



Determining the Relevance of the MIRA Reference Geometries to the Modern Automotive Design Process

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Introduction

This project focused on the use of simple reference geometries, in this instance the MIRA reference geometries (Fig 1), and determining how relevant they are to the modern automotive design process through extensive CFD (Computational Fluid Dynamics) testing. A great deal of research has been carried out on both the MIRA geometries and other simple reference bodies in the past. Certain papers have focused on shape optimisation using CFD [1], whilst others have used reference shapes as a starting point to develop new and more modern reference geometries [2]. However, a gap exists in the literature where in which these reference geometries are looked at as potential aids to actual automotive design. This project looks to explain how suitable, if at all, the MIRA reference geometries are to a company looking to develop and design a new vehicle. By conducting CFD simulations on the various MIRA geometries, as well as on some basic aerodynamic components, a picture can be formed of how these geometries act comparative to the characteristics seen in modern vehicles

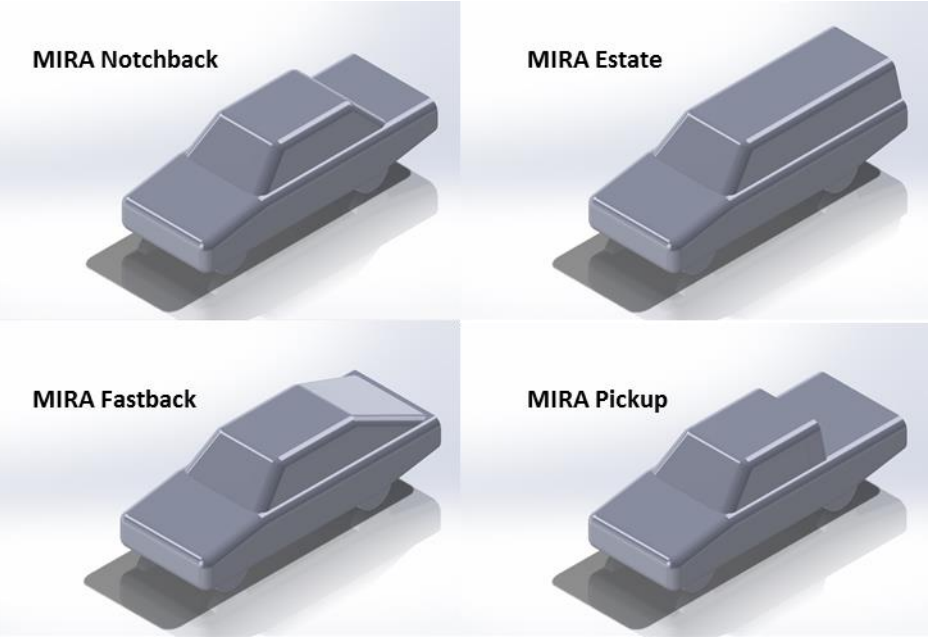


Figure 1 – 3D Representations of MIRA Reference Geometries

Project Aims & Objectives

Specific Aims:

1 – To develop a validated CFD model of the MIRA notchback geometry using methods previously determined through an Ahmed body study.

2 – Compare the drag and lift coefficients and air flow structures of the different MIRA reference geometries.

3 – Design and attach aerodynamic components to the notchback geometry to show how they affect the lift, drag, and air flow.

Objectives to Achieve Specific Aim 1:

1 – Complete software calibration using the Ahmed body and other relevant parameters derived from previous studies.

2 – Apply these calibration settings to the MIRA notchback geometry, making necessary alterations to achieve calibration reflective of real-world values.

3 – Attain a complete and calibrated simulation environment for use with the notchback and other MIRA reference geometries.

Objectives to Achieve Specific Aim 2:

1 – Run CFD simulations on all MIRA reference geometries within the previously calibrated simulation environment.

2 – Collate results from completed runs.

3 – Compare and analyse these results in terms of the drag and lift coefficients of each MIRA geometry.

4 – Compare and analyse the differing air flow characteristics of each MIRA geometry.

Objectives to Achieve Specific Aim 3:

1 – Use suitable computer aided design (CAD) software to design and attach aerodynamic elements to the MIRA notchback shape.

2- Run CFD simulations on the notchback geometry and added aerodynamic elements within the previously calibrated simulation environment.

3 – Compare and analyse how the addition of aerodynamic components alters the drag and lift coefficients and air flow characteristics of the notchback.

Methodology

Calibration of CFD Software:

Prior to testing the specific MIRA geometries, CFD simulation can be conducted as the software itself needs to be calibrated so suitably accurate results can be attained from the simulated running. By using another generic body, in this case the Ahmed body, calibration of the software can be completed.

Ahmed	25	Lift	0.345
Coefficient (Cl)			
Ahmed	25	Drag	0.299
Coefficient (Cd)			

Figure 2 – Target Cl and Cd values for Ahmed Body Simulation [3]

Once the Ahmed body matches the real-world values (Fig 2), adjustments can be made to the simulation environment to better accommodate the physically larger MIRA notchback geometry. Once the optimisation was completed a set of simulation settings could be documented and used for the remainder of the project. These final settings can be seen in Fig 3.

Solution Method	Coupled
Element Minimum Size	0.7
Element Scale	0.75
Prism Layers	5
Domain Size	3L Forward. 5L Backward. 2H Up. 2W Side.
Turbulence Model	K-e realizable
Wall Functions	Scalable Wall
Wake Box	Yes (0.5L Forwards. 1.5L Backward. 0.5H and 0.5W)
Underbody Box	Yes

Figure 3 – Summary MIRA Notchback CFD Settings

MIRA Geometry Comparison:

Upon completion of the initial notchback running and calibration, the other MIRA reference bodies were run using the same settings. From these runs a comparison was drawn between the different geometries in terms of their drag and lift coefficients. An assessment of how air flow differed between the different body shapes was also achieved, by utilising the pressure and velocity contour functions available in ANSYS.

Aerodynamic Element Study:

Two elements were tested at various heights as a part of this project. First of these was a front air dam (Fig 4) and the other a rear spoiler (Fig 5)

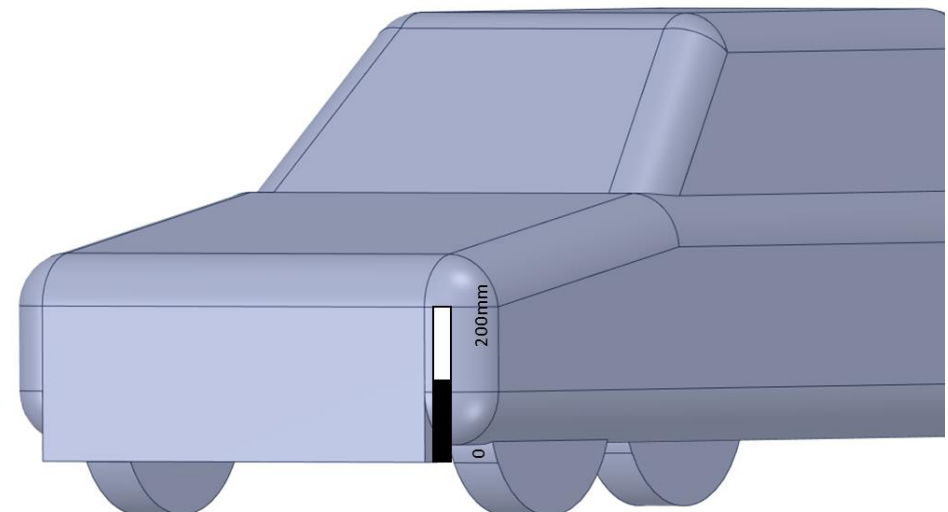


Figure 4 – Notchback Geometry with Air Dam

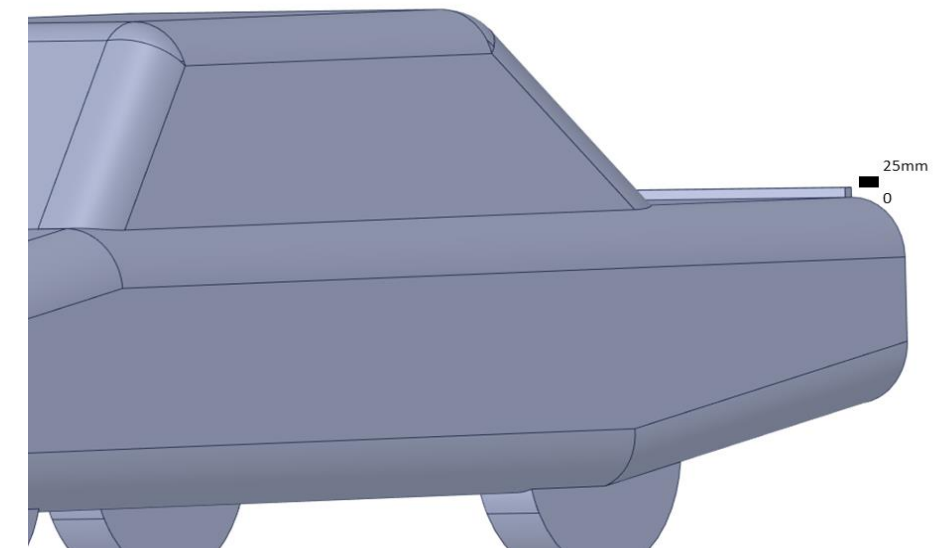


Figure 5 – Notchback Geometry with Rear Spoiler

For the front air dam a slight adjustment to the simulation environment was required. The prism layers were not effective around the harsh angles of the air dam, and thus had to be removed. An increased mesh density was introduced underneath the shape to compensate for this change. Once this adjustment was completed, a full set of results for air dam heights between 200 and 250mm was attained, at 10mm intervals.

The rear spoiler did not suffer from the prism layer issues experienced with the front air dam running. Therefore, simulation of the rear spoiler heights between 25 and 50mm, at 5mm intervals, was completed without issue and a full set of results collected and documented.

Results

MIRA Geometry Comparison:



Figure 6 – MIRA Geometries Drag and Lift Coefficients. Drag Values are in bold.

The drag and lift coefficients of each of the four MIRA reference geometries are compared in Fig 6. The calculated values matched those detailed in existing literature [4], and provided expected differences in the geometries lift and drag values.

The fastback geometry provided the most efficient air flow characteristics with a near to zero, neutral lift value, as well as the lowest drag of any geometry. This is due to a shallow rear window angle that keeps air flow well attached compared to the other geometries, thus forming less turbulent air behind the geometry. The estate lies at the opposing end of the efficiency spectrum, with high negative lift and a much larger drag coefficient than any other shape. Both the notchback and pickup performed similarly to one another, producing comparable levels of aerodynamic efficiency.

Front Air Dam Results:

The front air dam running yielded results not analogous to real-world instances of the same element.

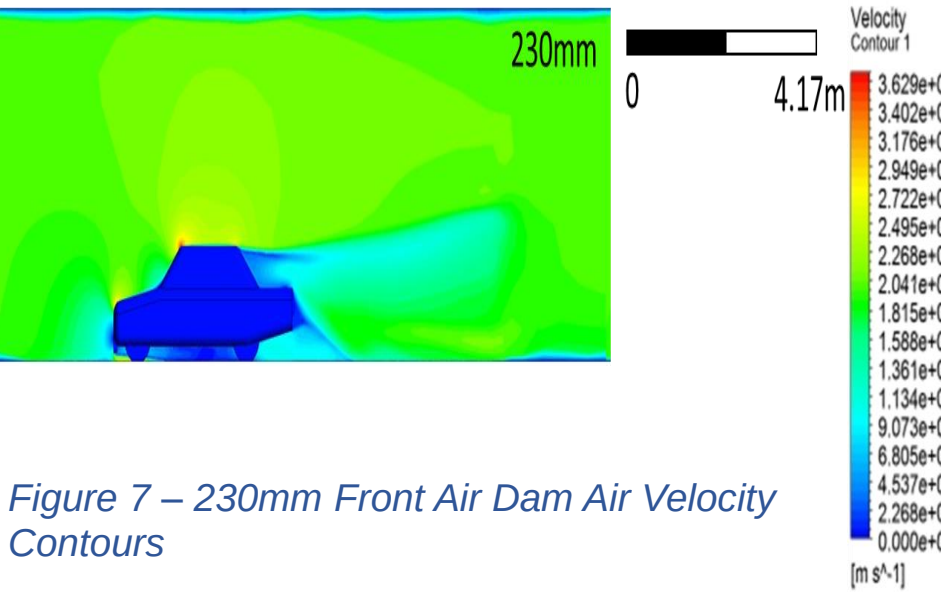


Figure 7 – 230mm Front Air Dam Air Velocity Contours

Fig 7 shows an example of how air flow structures form around the notchback geometry with the 230mm front air dam.

This height sits in the middle of those used and shows the characteristics that cause the results to differ from real-world situations. The front air dam should cause air to flow more quickly underneath the body, lowering the air pressure below comparative to the air pressure above, thus producing negative lift, or downforce. However, because of the angled diffuser found on the MIRA geometries, this does not happen. The air flow has to move further to re-attach to the body surface underside, creating turbulent, low velocity air. A delta in air pressure above and below the body is therefore not present. Consequently, instead of negative lift being produced, the testing for this project produced positive lift as a result of the MIRA geometry's design.

Rear Spoiler Results:

Although the rear spoiler produced values closer to those expected, there were still subtle differences between results and how the element would react in the real-world.

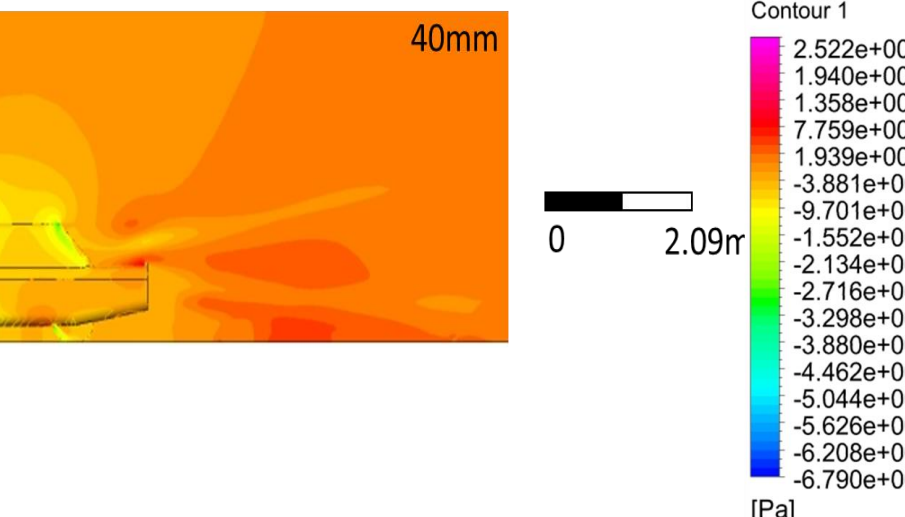


Figure 8 – 40mm Rear Spoiler Pressure Contours

Fig 8 shows how the air pressure changes around the rear of the notchback geometry with a 40mm rear spoiler attached. The small area of high pressure that builds up in front of the spoiler is the textbook way in which this element should work. By creating turbulent slow air in front of the spoiler, an increase in pressure is formed. This not only generates a delta above and below the body that promotes negative lift, but also allows the air flow to attach above the high pressure area off of the top of the body. Theoretically, this reduces drag and turbulent air flow behind the geometry.

Conclusions

Having gathered results for the different MIRA geometries, along with the front air dam and rear spoiler studies, clear conclusions can be drawn on the relevance of the MIRA reference geometries to the modern automotive design process.

The way in which the MIRA geometries are designed is far too angular when compared to current automotive design. This angular form causes much more turbulent air and separation across all variants of the MIRA geometries. Similar air flow structures have been designed out of modern vehicles for decades in favour of low drag, smooth curve designs. Because of this, the MIRA reference geometries in their current form are not relevant to the modern automotive design process and will not be suitable as a design aid. In addition, the rear diffuser present on all of the MIRA geometries causes different results compared to most real-world vehicles when aerodynamic elements are added and tested. For this reason, the MIRA geometries also do not function as a suitable test bed for aerodynamic element design and testing.

Recommended Further Work

- Wind tunnel validation
- Re-design of geometries
- Add new shapes e.g. hatchbacks and crossovers.

References

[1] Howell, J., Passmore, M.A. and Tuplin, S., 2013. Aerodynamic Drag Reduction on a Simple Car-like Shape with Rear Upper Body Taper. SAE International Journal of Passenger Cars – Mechanical Systems, 6(1), pp.52-60.

[2] 18. Heft, A.I., Indinger, T. and Adams, N.A., 2012. Introduction of a New Realistic Generic Car Model for Aerodynamic Investigations (No. 2012-01-0168). SAE Technical Paper.

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[4] 28. Palaskar, P.M., Kumar, V. and Vaidya, R., 2016. Methodology Development to Accurately Predict Aerodynamic Drag and Lift for Passenger Vehicles Using CFD (No. 2016-01-1600). SAE Technical Paper.