

CFD Report

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Report on Virtually Modelling the MIRA Notch-back Car

Abstract

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Introduction

This report will detail the process of creating a computer model of wind-tunnel analysis of the Notch-Back analogue created by the former Motor Industry Research Association, or MIRA, which was used to provide base data for car manufacturers to compare their models to, creating a guideline for vehicle manufacture.

The model is to be made by use of the ANSYS software package, which has been used for engineering modelling since 1970 (ANSYS, 2018), to create a virtual model of the aforementioned Notch-Back, and to then use the software to create both the wind-tunnel, and the fluid flow to thus create an effective model of the pressure and velocity of the fluid moving around the car.

Assuming that this model is of a high enough quality, a follow-up in the shape of modification to the vehicle's model itself will occur, as a means of testing whether the model will work for varying geometries, and adding a rear wing or similar item to the model will achieve this.

Initial Model

Geometry

The basic geometry to form the model was provided by Mr. Tudor, in the form of an X_T file, which is a specifically encode text file that is used to provide the data to the modelling software to produce the virtual model of the car, as seen in Figure 1.



Figure 1. X_T file for the Notch geometry.

Once this is loaded into the ANSYS package, the domain, or the area in which the fluid movement is to be contained, must be created. This is done by creating a box shell around the car, with measurements that are expected to be large enough to ensure that any turbulence will not be infringed upon by the walls. In this instance, as in Figure 2, the measurements are 5x5x25 meters, which should provide enough space to do so.

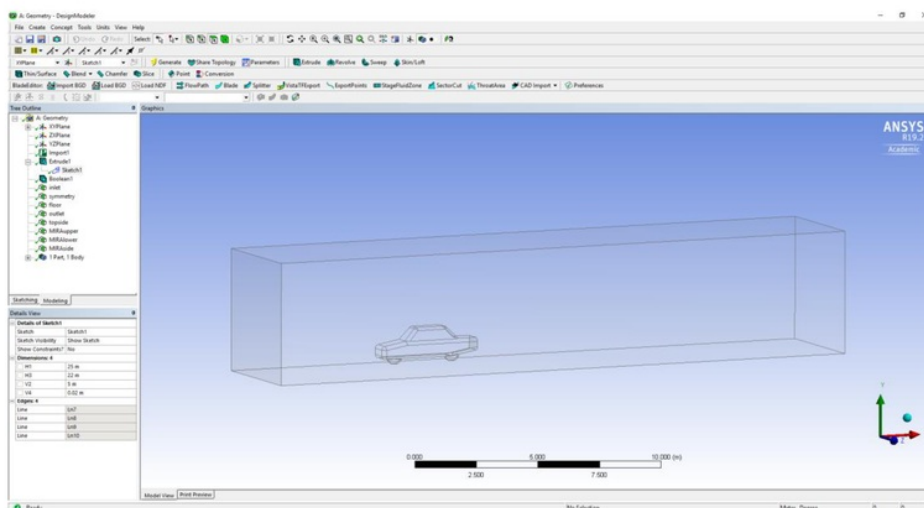


Figure 2. Domain Geometry.

Mesh

After the geometry of the domain is created, the model is then imported into ICEM, as seen in Figure 3, to provide the data on where the fluid is going to enter, leave, and be bound, in addition to mapping the cell layout of the structure. These cells are in the form of tetrahedra, which is to say, triangular pyramids, and they are sized and skewed in order to fill the volume assigned to them. In addition, there is the ability to modify the density of the tetrahedra in given areas, apart from the basic density level of the mesh. These additional areas are, specifically, prism layers, and density areas, which add additional layers of realism to the model, by modelling the boundaries and specific areas respectively, more accurately.

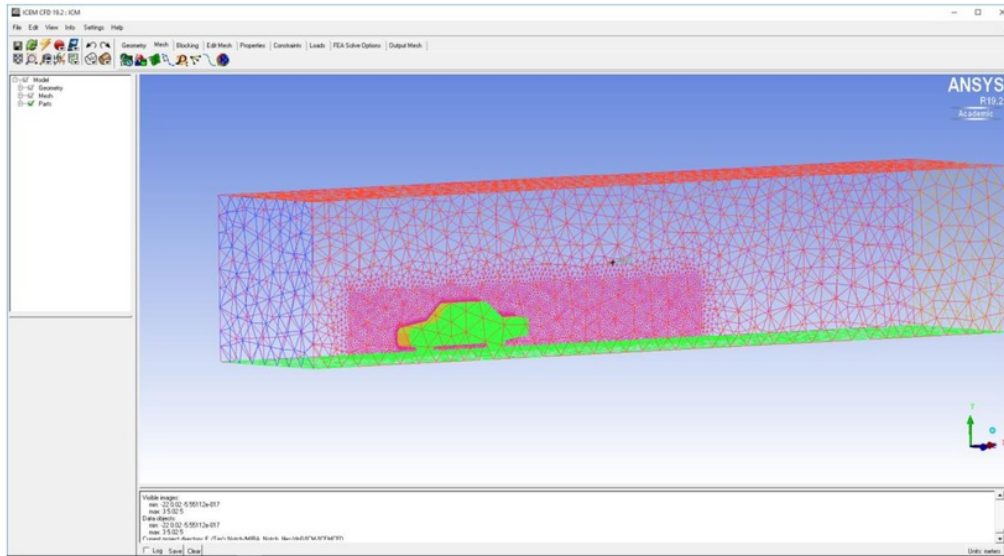


Figure 3. ICEM Mesh: Note increased Density Layer around the car.

As the whole point of this exercise is to model as accurately as possible, whilst optimizing the model so that it will actually run the calculations in a reasonable period of time, the balance between maximum precision and maximum speed has to be struck. Hence, the density box.

Results

Once the Mesh has been determined, it is exported to the third program in use, Fluent, and the actual fluid motion, i.e. the actual purpose of this whole scenario, is calculated. As the calculations are running, Fluent generates several graphs, one of which is shown in Figure 4. This graph in particular shows the three velocity components, k and ϵ , and the continuity. These lines show the errors in the calculations, therefore, the closer to approaching zero that these values reach, the better a representation of reality the model is.

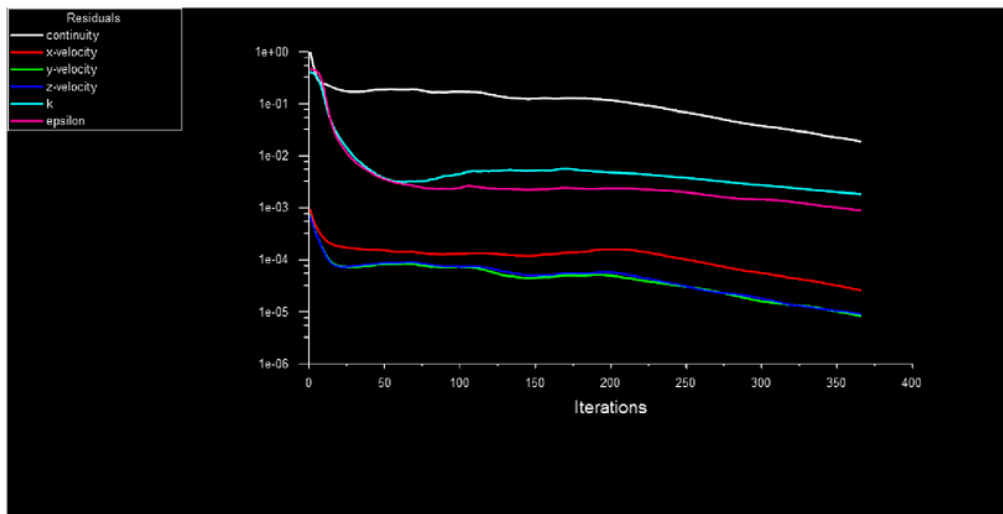


Figure 4. The Residuals Graph.

Analysis

After gathering the data, post-processing can show off the results in a way that the graphs above simply cannot do. These following figures show the pressure changes over the vehicle, from front to back, demonstrating the strengths and weaknesses of the test vehicle's design. In Figure 5, the provided data show the trends in pressure on the top and bottom surfaces of the real MIRA Notchback test model, which is what the virtual model is based on, and compared to.

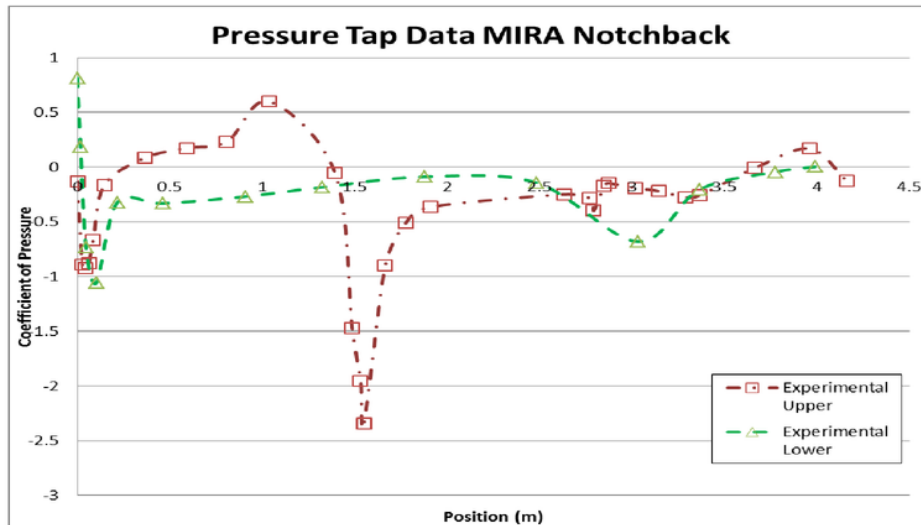


Figure 5. Pressure Data for the Actual MIRA Notchback (Tudor, 2018).

The data represented in Figure 6 show how the geometry of the MIRA Notch model interacts with the surrounding atmosphere whilst at speed. Whilst the air initially tends towards a gauge pressure of zero, once it approaches the front of the car, pressure rises to a peak when it makes contact, and

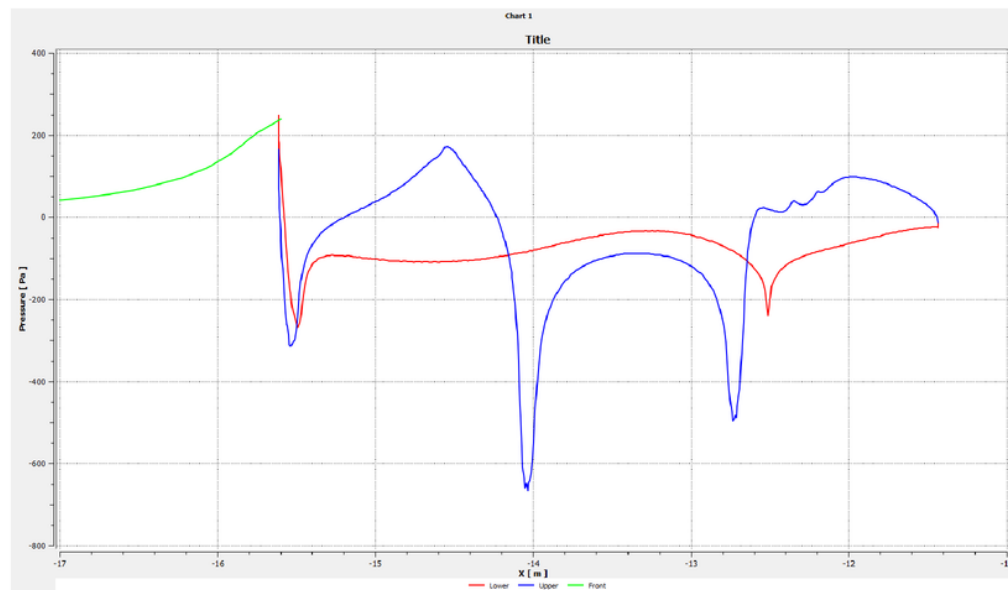


Figure 6. Pressure Curves for the MIRA Notch Car.

as it passes, accelerates and so loses the pressure, until it interacts with the rising surface of the hood and the windscreen, culminating in the massive drop in pressure on hitting the corner of the roof, as shown in Figure 8.

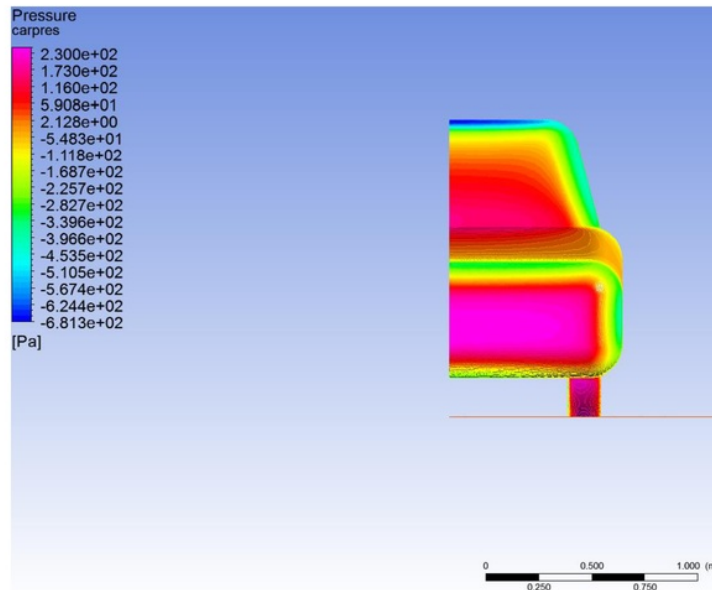


Figure 7. Pressure on the Front of the MIRA Notch.

On the underside, a similar pattern is observed, where any perpendicular surface, or any which are closer to vertical than horizontal, produce a large increase in pressure, with horizontal surfaces causing reduction.

Any drastic void in the geometry serves to create a partial vacuum, which is mostly negated on this model, save for behind the wheels, as the base of the geometry is smooth.

This effect is more pronounced, however, at the rear of the upper surface, as, once the pressure has returned towards zero after the initial decrease at the edge, is turbulently increased to 100 Pascals, as a result of the sudden void behind the back of the roof and the interaction upon hitting the actual surface, as shown in Figure 9.

The final edge operates in a similar manner, causing a reduction in pressure due to the increase in volume available for the air to fill, as per the Ideal Gas Law (Nave, 2016). This shows that pressure changes are directly related to the geometry, and that the smoother and flatter the geometry is, the lesser the changes in pressure should be.

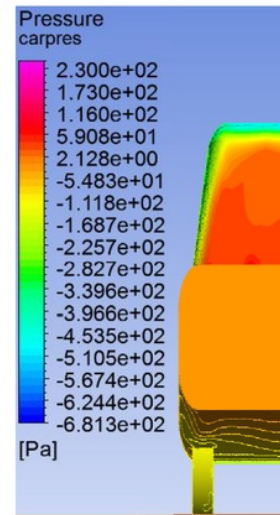


Figure 8. Pressure on the rear of the MIRA Notch.

In Figure 10 below, it can be seen that the pressure is, in general, higher in front of the vehicle than to its rear, save for the region of turbulence directly behind. This implies that the air rushing past the side of the car creates a cone of higher pressure immediately to its sides, causing a partial vacuum immediately behind it, which would also allow the turbulent air to rush in and form the zone seen behind the vehicle. This overhead view will be useful for comparison with any altered geometry.

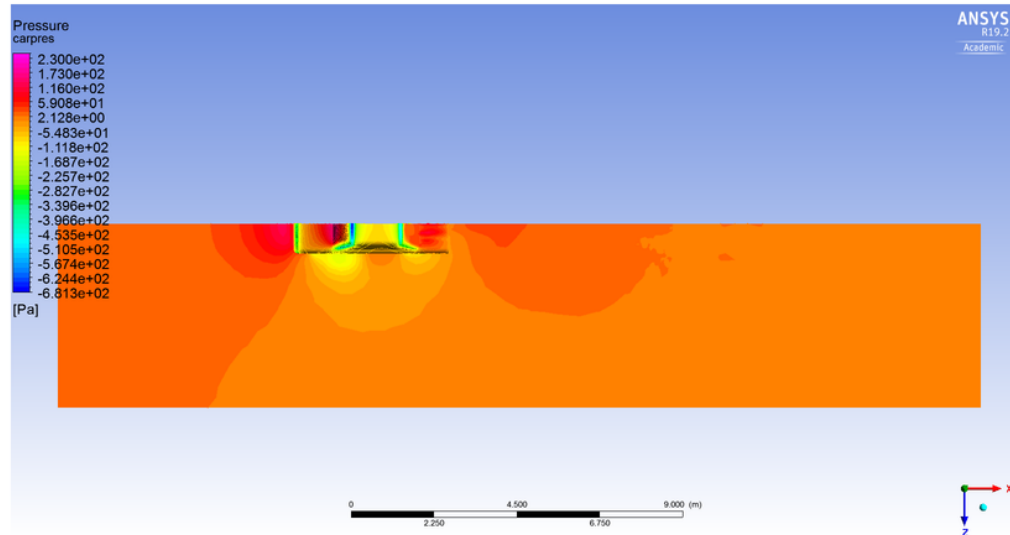


Figure 9. Pressure Map Top View. Note the turbulent region to the rear of the vehicle (Figure's Right).

Model Modification via Amended Geometry

To ensure that the model is reliable, and to provide another set of data to compare results to, the base geometry of the car is altered to, hypothetically, change the flow of air, and thus the measurements taken, around it. These two series of results can then be used to demonstrate whether or not the CFD work has been completed to a satisfactory standard.

The Altered Geometry

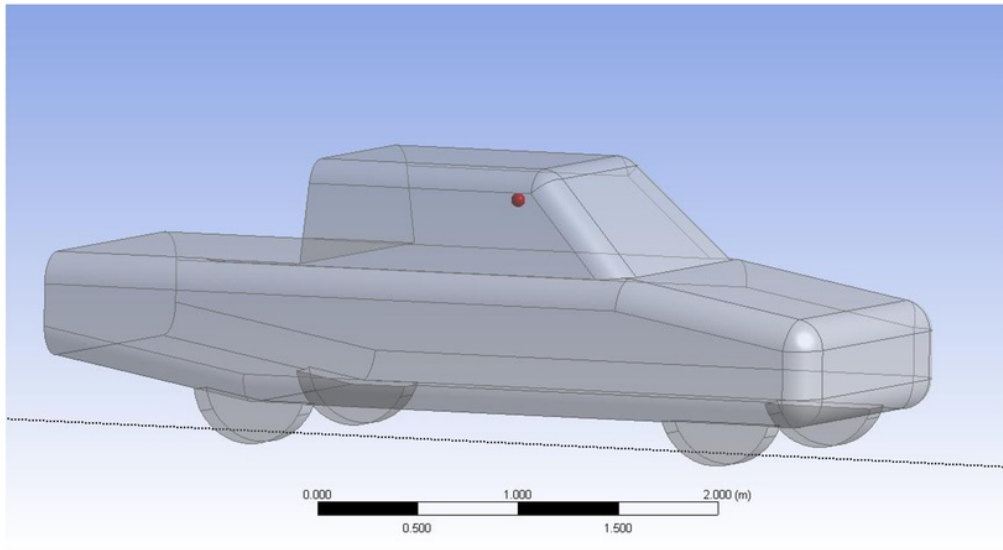


Figure 10. Notch-back geometry modified to form a pickup truck.

In this instance, it was decided that the alteration to the aerodynamic properties of the vehicle would be accomplished by transforming the geometry from that of the notchback to that of a pickup truck.

Modified Mesh

Whilst every attempt was made to replicate the original mesh, save for the obvious difference in vehicle geometry, each attempt to do so was met with repeated freezes, crashes, and losses of data, resulting in what ended up being a rather dissimilar, unsatisfactory product. Neither of the density boxes, nor the prism layers, which were set up worked, which was particularly infuriating.

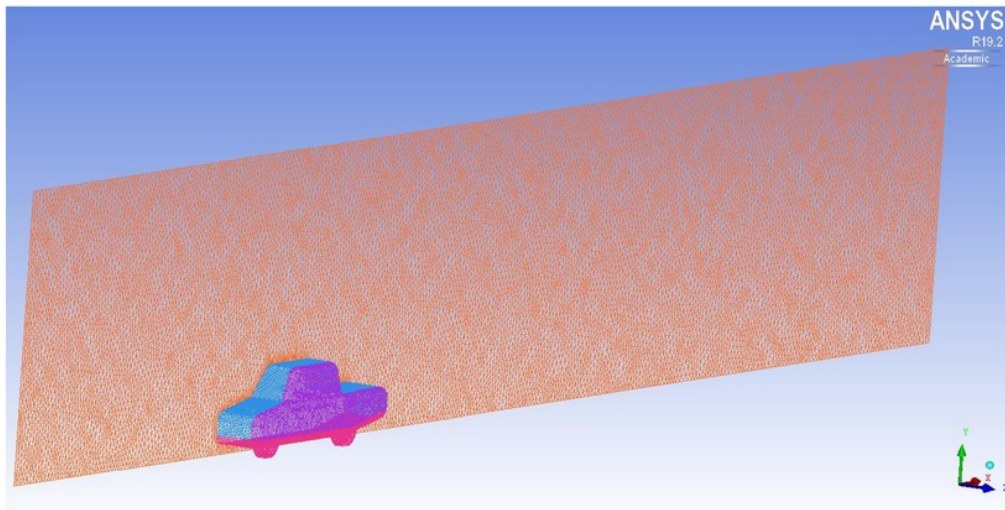


Figure 11. The mesh for the modified car geometry.

Results

As with the original geometry, a graph of errors was produced whilst solving the model. These bars, shown in Figure 12, should all be approaching zero, which would indicate a good model, but the lines indicate that this model was not very good, as the gradient, overall, is rather terrible. This would imply that the issues encountered during the modelling process were actually rather serious, resulting in a subpar set of results.

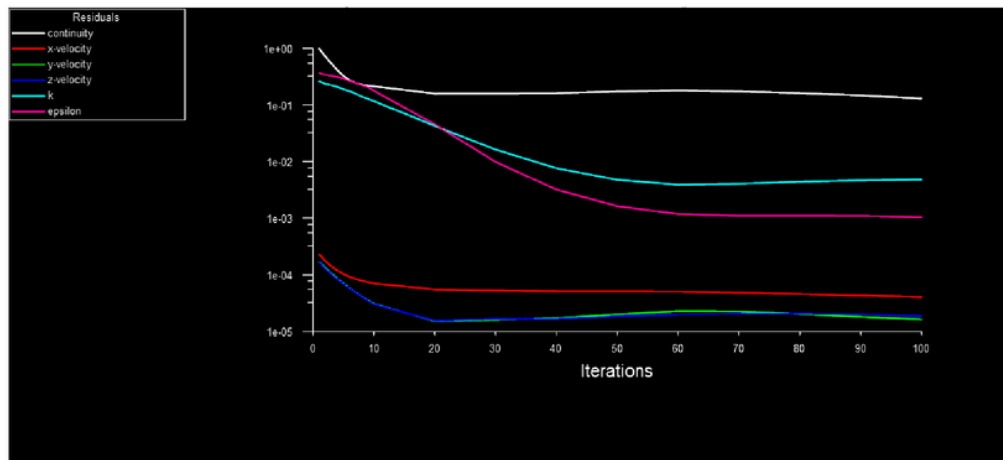


Figure 12. Results of a run with the modified geometry.

Analysis

Having found that the level of error in the model is quite high, the produced model should not be taken as entirely accurate. That said, the visualizations do demonstrate what was expected, with Figure 13 demonstrating the area of low-velocity air formed by the sharp corner of the pickup bed.

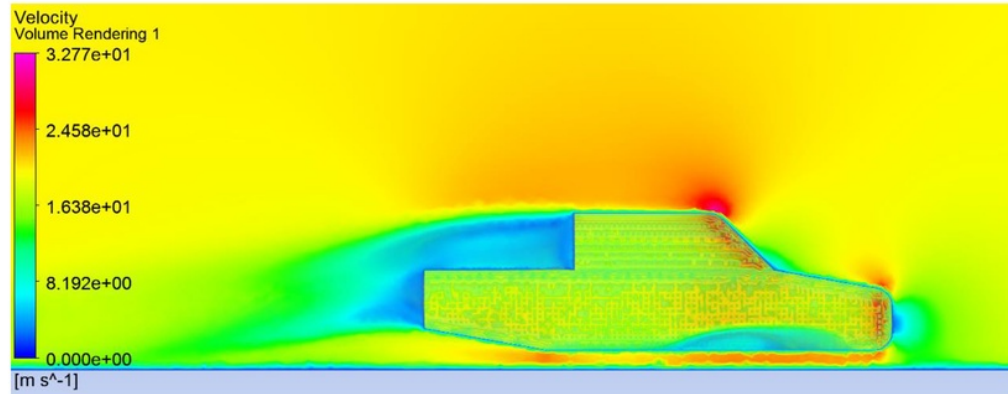


Figure 13. Air velocities over the pickup geometry.

This contrasts with the notchback, as the slanted roof occupied the majority of the space where the void is on the pickup. This can also be seen in Figure 14 below, where the region around the rear exhibits a much lower pressure than the analogous area in the notchback. The same high-pressure

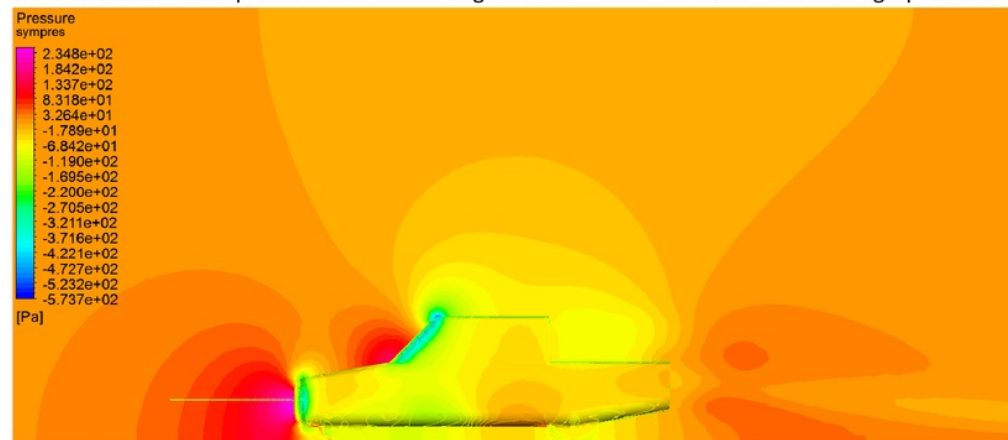


Figure 14. Pressure map of the pickup.

zones, as found in the notchback, are present at the front of the pickup: this is to be expected, as that area of the geometry has not changed. The void at the rear, in addition to introducing the already mentioned low-pressure zone, appears to have significantly altered the airflow at the absolute rear of the vehicle; that is to say that the high-pressure zone immediately after the car is greatly lessened in magnitude, as compared to the notchback.

As seen in Figure 15, the pressures present at the forward end of the vehicle are unchanged from those of the notchback vehicle. This is positive, as this implies some semblance of similarity in the two models, allowing for some comparison of results, in a meaningful manner.

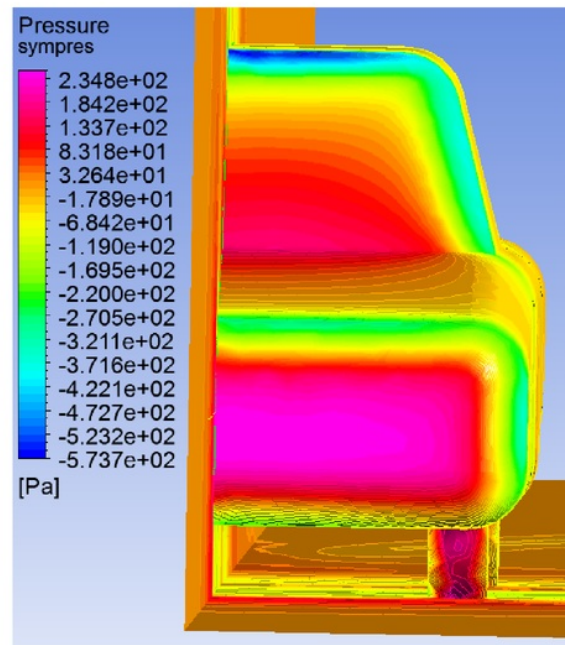


Figure 15. Pickup Truck, front view.

Figure 16, below, shows the rear of the modified geometry, which can be seen to have had significantly different results to those of the notchback model. Where the notchback had pressures of around three Pascals along its entire rear section, this pickup version has actually got a partial vacuum along its length, of around negative seven Pascals. Thus, the void in the rear of the pickup may actually reduce the drag found on the vehicle, by having an air pocket take the frictional forces, rather than the vehicle itself.

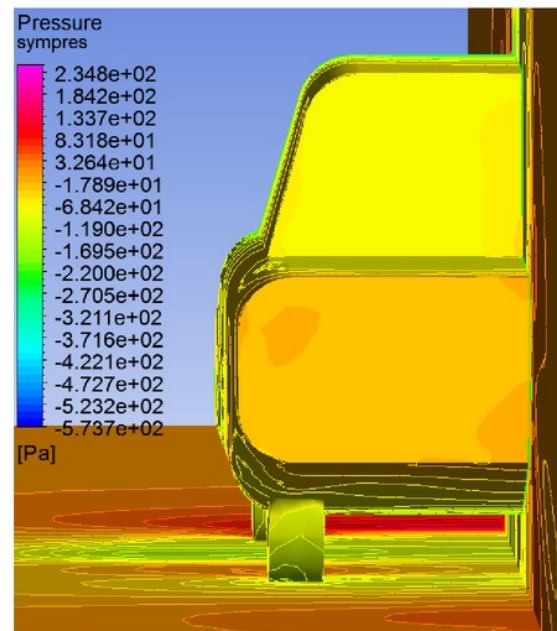


Figure 16. Pickup Truck, rear view.

As with the original car, pressure tap data along the upper and lower surfaces were simulated, resulting in the graph shown in Figure 17. This pressure graph demonstrates similar trends to that of the previous notchback but exhibits a significant difference in that there is no massive spike of negative pressure between minus thirteen and minus twelve meters. This smooths the curve out and is actually closer to the experimental data found in Figure 5 than are the modelled data of Figure 6. This produces an interesting quandary, in which the model which is not supposed to represent the actual, real data has, in one respect, represented it better than the model which was.

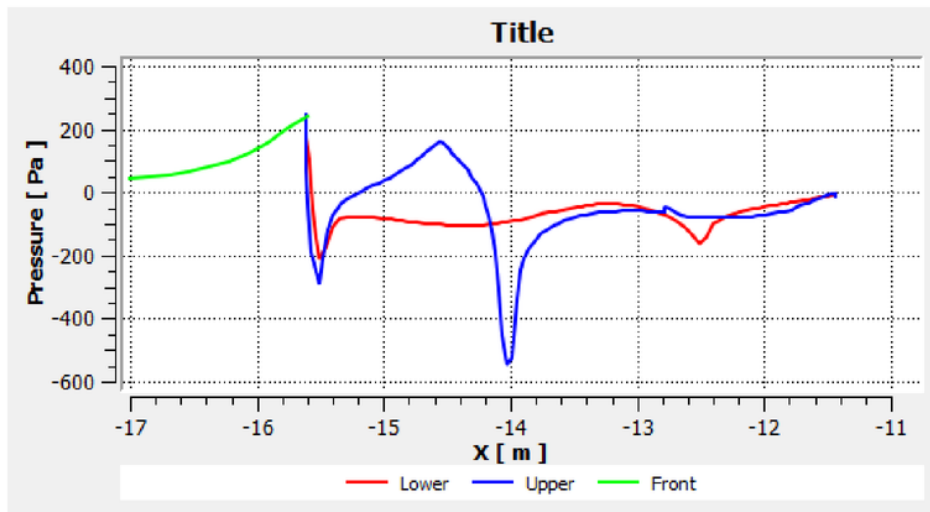


Figure 17. Pressure-Tap data for virtual Pickup Truck.

Other than the absence of the one large spike, the pressure data trends are basically the same, implying that, to noticeably improve the aerodynamics, a more drastic change in the vehicular geometry needs to occur.

Evaluation

Whilst this has been mainly an exercise in learning how to operate the ANSYS software, the models produced are not necessarily bad. Comparing Figures 5 and 6 show that the initial Notchback simulation was a reasonable replicant of the original data in most regions, considering that this is more a test than an attempt to accurately model. The peaks and troughs of the curves form in the same areas, and are of comparable magnitudes, when the scales are equated, save for one spike in the virtual model, which produces a large partial vacuum where there is not one in the real data.

The altered geometry produced some difficulties which resulted in an inferior mesh, as well as impacting on the CFD modelling in Fluent. As a result, the data from it are possibly unreliable, as are any comparisons made with the prior run. With this in mind, one could say that this entire experiment was a failure, with regards to producing useful data, but as it was not intended to do so, and was, in essence, an opportunity to learn how to use the software, it was somewhat successful.

Conclusion

Using ANSYS to model virtual wind-tunnels is not easy, requiring a large amount of effort and skill to master. These things both take a large amount of time (as does anything involving this software, as it turns out), and were not fully accounted for at the outset of this report. As such, the results presented here are nowhere near as good as they could be but are possibly fit for purpose. The data gathered do show the relationships expected, and the modification to the geometry produced drastic changes, as hoped. Therefore, this was a successful experiment, as the intended outcomes, that of practicing the software, gathering data, and utilizing it, have been met.

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