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Physics-Based Optimisation of Formula One Front Wings: Ground Clearance, Angle of Attack, Flap Deflection, and Element Gap Effects

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Abstract. The Formula One (F1) front wing is a complex multi-element aerodynamic device. It plays an important role in F1 racing, generating downforce and creating flow conditions that affect the performance of downstream components. Through decades of technical development and regulations, the fundamental aerodynamic performance of F1 front wings is now governed by many important design variables, the most notable of which include: ground clearance (h/c), angle of attack (α), flap deflection (δf), and inter- element spacing (g/c,o/c). This review explores the key peer-reviewed literature concerning these parameters, focusing on the fluid-dynamic mechanisms behind each of these variables. Findings from these studies demonstrate that aerodynamic behaviour is heavily influenced by interactions between factors like aerodynamic loading, ground proximity, and flow separation. Ground clearance affects how the wing contributes to aerodynamic loading, while angle of attack and flap deflection affect air circulation, pressure recovery, and boundary layer stability. Inter-element gaps can reenergize flow and prevent boundary layer separation, enabling high-lift operation unavailable to single-element configurations. The review demonstrates that optimizing F1 front-wing design is dependent on many different factors and conditions rather than the simple optimization of downforce with a singular variable.

Keywords: Formula One, Front Wing, Ground Effect, Multi-Element Airfoil, Aerodynamic Optimization

1. Introduction

Aerodynamics plays a crucial role in Formula 1 motorsport racing and vehicle design because aerodynamic forces strongly influence vehicle performance. Aerodynamic downforce in particular is important because it increases the vertical load placed on the tyres, allowing for better tyre grip on corners and therefore higher cornering speeds too.

Consequently, a common effect of increasing downforce in F1 vehicles is the generation of drag, which acts opposite to the vehicle's direction of motion. This creates an aerodynamic trade-off between generating aerodynamic downforce and limiting the amount of drag that comes about as a

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result. For this reason, aerodynamic F1 studies often evaluate designs while taking both drag and downforce into consideration, rather than just looking at downforce [1].

While modern diffusers generate most of a vehicle's downforce currently, the front wing still plays a critical role regarding the topic of downforce generation. Not only is it responsible for generating a portion of the downforce on the front end of the vehicle, but it is also the first component to interact with the incoming flow, and as a result controls the quality and momentum of flow encountered by downstream devices including the front wheel wake and the rear diffuser. Therefore, research on F1 front wings has taken into consideration both the aerodynamic forces generated by the front wing and the effects of the front wing on downstream components. For instance, Martins et al.'s research on the F1 front wing found that changing certain aspects of it could also affect wheel wake [2]. Furthermore, the design of the front wing is further complicated by the fact that it is not a single, isolated airfoil. It must also be taken into consideration that the wing operates close to the ground and consists of multiple unique elements that interact differently with each other. These characteristics result in airflow around the wing and its performance depending on many different parameters.

Among the many geometric parameters that influence the behaviour of the front wing, this literature review focuses primarily on four parameters in Formula 1 research that are important to aerodynamic performance: 1. Front wing and ground clearance (h/c) 2. Main-element angle of attack (α) 3. Flap deflection angle (δ) 4. Inter-element gap (g/c) and overlap (o/c).

Because of the number of interacting factors, the F1 front wing performance cannot be determined by a few independent parameters. Important considerations such as ground clearance, main-element angle of attack, flap incident angle, and inter-element gap and overlap not only just affect performance independently but also behave differently depending on how the elements interact with each other.

The objective of this literature review is to examine how these four design considerations of the F1 front wing influence aerodynamic performance alongside airflow surrounding and downstream of the front wing, incorporate core findings from foundational fluid literature and recent peer-reviewed optimisation studies (2020-2026), and establish the physical mechanisms through which these factors interact to dictate front-wing performance. To conclude, this paper will also briefly explore some possible directions in the future of F1 development.

2. Aerodynamic framework

2.1. Downforce generation

The front wing generates downforce through pressure differentials. According to Bernoulli's principle:

$$P + \left(\frac{1}{2}\right)pV^2 = Constant \tag{1}$$

The wing accelerates airflow beneath the profile, reducing static pressure and creating downward force. The resulting aerodynamic load is:

$$L = \frac{1}{2}\rho V^2 S C_L \tag{2}$$

where: L= aerodynamic force, ρ= air density, v= velocity, S= reference area (wing size), C_L = lift coefficient. For F1 applications, it is negative due to downforce production.

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2.2. Drag production

Downforce inevitably introduces drag.

Optimisation aims to maximise downforce while minimising drag, and this is typically measured through |Cl|/Cd, which can be taken to represent aerodynamic efficiency.

3. Ground clearance effects

Among all previously mentioned variables, front-wing ground clearance exerts the strongest influence on aerodynamic loading. When an inverted wing approaches the ground, the airflow passage between the wing and road surface becomes constricted.

For approximately uniform density and flow, conservation of mass dictates:

$$A1V1 = A2V2 \tag{3}$$

where: A1= flow area, V1= local velocity

Thus, as available flow area decreases, this can also produce an increase in flow velocity, which in turn can contribute to a lower pressure under the wing, the relationship of which can be expressed through Bernoulli's equation for cases with inviscid flow (1). Where: P=static pressure, ρ = fluid density, V=fluid velocity.

Thus, increases in velocity are accompanied by decreases in pressure in the equation. The resulting pressure distribution is responsible for generating aerodynamic forces on the wing:

$$F = \int S - pndS \quad \text{(Integration of pressure over wing surface)} \tag{4}$$

The accelerated flow beneath the wing lowers static pressure and increases downforce.

However, this does NOT mean that decreasing h/c continuously increases downforce. The prior equations describe part of the velocity-pressure relationship, as a lot of the aerodynamic performance also depends on factors like flow behaviour, boundary layer behaviour, and flow separation. Zhang, X., & Zerihan, J. (2003) found that this process is not entirely uniform [3]. As ground clearance decreases, suction on the lower surface increases and tends to raise downforce. However, pressure changes on the upper surface and airflow separation downstream partially offset these gains. At small ground clearances, downforce generation depended strongly on flap configurations. The paper states that low flap angle configurations produced a plateau, while higher angle configurations created a reduction in downforce. This reduction can be attributed to changes in how the boundary layer and flow behave past a certain point. The acceleration of flow along the boundary layer can be written as:

$$u(\partial u/\partial s) = -(\tfrac{1}{\rho}) \times (\tfrac{dp}{ds}) + v(\partial^2)u/\partial y^2 \tag{4}$$

Where: u=fluid velocity along surface, S=distance along surface, Y=distance from surface, ρ=fluid density, P=pressure, V=kinematic viscosity

The equation dictates that fluid acceleration along the surface is dependent on the pressure and viscous effects. At low clearances, changes to pressure distribution and flow under the wing can create adverse pressure gradients, causing the flow to decelerate as it moves downstream. This deceleration, combined with the already low momentum near boundary surfaces due to air viscosity, means that the flow no longer has the momentum to overcome adverse pressure gradients, which

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can result in the flow near boundary layers separating from surfaces and reversing direction, creating a reduction in downforce that Zhang & Zerihan attribute to flow separation [4].

Maximum downforce occurs when the previously mentioned effects balance; beyond a certain point, flow deterioration causes the downforce to decrease. The results of Zhang & Zerihan are also supported by recent multi-element optimisation literature based on simulations done by Granados-Ortiz et al. [4, 5].

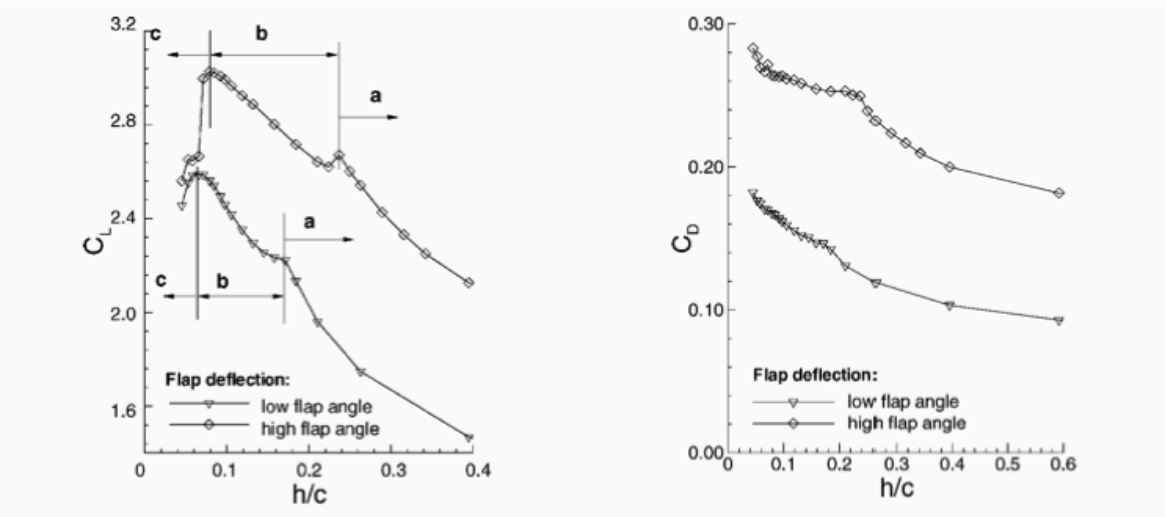


Figure 1. Downforce and drag with normalised ground height h/c, where h is the minimum wing-ground distance and c is the main-plane chord [4]

Fig. 1 shows that the main plane experiences three distinct aerodynamic regimes as ride height decreases.

Force Enhancement. At relatively large ride heights around: h/c>0.2, downforce increases as the wing approaches the ground, with the primary contributor being the increased downforce generated under the main element. The flow remains attached, and circulation continues to increase.

Plateau / Transitional Region. As clearance continues to decrease, further downforce gains under the wing become smaller, while pressure recovery becomes increasingly difficult and the aerodynamic benefit begins to decline. For low flap settings, the authors observed a plateau in downforce rather than continued growth. This finding contradicts the common simplified assumption that lowering the wing always increases downforce.

Force Reduction. At very low ride heights, boundary-layer growth becomes significant, as the narrow passage restricts flow and separation develops. The paper found that after reaching maximum downforce, further reductions in ride height caused downforce to decrease. For aggressive flap settings, the reduction was particularly severe because the boundary layer separated and circulation on the main element collapsed. This phenomenon is often referred to today as force reduction or downforce collapse.

This sharp downforce collapse at very low ride heights is caused by boundary-layer separation and loss of circulation. For the high-flap-angle configuration, PIV measurements demonstrated that trailing-edge separation develops on the main element at low clearance. This alters the wake, increases pressure-recovery demands on the flap, promotes flap-flow separation through adverse pressure gradients as mentioned earlier in the review, and ultimately causes a significant reduction in circulation and downforce. The paper identifies this as the primary mechanism behind the reduction in downforce.

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The paper also shows that for a multi-element wing, adding the flap increases circulation around the main element, raises suction on the lower surface, and reduces the severity of pressure recovery. For both flap settings, downforce initially increases as the wing approaches the ground, but the response subsequently exhibits either a plateau (low flap angle) or a reduction in downforce (high flap angle), followed by another increase to a maximum and then a sharp force reduction at very low ride heights.

4. Main-element angle of attack (AOA)

The attack angle of the F1 front wing determines its orientation to incoming airflow and has a significant effect on the aerodynamic forces acting on the wing. Increasing attack angle changes how airflow accelerates and moves around the wing. This alters pressure and velocity distributions around the front wing, which produces an aerodynamic force. This force can be separated into two components: lift and drag. Lift acts perpendicular to the airflow, while drag always acts parallel to the airflow in the opposite direction. Since the F1 front wing is an inverted airfoil (see Figure 2), its lift force is directed downwards, acting as downforce. Increasing the angle of attack on the front wing generally creates a pressure difference that generates more lift, or downforce in the case of an F1 front wing in conditions where flow is attached.

However, this increase in downforce is accompanied by an increase in drag too, which acts against the car, negatively affecting performance. Therefore, engineers cannot evaluate the efficiency of the wing solely by generated downforce, and must also take other factors like drag into consideration. In addition, at sufficiently high angles of attack, the performance of the front wing will begin to falter due to boundary layer separation, as airflow is no longer capable of following the shape of the wing. This limits further increase in downforce, and at even higher attack angles causes air to stall, actively decreasing downforce. Because of the role attack angle plays in downforce generation along with its various trade-offs, it is an important parameter when it comes to front wing optimisation.

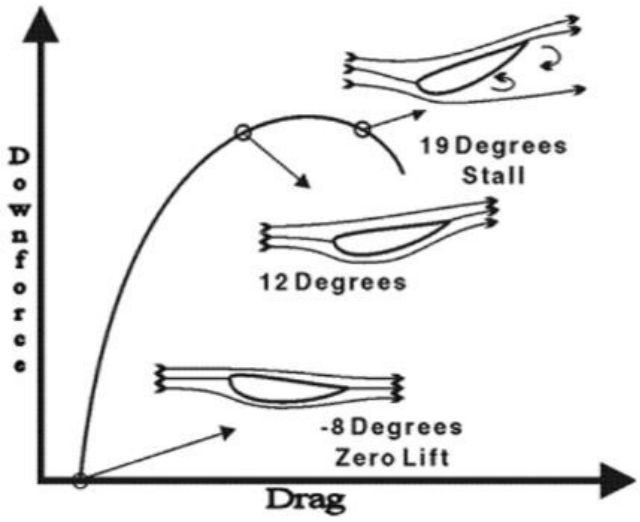


Figure 2. Downforce v.s. drag graph for estimated angles of attack of front wing [6]

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4.1. Definition of front wing angle of attack

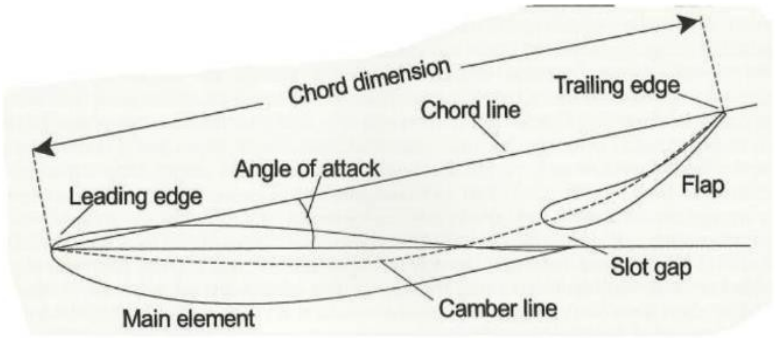


Figure 3. Cross section of an airfoil [7]

As illustrated, the leading edge is the front end of the wing, while the back end of the wing is known as the trailing edge. The chord line connects the leading edge and the trailing edge. The angle of attack is the angle between the chord line and the incoming airflow, as can be seen in Figure 3.

Modern F1 race cars use multi-element front wings with several flaps. The angle of attack in a multi-element F1 car's front wing is measured through the angle between the chord line and a line parallel to the incoming airflow starting at the leading edge. To put simply, the angle of attack is a way of calculating the angle of attack of the wing as a whole, rather than based on the individual angles of each of the flaps and figuring out an average angle of attack that the entire wing possesses. The effect of angle of attack for the flap will be further discussed in the next chapter of this review.

4.2. Optimising front wing angle of attack

An extended essay by Hu investigated the effect of front wing attack angle on aerodynamic efficiency using SolidWorks CFD simulations on a 3d model of an F1 front wing [8]. The study simulated the F1 front wing at attack angles 0 through 18 degrees, measuring the drag and lift forces created by each angle.

As the angle increases between 0 and 11 degrees, this paper can see from Figure 4 and 5 that downforce increases from approximately 59.9 N to 145N, while drag increases from approximately 33.7N to 64.1N, demonstrating that although increasing attack angle also increased downforce, this was accompanied by an increase in drag too.

From the simulation results, it can be observed that the amount of drag generated by the wing first increases moderately as the angle of attack increases, with the drag increasing at a faster rate the larger the angle of attack becomes. Hu's explanation is that as the angle of attack increases, it leads to a larger surface area of the wing to be hit by the air flowing by, which ultimately increases drag [8]. Meanwhile, the downforce increases quickly in the beginning as AOA increases but gradually slows down when AOA goes beyond 10 degrees.

Although Hu explicitly states that the wing used in his simulation does not stall through 0-18 degrees as the downforce levels in the wing consistently increase, this paper can see the decline in performance in the wing past 11 degrees-the optimal AOA in Hu's case- as the magnitude of the Lift-to-Drag Ratio shows a decreasing trend, signalling a decrease in the efficiency of the wing as mentioned prior [8].

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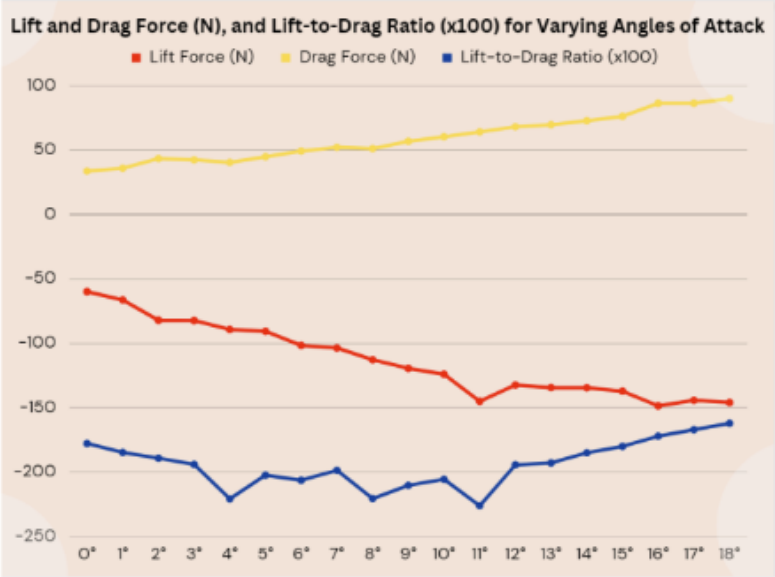


Figure 4. Graph of lift and drag forces with various front wing angles of attack (AOA) [8]

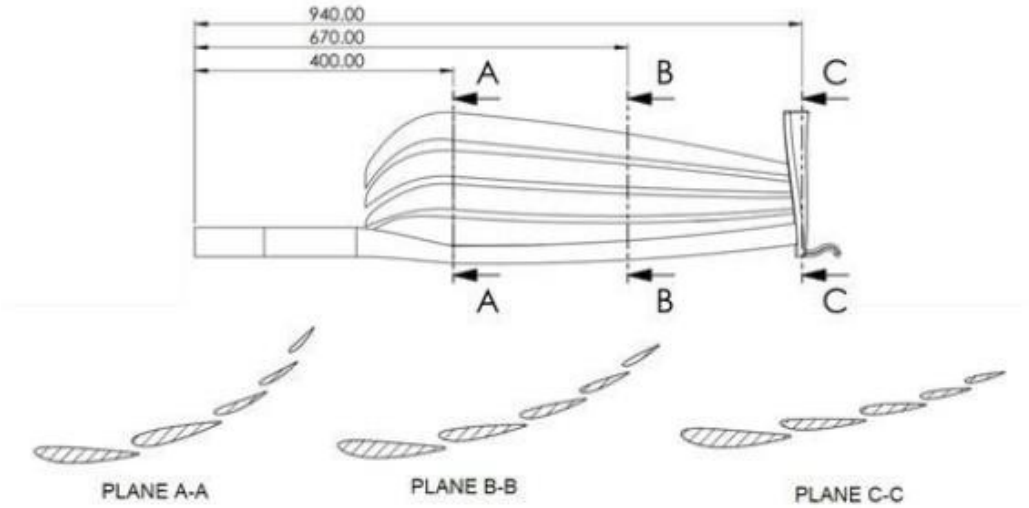


Figure 5. View and location of the three different planes where the cross-sections for a 5-element front wing shape design optimisation have been defined, Granados-Ortiz [5]

Granados-Ortiz et al. also conducted CFD simulation studies about the impact of front wing AOA on aerodynamics [5]. Using a model of a 5-element F1 front wing, they measured performance at different cross-section regions on the front wing: A, B, C. Sections B and C correspond to attack angles of ~20 degrees and ~10 degrees.

The results show that for plane B, due to a steeper AOA, the downforce is about 3X larger than C. However, it is also accompanied by a >4x increase in drag, which makes plane C more efficient based on CL/CD value (Fig. 6).

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	Number of Adjoint Iterations	C_L	C_D	C_L/C_D
B-B Plane	0	-3.61×10^{-1}	1.50×10^{-2}	−24.06
	10	-3.67×10^{-1}	1.45×10^{-2}	−25.31
	20	-3.72×10^{-1}	1.31×10^{-2}	−28.40
C-C Plane	0	-1.12×10^{-1}	3.34×10^{-3}	−33.51
	10	-1.21×10^{-1}	3.34×10^{-3}	−36.23
	20	-1.24×10^{-1}	3.34×10^{-3}	−37.15

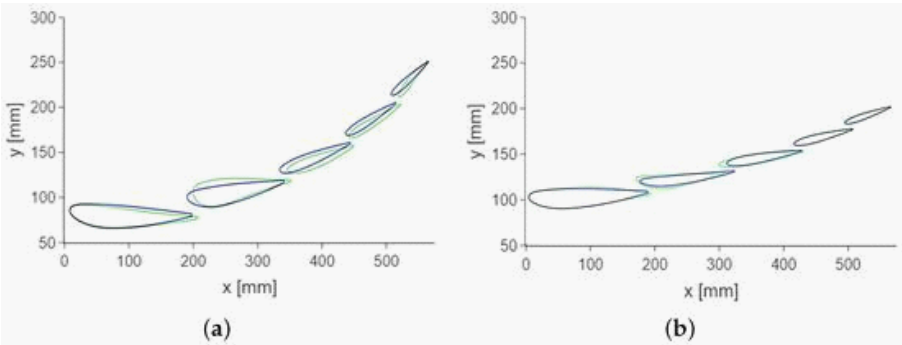


Figure 6. Simulated downforce (Cl), drag (Cd), and efficiency Cl/Cd) for Plane B-B and Plane C-C [5]

5. Flap deflection effects

As mentioned previously, rather than using a single continuous airfoil, F1 front wings are comprised of many unique elements. The primary element of the wing is the mainplane, which is responsible for generating a large portion of the wing's aerodynamic forces, while smaller flaps downstream from the mainplane are used to modify the airflow or adjust the aerodynamic forces generated by the main wing. The force generated by the front wing is known as aerodynamic loading and is mostly composed of downforce and drag. Some of the many design considerations of these flaps are their spacing, orientation, and positioning.

One such design consideration of these flaps is the incidence angle of the flaps, which is the angle the individual flaps make relative to incoming airflow. Flap angle affects how air flows around the flap, changing the air velocity and pressure distribution across the wing, similar to how changing the attack angle of the front wing also affects downforce and drag. Adjusting the angle of the flaps gives engineers more precision over controlling aerodynamic load and allows for adjustment to another important design consideration of the front wing, which is how it diverts flow throughout the rest of the vehicle. Therefore, a balance must be struck between creating high downforce and desirable flow downstream when it comes to front wing design.

5.1. Physics of flap systems

The inclusion of flaps on the main element of the front wing converts it from a single-element wing into a multi-element system. Based on the high-lift dynamics described by A.M.O. Smith and adapted to ground effect flow by van den Berg, the flap has two main functions [9, 10].

Circulation Effect (Upstream Influence): The flap increases velocity at the trailing edge of the main element. This reduces the pressure at the main element's trailing edge, allowing the main

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element to achieve higher suction levels without increasing its local adverse pressure gradient to the point where boundary layer separation occurs.

Dumping Effect (Downstream Influence): The flap helps flow leaving the front wing to expand into a lower pressure region, reducing pressure behind the main element, and thereby allowing for greater sustained circulation.

5.2. Experimental and numerical findings on flap deflection angle (δ)

Zhang & Zerihan observed the effects of flap deflection across a wide range of h/c (ground clearance). Their data, supported by recent multi-element optimisation studies, highlighted a trade-off between maximising downforce and avoiding flow separation [11]:

Low Flap Deflection (δ ≈10°-15°): Downforce increases alongside deflection angle at a moderate rate. The relationship between downforce and ground clearance is very smooth, with force reduction occurring only at extreme ground proximity (h/c≈0.05). Flow remains generally attached across both elements.

High Flap Deflection (δ ≥25°): Max downforce CDF increases substantially. However, the force-height curve displays a sharp "cliff" as the wing approaches the ground. Ground stall occurs much earlier (h/c≈0.10-0.12). The breakdown is linked to boundary layer separation on the suction side of the main element due to the trailing-edge pressure gradient created by the high aerodynamic loading.

Martins et al. also investigated how changing the angle of the second flap of a 3-element F1 front wing affected pressure distribution, vortex structures, wheel wake behaviour, and aerodynamic forces. Using a model of the front wing and wheel based on 2022 regulations, they tested three flap angles of 30, 32, and 34 degrees, analysing the flow characteristics at different points in the vehicle.

The authors found that flap angle had a strong influence on the lower-edge vortex generated by the front wing. Increasing flap angle increases wing circulation and strengthens the upwash. However, beyond a certain point, the vortex cannot sustain itself and undergoes breakdown. More aggressive flap configurations generate stronger upwash, energising the boundary layer near the tyre and delaying separation. The delayed separation creates more central downwash and larger low-energy regions in the wheel wake. Thus, increasing flap angle does not simply improve aerodynamic performance.

The paper shows that angle of attack affects the wheel wake more through modification of tyre separation than through direct changes in wing performance. Increasing flap angle strengthens upwash generated by the wing, delays separation on the wheel, increases wake downwash, and transforms the wheel wake from a long, narrow structure to a shorter, wider structure. However, overly large angles can generate vortex breakdown and higher drag, so an intermediate AOA (~32° in this study specifically) provides the best aerodynamic balance.

Below is Trade-off Table 1 for flap angle to different aspects of aerodynamics [12, 13]:

There is no single best value for F1 front wing flap angle. Changing the angle will bring different effects for different aspects of aerodynamics. The angle needs to be set based on track conditions, layout, and balance requirements from other components. Recent studies and FIA regulations have shifted focus toward Active Aerodynamics, where the flap angle considerations are modified throughout races inside designated zones to maximise performance according to track conditions [14, 15].

High-Downforce Configuration (Cornering): Way et al. demonstrated that a multi-element front wing could switch between high downforce and low drag configurations by rotating the wing about its quarter-chord point. The study found that, under the conditions in their simulations, the most optimal setup increased overall downforce by 25% in their configuration.

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Low-Drag / DRS Configuration (Straights): Jacoulot et al. demonstrated that rotating the primary wing elements about a designated pivot axis to reduce drag created reductions of 62.3% while simultaneously reducing front-end downforce by 64.3% to prevent dynamic pitch imbalance at high speeds [16].

Table 1. The trade-off table for flap angle to different aspects of aerodynamics

Aspects of aerodynamics	High flap angle	Low flap angle
Downforce Generation	Increases the pressure differential between the upper and lower surfaces, generating more front-end downforce and grip for slow and medium-speed corners	Reduces the pressure differential, dropping front downforce for high-speed tracks where stability and low drag are prioritised
Aerodynamic balance	Increasing the flap angle shifts the car's aerodynamic balance forward, increasing front axle loading to reduce understeer.	Decreasing the flap angle shifts the balance backward, increasing relative rear grip to calm an oversteering car.
Drag efficiency	Steeper flap angles increase aerodynamic drag at a higher magnitude than the gain in downforce, reducing overall aerodynamic efficiency.	Excessive flap angles push the airflow past its critical threshold, risking boundary layer separation or wing stall.
Downstream airflow	The flap angle dictates the strength and trajectory of the vortices shed off the wing elements, which alters how cleanly air is channelled around the front tyres and fed into the floor and sidepods	

6. Inter-element gap effects

6.1. Physics of multi-element interaction

The space between the main element trailing edge and the flap leading edge is defined by the gap (g, perpendicular distance) and overlap (o, streamwise overlap distance). As demonstrated by Smith and further adopted for ground-effect wings by Ranzenbach et al., the slot gap primarily performs two functions [9, 17]:

Fresh Boundary Layer Priming: Each subsequent element in the multi-element wing starts its own boundary layer from its leading edge. This prevents the formation of a single, thick, easily separated boundary layer that would occur on a single-element airfoil with equivalent camber.

Off-Surface Boundary Layer / Slot Jet Effect: The high-pressure flow on the pressure side (upper surface) of the main element accelerates through the slot gap and exits as a high-velocity jet along the suction side (lower surface) of the flap. This transfers momentum directly into the flap boundary layer, allowing the flap to achieve high deflection angles without stalling.

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6.2. Gap (g/c) and overlap (o/c) sensitivity

Excessively Small Gap: The boundary layer of the main element merges with the boundary layer of the flap, creating pressure loss and flow separation on the flap.

Excessively Large Gap: The slot jet loses a portion of its velocity and fails to energise the flap boundary layer. This leads to a reduction in the energy supplied to the boundary layer, increasing vulnerability to flow separation.

NASA multi-element airfoil experiments by Morgan et al. indicate that the optimal non-dimensional slot gap generally lies within g/c=0.02 to 0.03, with optimal overlap o/c=0.00 to 0.015 [18]. However, these numbers come from general airfoil research, so they should be treated as reference ranges rather than a universal optimal value.

6.3. Evidence from contemporary metaheuristic and adjoint optimisations

More recent research has shown that design considerations concerning the slot must be considered alongside other variables in a multi-element wing too.

Granados-Ortiz et al. utilised a hybrid optimisation methodology (combining evolutionary algorithms with adjoint-based gradient refinement) on a 5-element F1-inspired front wing, considering multiple parameters simultaneously.

Similarly, recent studies deploying Improved Harris Hawks Optimisation (HHO) algorithms on inverted double-element airfoils in ground effect revealed that optimising g/c independently of h/c yields suboptimal results. When h/c decreases, the pressure ratio across the slot changes, affecting the flow of the slot jet. It was found that an adaptive gap expansion of 0.5-1.2 mm at extreme ground clearances preserves slot jet momentum and delays ground stall.

It was also found that in 4- and 5-element modern configurations, the slot gaps between successive flaps must progressively decrease downstream to maintain boundary layer flow along the highly cambered rear flaps.

7. Interactions between front wing parameters

The different parameters covered in this paper cannot just be optimised and treated as independent factors in front wing performance, as changing one parameter can affect the flow conditions that will in turn change the performance of other parameters. Ground clearance plays a role in creating the general flow environment around the front wing, while parameters like front wing angle of attack and wing element deflection angle, which generate aerodynamic loading, are affected by that flow. Factors like the gap between elements also control the effectiveness of the previously mentioned considerations. As a result, changing one parameter can have potentially major effects on others too.

Ground clearance provides a good example of this. As ground clearance shrinks, the restricted passage beneath the wing accelerates air and generates downforce. However, as this gap becomes too small, flow separation can cause a reduction in downforce. Zhang and Zerihan found that this decrease was actually connected to wing configuration. Specifically, they noted that higher flap angles produced a larger reduction in downforce at lower ground clearances. Therefore, this instance demonstrates that ground clearance cannot be selected without also taking into consideration the effects of flap angle on it. Configurations with high flap angles designed to maximise aerodynamic loading may have negative effects on ground clearance effectiveness.

Interactions between elements can also be seen in the angle of attack of the front wing. Similar to ground clearance, increasing the AOA of the front wing can increase downforce to an extent, but if it

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is too high, it increases drag and can create flow separation, which reduces the downforce generated. Hu found that past a certain point, increasing the AOA of the wing provides diminishing returns in downforce, and although not seen in the simulation, briefly talked about wing stalling, which can create reductions in downforce if the wing AOA is too high. However, Ortiz et al. found that certain configurations of the angles of individual wing elements could produce about 3x the downforce compared with less optimised configurations, although this was also accompanied by a 4x increase in drag, demonstrating the interactions between these 2 elements, along with the observable trade-off between drag and downforce [5].

Martins et al. also observed that changing the angle of the second flap not only altered the forces produced by the front wing, but also affected the flow leaving the wing and the wake behind the tyre as well [2].

8. Future research directions

Research indicates that optimising front-wing parameters alongside each other is critical to optimisation because aerodynamic performance is governed by interactions among multiple geometric variables. Studies should focus on the simultaneous optimisation of major front-wing elements, such as endplates and Gurney flaps. Granados-Ortiz et al., for instance, have tried to develop a hybrid shape optimisation approach to obtain an optimal five-element airfoil front wing under the FIA regulations and 17 design parameters.

To this end, advances in computing power and artificial intelligence (AI) are making more advanced multi-element simulation increasingly practical. Physics-Informed Neural Networks (PINNs), surrogate models, and high-fidelity CFD simulations could be used in future optimisation studies to efficiently simulate larger experiment designs and operating conditions.

Another future research direction could be the co-optimisation of the front wing and more downstream components, since changing the front wing influences the flow and behavior throughoutthe rest of the vehicle. These parts could be treated as an interconnected system and observed together in future studies. Optimising these components as a whole could provide a more complete understanding of the effects of the front wing.

9. Conclusion

This literature review showed several important parameters in the F1 front wing that play a major role in performance. Four variables examined particularly closely are:

Ground Clearance (h/c): Controls the pressure distribution beneath the wing, establishing the boundary between force enhancement (Region II) and ground stall (Region III).

Angle of Attack (α): Affects aerodynamic loading on the wing and flow circulation. Increasing the angle is typically associated with an increase in downforce but also strengthens pressure gradients that lead to flow separation at high angles.

Flap Deflection (δf): Modifies wing camber and pressure distribution. When optimised, it can increase peak downforce at the cost of narrower operational ground clearance ranges.

Inter-Element Gap (g/c): Controls flow through the slot between elements. Allows higher momentum airflow to reach the suction side of the wing, energising the airflow and avoiding boundary layer separation.

The most optimal aerodynamic performance and design don't come from focusing on optimising single variables, but rather from balancing factors such as aerodynamic loading, boundary-layer attachment, and flow stability across the entire vehicle as a whole.

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