM	- bending moment		

1. Introduction

Events caused by aircraft collision with birds during the flight have posed serious problems 100 years ago. According to the specialized references [1, 8], the number of such collisions increased exponentially in 1990-2015. For a specific location of collisions on a commercial airplane, it is possible to see the percentages in Figure 1, impact areas with birds in flight [2].

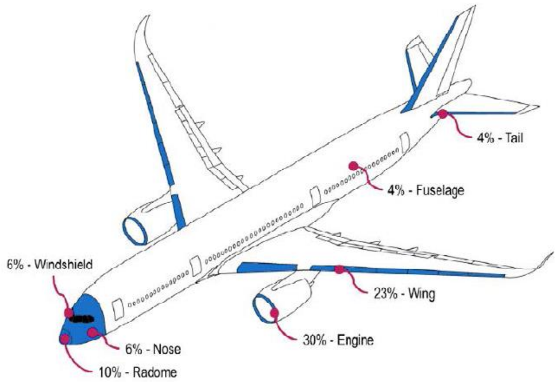


Fig. 1. Areas of impact - FAA [2]

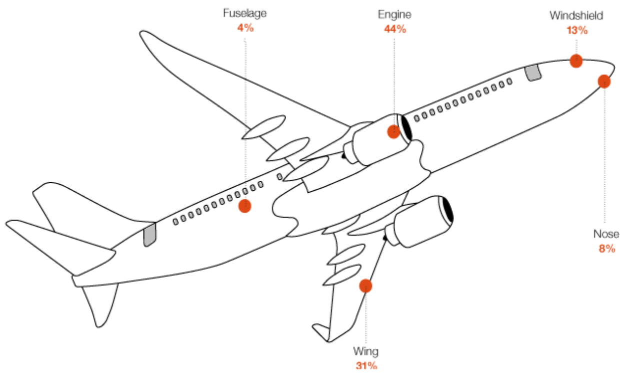


Fig. 2. Areas of impact – Boeing [8]

According to the two references [2, 8] the propulsion system (30% FAA, 44% Boeing) and wings (23% FAA, 31% Boeing) are the most exposed to collisions with flying birds. Bird strike of low altitude aircraft for landing or take-off stages; highlight the need for wildlife management for airport areas, these incidents may have significant consequences for the safety of flight operations. Pilots and operators can be informed about ornithological threats and flight crews use standard operating procedures for such events to reduce the potential and consequences of a bird incident. Figure 3 shows a number of examples of damage caused by the impact of aircraft wings on flying birds.

Fig. 3. Damage caused by birds [3, 4, 5]

The most problematic cases that have led to accidents are those involving single large birds, large flocks of small birds and small fleets of medium-sized birds; in the US, a list of the most dangerous birds for the activities: large birds (geese, seagulls), raptors (hawks, eagles), pigeons and sparrows [8], can be observed in Table 1, highlights the data on aviation ornithological events of US civil aircraft.

Table 1. Ornithological aviation events [8]

Location	SUA		Foreign	
Year	Strikes	Damage strikes	Strikes	Damage strikes
1990	1813	363	34	6
1995	2716	485	52	11
2000	5871	741	129	21
2005	7046	585	181	20
2010	9673	578	231	18
2015	13546	604	249	12

Figure 4 highlights the percentage of aviation ornithological events reported at an altitude of 500 feet, between 1990 and 2015, where a significant percentage distribution of events in the take-off / landing stage is observed.

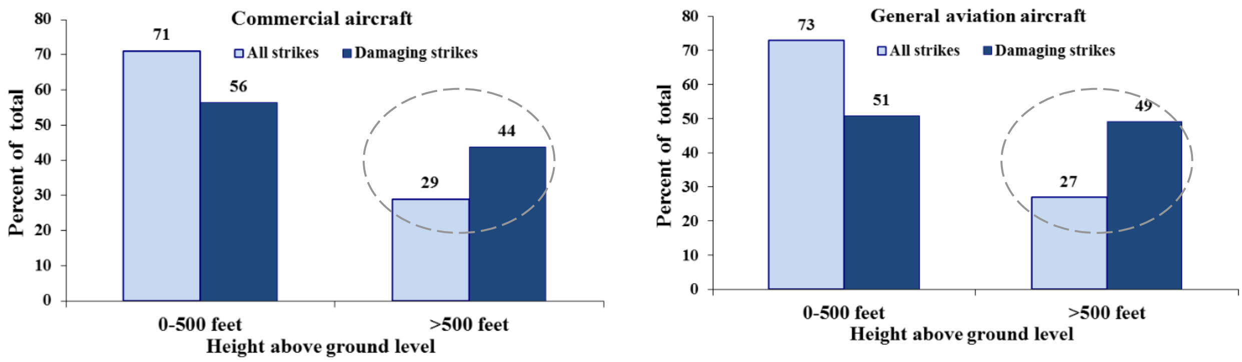


Fig. 4. Ornithological events 1990-2015 [8]

This requires certification of bird impact structures based on: economic and impact assessments on aeronautical safety and security [1, 6, 7, 11]; accurate and valid simulations and tests that include approaches to physical modeling structures with structural models [9, 12] and aerodynamic approaches through CFD analysis, see Figure 4 [10].

2. Aerodynamic Analysis

CFD 2D analyzes can be preceded by sufficiently precise mathematical estimates of aerodynamic profiles used both on airplanes and helicopters [14, 15, 18] with possible later approaches more carefully managed both with regard to the choice of the optimal profile and the conditions of analysis used. 2D profile and 3D wing analyzes are performed with the XFLR5 freeware tool [13].

2.1. 2D profile analyzes

For the 2D comparative analysis, a profile often used in aircraft wing construction, Clark Y, see Figure 5, with the geometric features and initial conditions in Table 2, is deformed on the leading edge [16, 17].

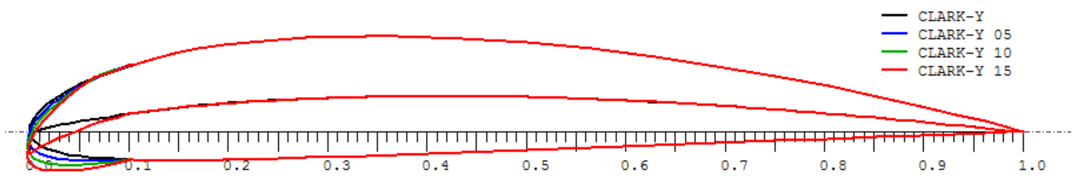


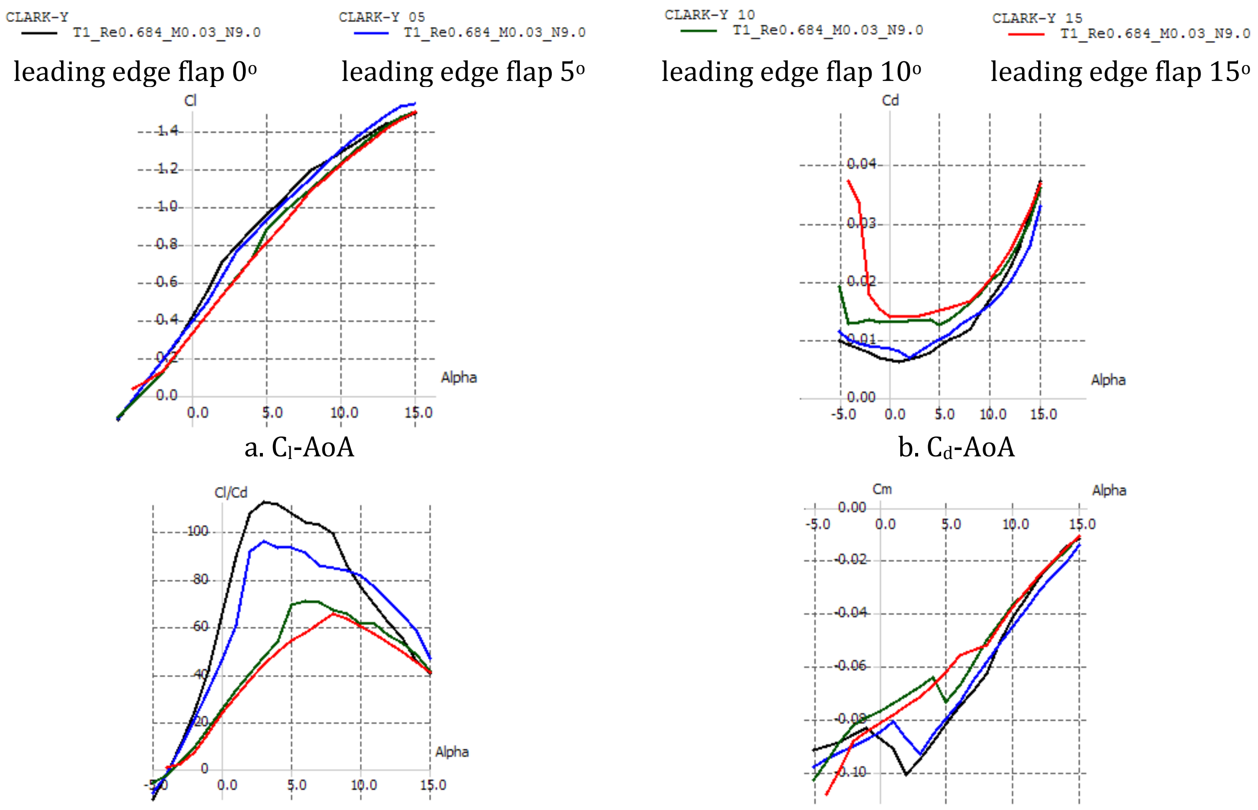
Fig. 5. Clark Y airfoil

Table 2. Geometrical data and 2D analysis conditions

Data	Value	Data	Value
Speed	10 m/s	Re	6.8×10^5
Altitude	0 m	Chord	0.1 m
AoA range	–5° ÷ 15°	ρ_{air}	1.225 kg/m^3

The airfoil geometry after impact was achieved by modifying the curvature of the airfoil by turning the leading edge flap by 5°, 10° and 15° (see Figure 5), thus simulating the degree of deformation.

Figure 6a shows an increase in load on the profile with maximum turning due to the curvature increase of the profile with an increase in forward resistance (Figure 6b). The increase of the glide ratio (C_l/C_d) with the leading edge flap, is highlighted in Figure 6c, and on the analyzed AoA interval (–5° to 15°) the pitch moment coefficient C_m has significant differences especially on the 0° to 5° interval of the angle of incidence, AoA (see Figure 6d).



a. C_l-AoA

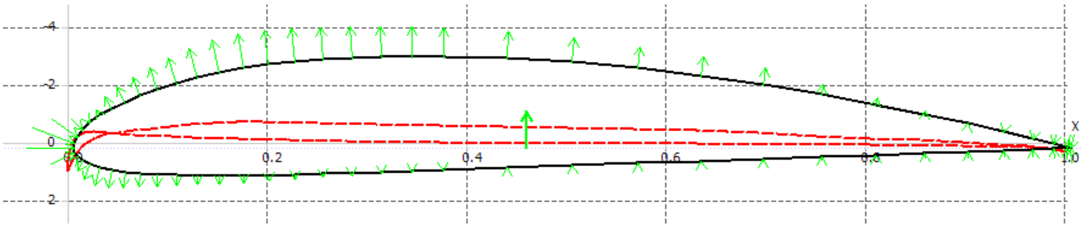
b. C_d-AoA

c. C_l/C_d-AoA

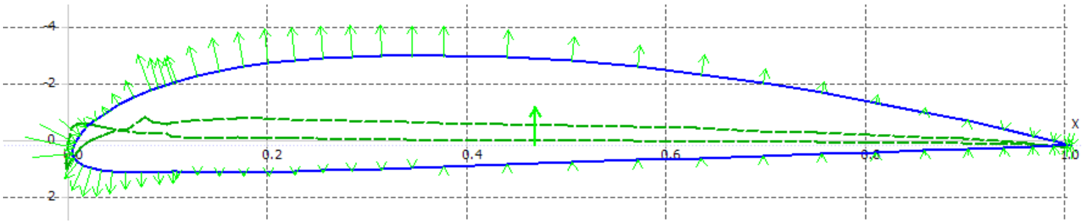
d. C_m-AoA

Fig. 6. Clark Y airfoils

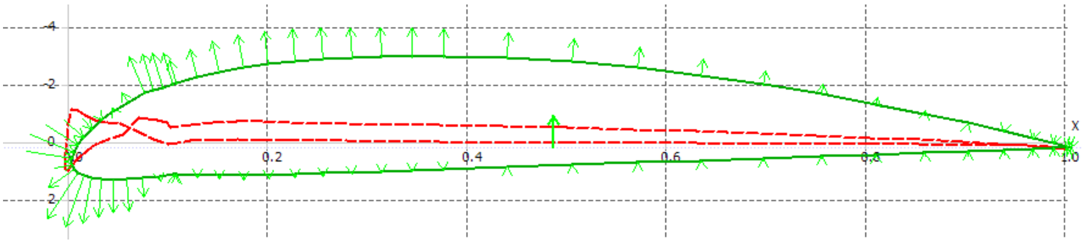
Figure 7 for the null incidence of the profile shows the variation in the pressure coefficient distribution (C_p) depending on the variation of the leading edge flap turning. An inflection of the distribution curve of C_p is noticed at the extraction, more pronounced as the turning flap has a higher value (see Figure 7d). The C_p value on the leading edge has the maximum value at the maximum curvature of the voucher, see Figure 7d.



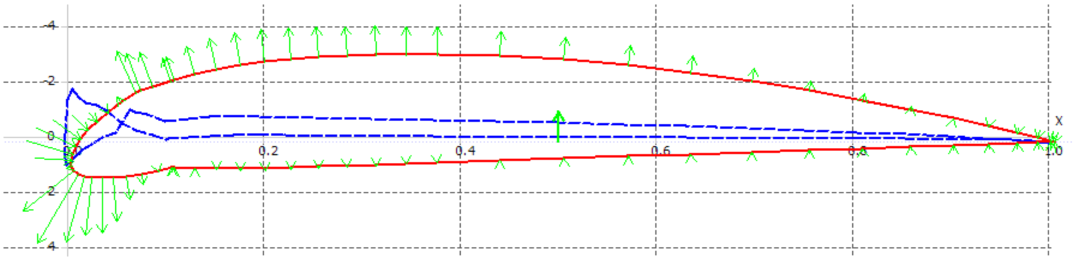
a. Clark Y attack flap at 0°



b. Clark Y attack flap at 5°



c. Clark Y attack flap at 10°



d. Clark Y attack flap at 15°

Fig. 7. C_p distribution Clark Y airfoil

2.2. 3D wing analyzes

For 3D analysis, is considered a wing with the geometric features and initial conditions in Table 3 for the aerodynamic parametric study.

Table 3. Geometric features and 3D analysis conditions

Data	Value	Data	Value
Span	10 m	Speed	10 m/s
Chord	1 m	AoA range	-5°÷15°
Aspect ratio	10	Re	6.6×10^5
Analysis method	VLM1 (horseshoe vortex)	Boundary condition	Dirichlet
Max iteration	100	Ground effect	no

For the 3D analysis, the right wing type (see Figure 8) was modeled with the profile with the maximum curvature (see Figure 7d), thus simulating the wing tip leading edge deformation by approximating.

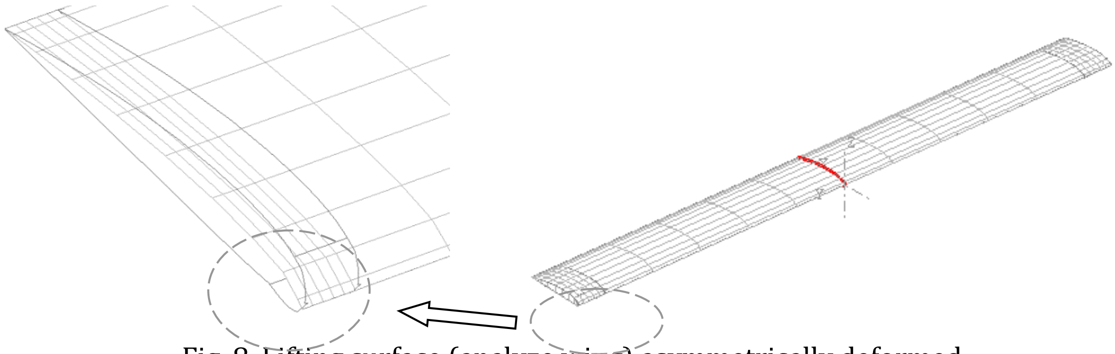
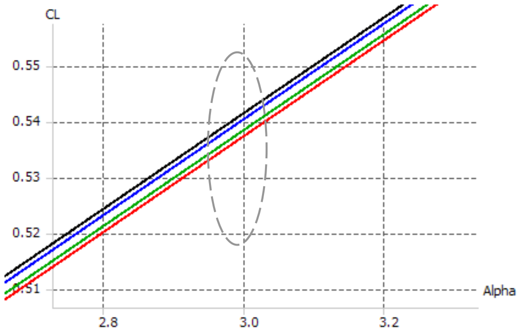
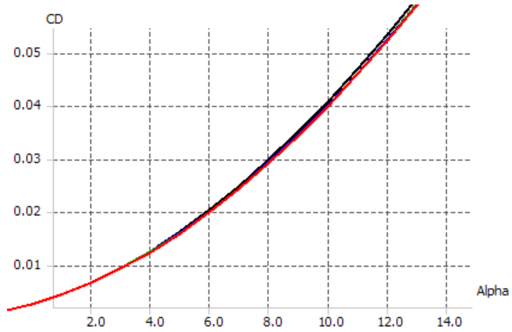


Fig. 8. Lifting surface (analyze wing) asymmetrically deformed

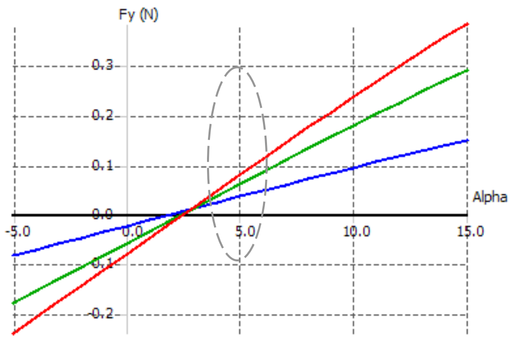
To interpret the results of the influence of the wing deformation on the flight performances, a series of parameters according to Figure 9 (lifting coefficient -C_L; drag coefficient - C_D; rolling coefficient - C_1; yaw coefficient - C_n; lateral force - F_y; bending moment- BM).



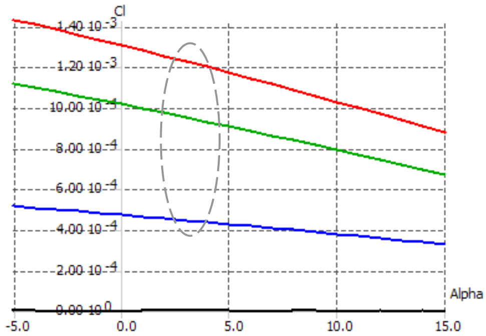
a. C_L-AoA



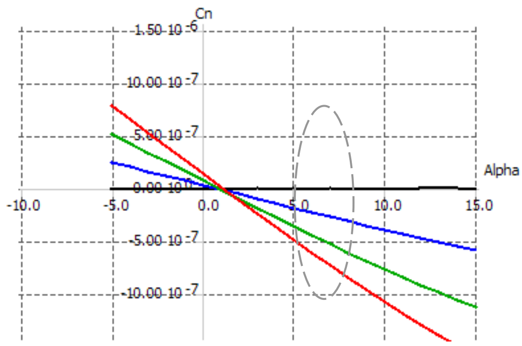
b. C_D-AoA



c. F_y-AoA



d. C_n-AoA

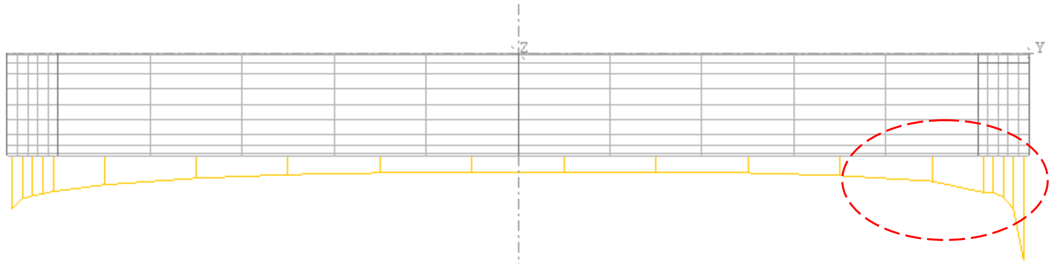


e. C_l-AoA

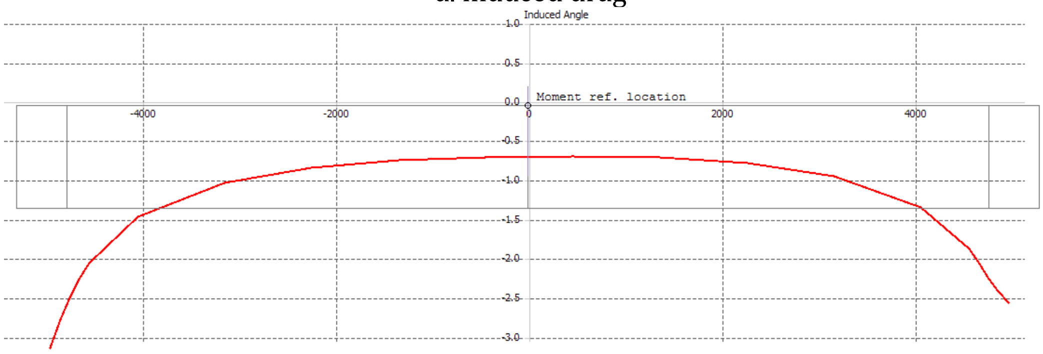
Fig. 9. Comparative performances of the deformed wing

According to the graph in Figure 9a, the C_L coefficient of recording records a constant difference on the analyzed incidence rate with a decrease of 0.004 units (from 0.541 to 0.537). The graph in Figure 9b shows a small difference in drag coefficient (C_D). The lateral force (F_y) value differences are increased from AoA > 3° (Figure 9c), which generates differences in the rolling coefficient (C_1) and the yaw coefficient (C_n), see Figures 9d and 9e.

The variation of induced resistance is asymmetric (Figure 10a), more pronounced at the tip of the deformed wing, which naturally generates an asymmetric variation of the induced angle (Figure 10b).



a. induced drag



b. induced angle

Fig. 10. The variation in induced resistance and induced angle (AoA)

3. Conclusions

A freeware tool with the equivalence of the deformed profile and the structural contamination mode was used due to ornithological contact; however it was possible to highlight the implications of aerodynamic asymmetry on flight characteristics and performance on a singular speed case.

The aerodynamic asymmetry can be highlighted successfully, and in the case of non-interference-bearing surfaces, the UAV type wing, the influence of impact after impact is even greater as the UAV is less. The aerodynamic asymmetry determined by the mobility of aircraft control bodies can be extended, and in cases caused by external causes, both types of asymmetry can be treated similarly. In order to achieve more reliable results, it is recommended to use both complete 3D geometries (fuselage, wing and tails) as well as multiple flight speeds.

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