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Computational Analysis of Air Wings to Evaluate Downforce and Lift-Drag Ratio: Technical Note

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ABSTRACT:
Air wings with NACA air foil profiles are designed and analysed for their aerodynamics at 40m/s. More than one air profile has been analysed to find the suitable air wing meeting the requirement and efficiency. An air wing in an automobile experiences aerodynamic forces and act as an inverted air foil. The efficiency of an air wing can be determined by down force - drag ratio i.e., it has to produce more down force with least possible drag caused by its frontal area of cross section.

KEYWORDS:
Aerodynamic analysis; Air wings; NACA air foil; Down force; Drag reduction

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1. Introduction

An air wing may have symmetrical or asymmetrical airfoil cross section. A symmetrical cross sectioned air wing needs to be held at negative angle of attack to deflect air upward and produce downforce. With an asymmetrical cross sectioned air wing, the down force is produced even at nil angle of attack, because the difference in pressure on upper surface is vastly higher than lower surface. The front air wing of a car is an important part affecting the aerodynamic characteristics. It increases down force, reduces under body air flow and enables the driver to turn the car at higher speeds with better stability further it improves steering response and helps to maintain the centre of gravity of the car as low as possible. An air wing doesn’t disturb the air flow like a spoiler, but it reduces the amount of air flowing under the vehicle body, thus creating a low pressure region. Since it creates a downward push at the front end of vehicle, it helps to avoid rolling and yawing of vehicle while cornering at high speed, thus affects the overall vehicle dynamics [1-2].

Parab et al [3] is focussed on adding a diffuser to an SUV at different angles and the aerodynamic characteristics of the vehicle. After confirming the approved aerodynamic characteristics value by CFD analysis, they added a diffuser to the car. Same CFD analysis is carried over on the car, with the diffuser at different angles. Their testing resulted in 34% of reduction in Cl compensating with increase of Cd by 0.5%. Borole et al [4] improved the design of front air wing of a F1 car to reduce drag and improve down force to give stability to the vehicle. Their analysis showed an increase in the down force with reduction in drag. This study helped in understanding the effects of front air wing design and their effects on the performance of the car [5]. Jasinski et al [6] investigated the performance of open wheel race car front wing configuration and flow field effects are also studied. Sunanda et al [7] designed a rear spoiler for an automobile, made of different materials to reduce its weigh, with same strength. A composite of aluminium and foam has been used to construct the spoiler. The spoiler design is chosen as NACA2412, after comparing with different designs, using Design Foil software [8]. In this work, four air wings and car body is separately modelled and analysed in ANSYS Fluent CFD software to find out the aerodynamic properties such as static pressure, velocity magnitude, turbulent kinetic energy, downforce, drag and lift to drag ratio.

2. Design

The national advisory committee for aeronautics (NACA) had developed several shapes of airfoil. The shape of airfoil had been described by numerical code followed by the word NACA. The numerical code describes the cross sections of the airfoil. Air wings are designed in air foil shape for its aerodynamic characteristics. Four NACA airfoils have been chosen to use for air wings. Their profiles are shown in Fig. 1 to Fig. 4 and their dimensions are given in Table 1.

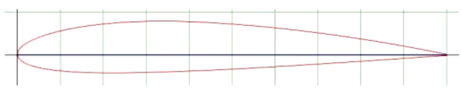

Fig. 1: NACA 2412 profile

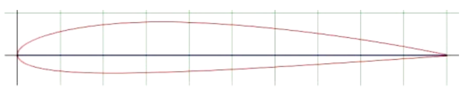

Fig. 2: NACA 5210 profile

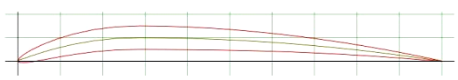

Fig. 3: NACA 5205 profile

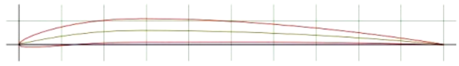

Fig. 4: NACA 3205 profile

Table 1: Dimensions for NACA profiles

Parameter	All profiles
Max. camber (m)	0.02
Position of camber at max(m)	0.4
Thickness(m)	0.12

To design the body of car and the air foil shapes, CATIA V5 R20 is used. Surface creation and editing tools were used to create the body of car. To simulate the aerodynamics of car and air wing, Ansys Fluent 14.0 is used. The cad models created in CATIA is saved in. igs format and imported to Ansys Fluent software. The imported model is then simulated for necessary research. Isometric view of the Volkswagen Polo CAD model is shown in Fig. 5. The CAD model of NACA2412 air wing is shown in Fig. 6. Other profiles are modelled but not shown here.

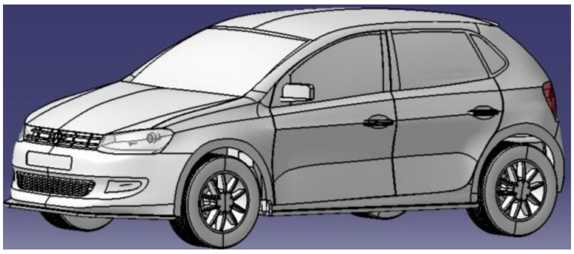

Fig. 5: Car CAD model - Isometric view

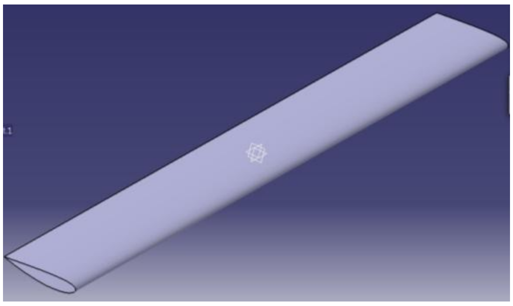

Fig. 6: CAD model of NACA2412 air wing

3. Simulation

Both the car and the air wing fixed to the car are going to travel in same environment conditions. So, the aerodynamics simulation process is also similar The mesh of NACA air wings are shown in Fig. 7 to Fig. 11.

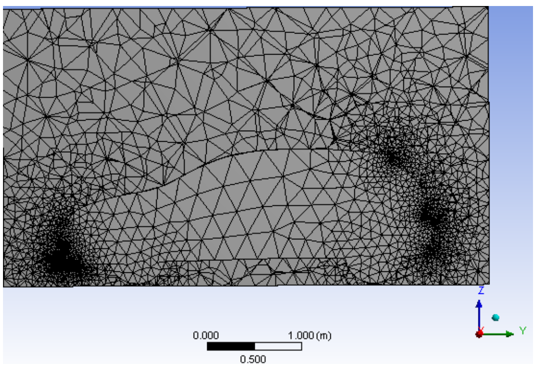

Fig. 7: Meshing of car body

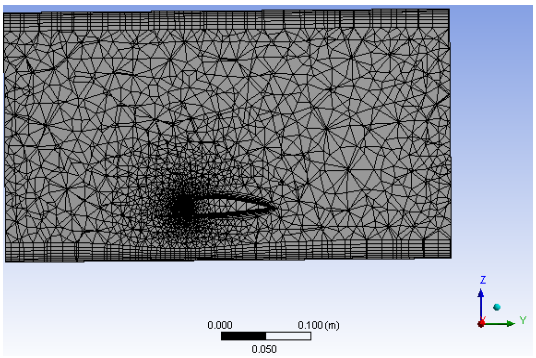

Fig. 8: Meshing of NACA 2412 air wing

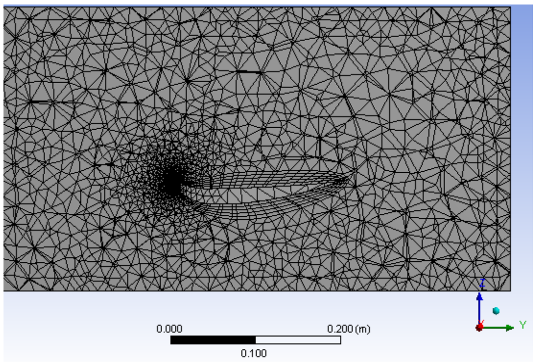

Fig. 9: Meshing of NACA 5210 air wing

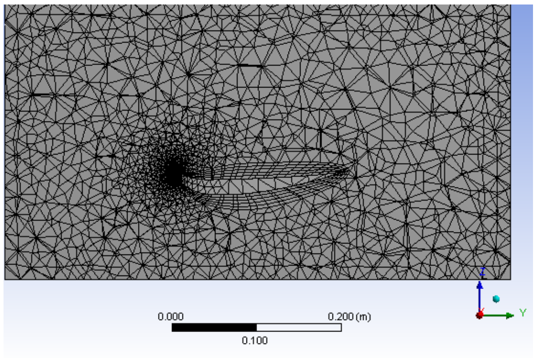

Fig. 10: Meshing of NACA 5205 air wing

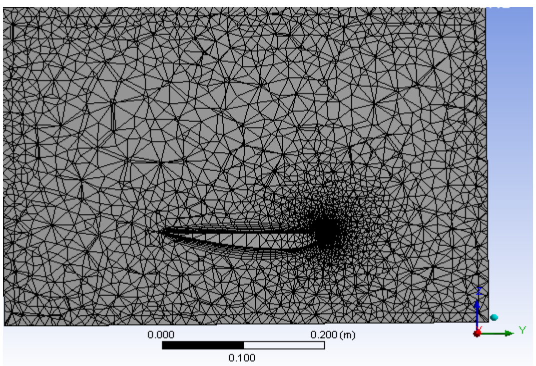

Fig. 11: Meshing of NACA 3205 air wing

The following settings are used to solve the aerodynamics problem with car and air wing.

- Inlet Velocity = 41 m/s
- Outlet pressure = 101.325 Kpa
- No of iterations for car body = 1000
- No of iterations for air wing = 1700
- Scheme = SIMPLE
- Pressure = PRESTO

- Momentum and turbulent kinetic energy = Quadratic Upwing Interpolation (QUICK)
- Specific Dissipation Rate = First order upwind.

4. Results and discussion

The simulation results of air wings are shown in Fig. 12 to Fig. 23 for all NACA profiles. The results are summarised in Table 2 to find out the efficient air wing for the best results, when implemented in car. The aerodynamics simulation results for car are shown in Fig. 24 to Fig. 26. The result of car body analysis is summarised in Table 3. The total down force that could be produced by fixing the air wing to the car is given in Table 4. NACA 5205 air wing profile is found to be generating high down force.

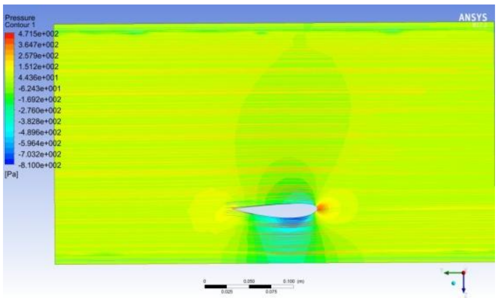

Fig. 12: Static pressure around NACA 2412

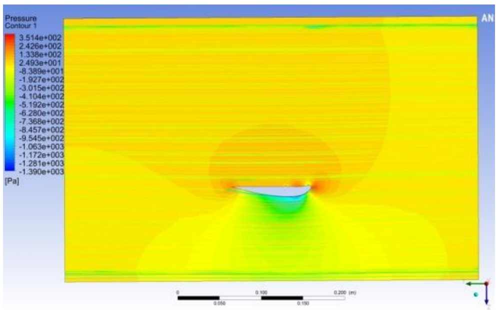

Fig. 13: Static pressure around NACA 5210

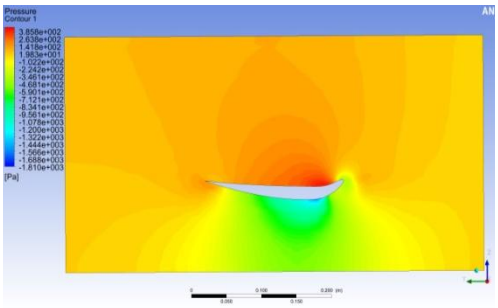

Fig. 14: Static pressure around NACA 5205

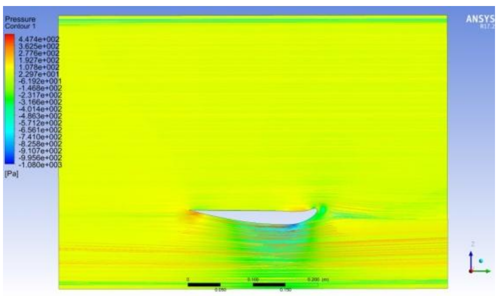

Fig. 15: Static pressure around NACA 3205

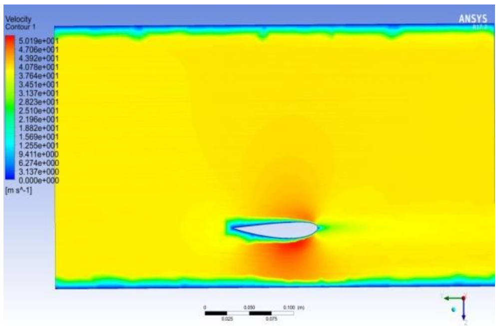

Fig. 16: Velocity magnitude around NACA 2412

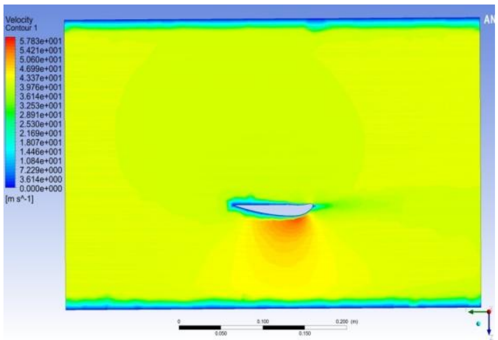

Fig. 17: Velocity magnitude around NACA 5210

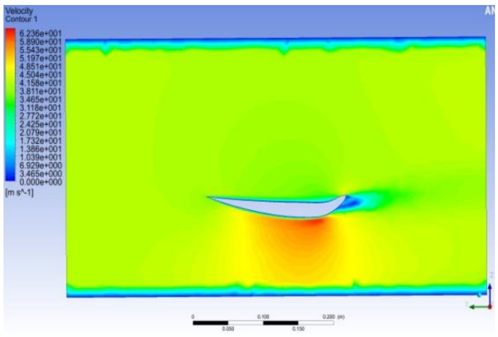

Fig. 18: Velocity magnitude around NACA 5205

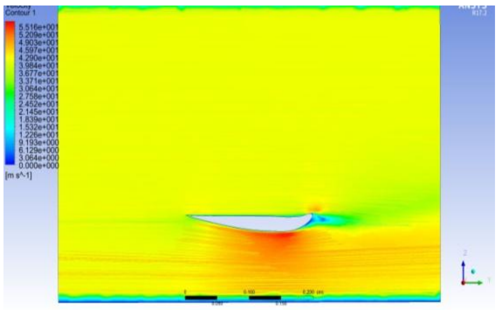

Fig. 19: Velocity magnitude around NACA 3205

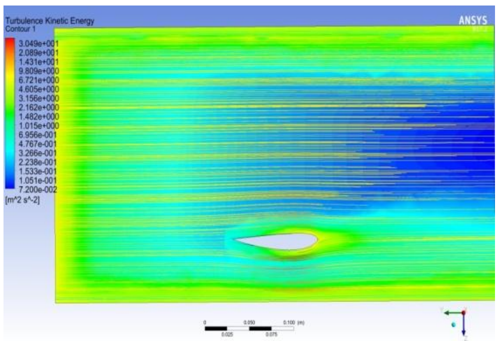

Fig. 20: Turbulence kinetic energy around NACA 2412

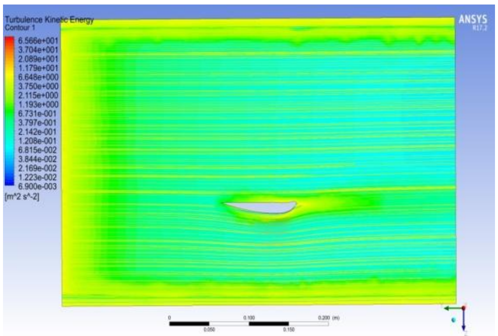

Fig. 21: Turbulence kinetic energy around NACA 5210

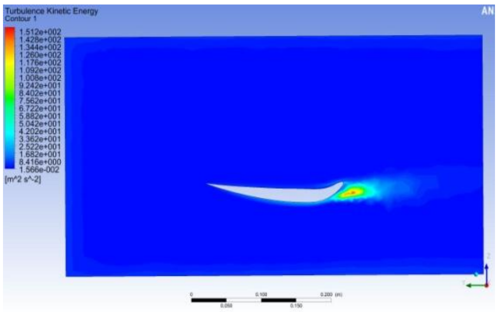

Fig. 22: Turbulence kinetic energy around NACA 5205

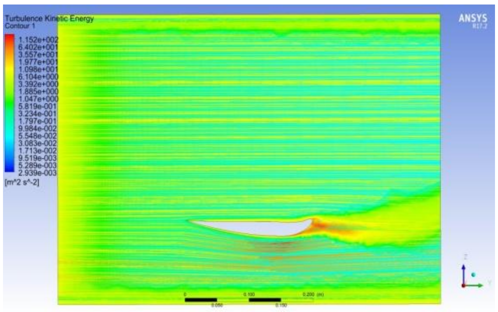

Fig. 23: Turbulence kinetic energy around NACA 3205

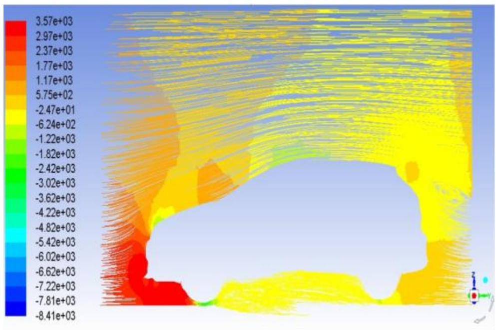

Fig. 24: Static pressure around car

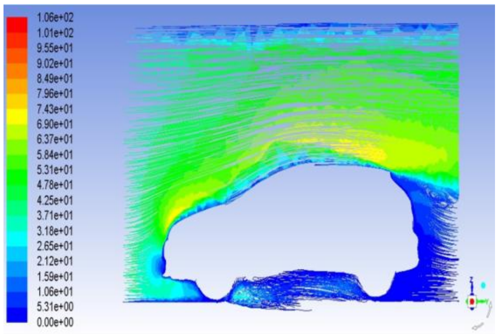

Fig. 25: Velocity magnitude of air around car

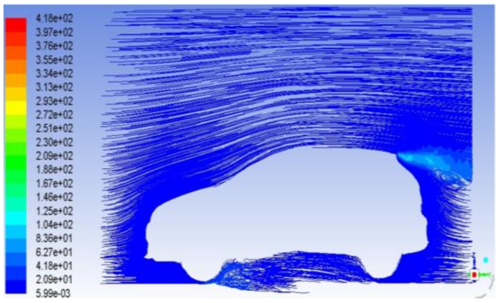

Fig. 26: Turbulent kinetic energy around car

Table 2: Results of air wing analysis

Parameters		NACA 2412	NACA 5210	NACA 5205	NACA 3205
Static pressure (Pa)	Min.	-810	-1390	-1810	-1080
	Max.	471.5	35.14	385.8	44.74
Velocity magnitude (m/s)	Min.	0	0	0	0
	Max.	50.19	57.83	62.36	57.07
Turbulent kinetic energy (m^2/s^2)	Min.	0.072	0.069	0.01566	0.02939
	Max.	30.49	65.86	121.2	115.2
Downforce (N)		6.8832	5.42273	153.009	63.7114
Drag force (N)		0.90032	8.3954	157.72613	12.0506
Lift - Drag ratio		7.65	0.65	0.97	5.29

Table 3: Results of car body analysis

Parameters		Volkswagen Polo
Static pressure (Pa)	Min.	-8414
	Max.	3570
Velocity magnitude (m/s)	Min.	0
	Max.	106
Turbulent kinetic energy (m^2/s^2)	Min.	5990
	Max.	418
Downforce (N)		192.679
Drag (N)		3646.6

Table 4: Downforce details

Downforce produced (Newton)			
Air wings		By car	Total
NACA 2412	6.8832	192.679	199.5622
NACA 5210	5.42273		198.10173
NACA 5205	153.009		345.688
NACA 3205	63.7114		256.3904

5. Conclusion

The aerodynamics of Volkswagen Polo is analysed using Ansys. The total downforce produced by the car is found as 192.7 N at 40 m/s. Four air wings of different profiles are simulated for same boundary conditions. Air wings are compared based on the amount of downforce produced by the air wings and their efficiency. With an efficiency of 97%, air wing with NACA 5205 profile is found to be the most efficient among 4 air wings. This efficiency is determined by the ratio of downforce and drag. It creates 74% more downforce, when mounted to the car.

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