Suspension and Aerodynamics of A Formula Car

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ABSTRACT

A Formula car is specifically a open-wheel, open cockpit, single-seat racing car with front and rear wings, with an engine positioned behind the driver, meant to be used in competition at Formula One racing events. The rules governing the vehicle are unique to the competition. In this paper the design of the suspension of a formula car with the class formula SAE is taken into account. A double wishbone suspension geometry is considered. The basic requirements to the characteristics of this class are formulated. Calculated suspension geometry is adduced. The kinematic model for determining the position of the system depending on the inclination of the upper arm has been studied. The analysis and the selection of the geometric parameters of the suspension of a sports car with the class formula SAE were done. This paper discusses about its design as per dynamics. This article traces the design and CFD analysis of a Formula SAE car. The focus of the study is to scrutinize the aerodynamics features of a SAE race car with firewall vents, with front spoiler and without front spoiler. Formula SAE is a college level student design championship where every year students of colleges all over the world manufacture and compete with open-wheel formula-style race. The main aim of this study is to increase the stability of the car and reduce the drag. With this the resistance of air to the vehicle gets reduced. The CFD analysis is done on full scale structure. The aerodynamic study is conducted in the ANSYS FLUENT software to carry out a turbulent stimulation of the air flow on the SAE vehicle. The results are presented with pressure contour.

Keywords: *Suspension, Vehicle Dynamics, Aerodynamics, Formula*

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1) INTRODUCTION-

The most popular automotive events in the world are racing "Formula-1". The cars that are designed to participate in these championships, in addition to traction-speed characteristics, to have the highest
levels of maneuverability is necessary to ensure maximum speed cornering and perfect safety pilot when driving at high speeds.

The engineers need to tackle extra tasks in accordance to performance handling, stability and safety to surpass the curvilinear sections of the track at high speed. When the vehicle goes through a turn, there are cornering and lateral forces causing the demolition and roll of the vehicle. In order to reduce these negative
consequences, parameters such as the characteristics of the tire, the kinematics of the suspension and steering
and damping parameters of the suspension need to be considered. As a result, the result of the championship of a vehicle depends on the kinematics of its suspension geometry.[1]

2) KINEMATICS OF THE SUSPENSION OF A RACE CAR

Suspension of a vehicle should provide the optimum kinematics of the wheels of the car and should have minimum unsprung mass. Almost all of the race cars are equipped with double wishbone suspension system in connection with their optimal kinematic properties.

Requirements for the suspension of a race car class FORMULA SAE:

Camber angle should change as the vehicle rolls. So that when the vehicle corners, the suspension provides a constant tire contact patch. This is necessary to allow the transmission of large cornering forces and uniform tire wear

The half track change should be minimum in order to increase the contact between the road and wheels. [1]

Changing the relative position of double wishbones suspension levers, changes the height of the transverse and longitudinal tilt of the car, so this type of suspension is able to provide the perfect motion ratio. On the other hand, the change in distance between the arms affects the change of forces acting on the pivot devices and hinges.

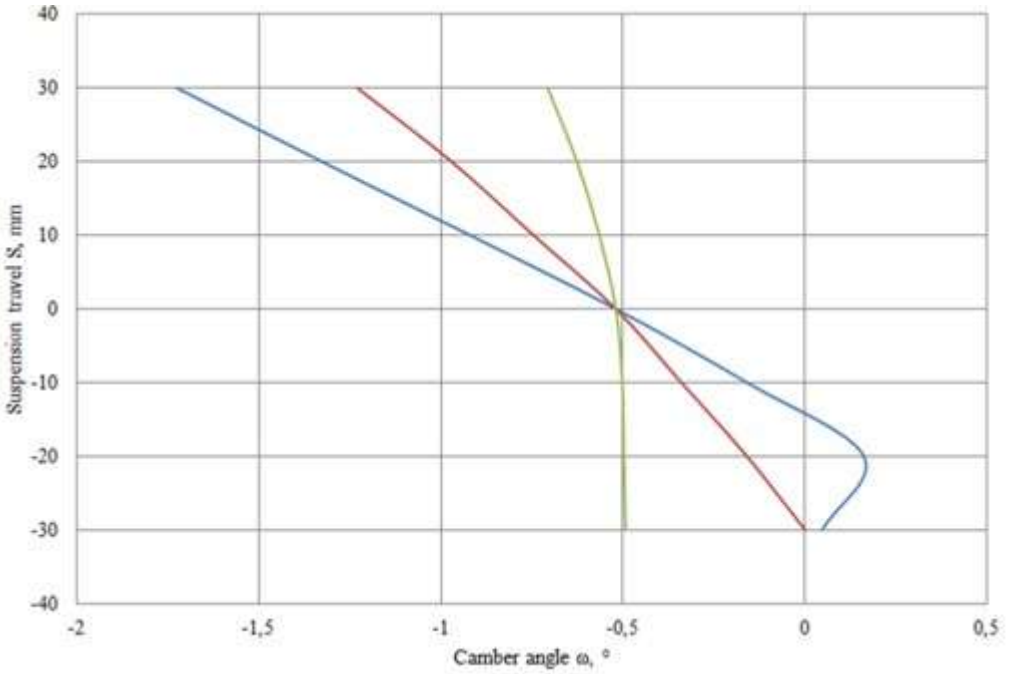

Fig-1: Camber change rate [1]

3) DESIGN

The design of suspension of a formula car is complex; hence there is a need to have amethod by following which the suspension geometry can be designed. This paper illustrates a procedure which involves kinematic and dynamic analysis for the design of a Double A-arm pushrod suspension geometry. The results include geometrical position of linkages and characteristics of spring and damper. These results were validated through roll steer analysis. In most of the theory the kinematic analysis of double wishbone geometry is carried out by assuming the suspension geometry to be a two dimensional 4 bar mechanism. But, this analysis is an conjecture because of the presence of spherical joints in the actual built suspension system. Hence, in the proposed method, the kinematic analysis was done using 3D graphical method and the change in alignment of the wheel was plotted with the wheel travel.

1.1. Design Expectations

The suspension is designed so as to satisfy following design criterion:

Allowable wheel travel of at least 50.8 mm, 25.4 mm jounce and 25.4 mm rebound.
Roll centre significantly above ground for good cornering stability.
Easy to design and manufacture
Small variations in wheel alignment during the desired wheel travel.

3.2. Design Considerations

Co-ordinates of pivot points and dimensions of wishbones and pushrod.
Height of roll centre from the ground, caster, camber and toe angle at vehicle's standstill position with a 75 kg driver seated inside.
Dimensions of the upright.
Spring constant and damping ratio.
Dimensions of the bell crank.

3.3. Design Procedure

Height of the roll centre is generally taken to be 50mm from the ground also race car prefer negative camber to have lateral force and toe out in order to have ease while turning. The values of camber, caster and toe angles should be around -1^{o}, 5^{o} and 1^{o} . These values can be attained when the vehicle is in a static position with around 75 kg person seated inside. Taking these design factors as constraint, an iterative design procedure should be followed to make other design decisions. The first decision that should be made is the coordinates of pivot points and dimensions of the wishbones.

From the study of commercially available knuckles, the KPI of 7^{o} was chosen for the first iteration. The coordinate system shown in Fig.2 was followed throughout the procedure.

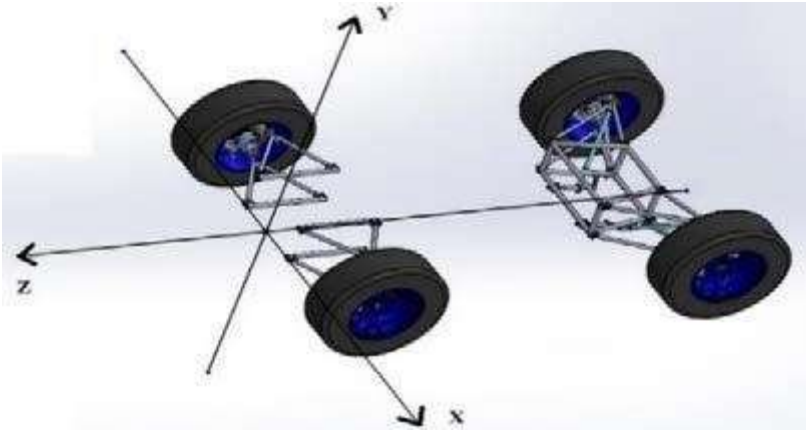

Fig-3: Coordinate System [2]

The pivot points of the A-arms on chassis were labeled as shown in Fig.4.

Fig-4: Front Suspension (a) Isometric view (b) Front view with labeling [2]

The next step should be the coordinates of pivot points and dimensions of bell crank and pushrod. One pivot of the pushrod should be mounted on the lower wishbone at point E. Considering the space constraints on the roll cage, the maximum length of spring (IG) should be fixed and the maximum compression of the spring should 25.4mm. Thus, the final problem is the maximum and minimum inclinations of line HG for 25.4mm travel of the spring. The maximum and minimum inclinations of line AE are also known for 25.4mm bump and 25.4mm droop. Thus, it is the characteristic of four bar mechanism in which the length of central link (HA) is decided and the scope of inclinations for input link (GH) and output link (AE) is known. Thus, the shape of bell crank is determined. Then the FEA of each link and the performance of suspension characteristics is carried out. An iterative procedure should be carried out until desirable kinematic and dynamic results are obtained.

3.4. Design Modifications

The main goal of the aerodynamic study is to reduce the drag and optimize the stability of SAE formula car. The reduction in drag will assist in increasing the clock speed of the SAE car. This is achieved by making the body aerodynamic and lesser obstruction for the air flow. The stability is achieved by providing spoilers or wings. In this article the front wing is installed onto the SAE car to enhance the stability, the aerodynamic study of three different solid models are taken.

The preliminary solid model is the basic SAE Formula model that traces the overall shape with general dimensions.

The second solid model is a model with blank in the firewall to reduce drag.

The third solid model is a model with cut out in the firewall and a front wing. This will reduce drag and increase stability by increasing the down force.

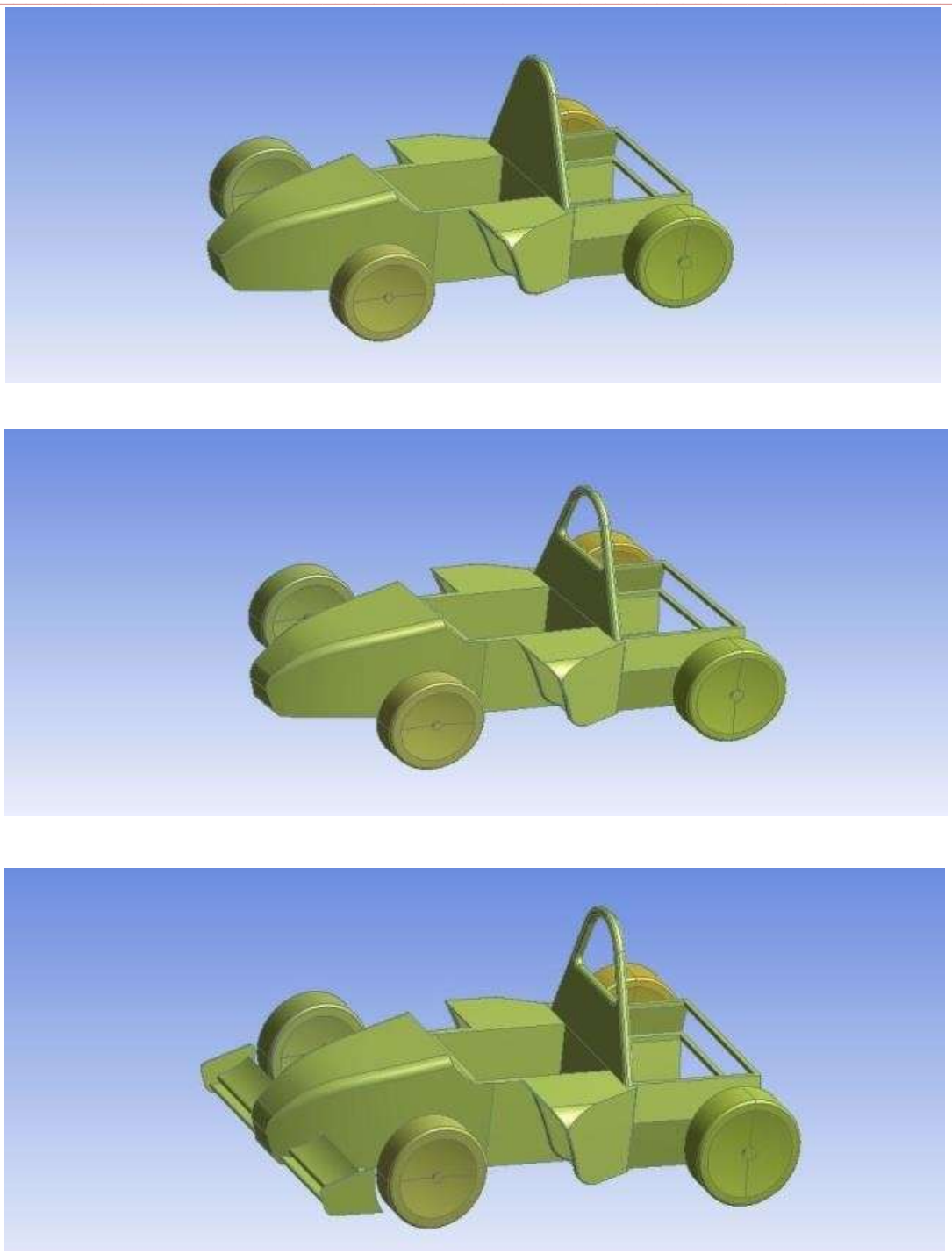

Fig-5: Model 1,2,3 [4]

To lessen computational time, only half of the model is considered. This is possible as the vehicle has symmetry along its longitudinal axis. Triangular meshing is done so as to obtain an unstructured grid. To get boundary layer effect, program controlled inflation layer is used.

3.3. Static Pressure Contours:

The preliminary model is the basic model of SAE car. All three cars were designed in SOLIDWORKS and analyzed in ANSYS FLUENT.

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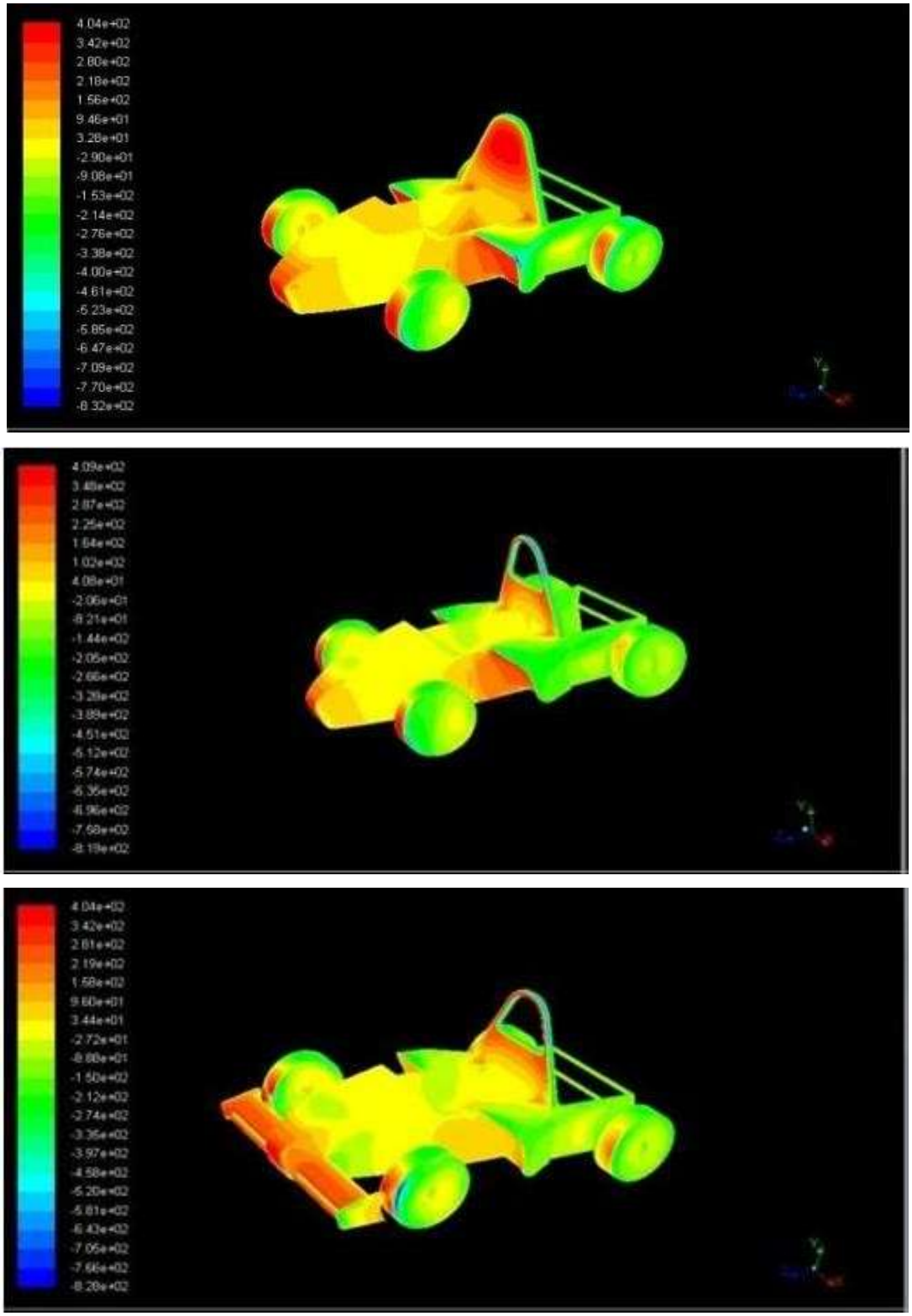

Fig.6 Static Pressure Contours Model 1,2,3 [4]

Conventional race car model has flat firewall. Hence, more air flow strikes on front part which increases the pressure. For model 2, blanking upper portion of firewall provide scope for air flow. This increases the velocity of air and decreases the pressure at that point. For all the models, more pressure is originated at the stagnation portion, on front tires.

4) CONCLUSION

The vehicle dynamics parameters were thoroughly looked upon and the significance was studied. Castor, camber, toe, roll centre and other basic parameters were carefully studied and their effect on vehicle dynamics was brought to notice.

To enhance the aerodynamic performance of formula car, an attempt is made to modify the design of a Formula SAE car. Study is done on three car models by carrying out CFD analysis. Blanking out the portion of firewall and introducing wing at front end. The pressure at firewall found to be reduced for the modified vehicle due to providing space to flow the air through cut out portion, where flow remains bound and helps to reduce the drag.

Thus, net pressure near the driver head region is decreased for the modified car with front wing. Velocity of air is found to be enhanced below the stagnation point of car for model 3. Model 3 having wing at the front end and having blank portion at firewall shows reduced drag and lift, shows better aerodynamic parameters than other two models.

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