# Effect of afterbody rounding and rear spoiler on the aerodynamic performance of a hatchback vehicle

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**ABSTRACT:** The objective of the present study is to investigate the effect of afterbody rounding and rear spoiler on the aerodynamic performance of a hatchback model. A CFD method is employed to simulate the flow past a simplified hatchback vehicle model at the Reynolds number of 5.25 x $10^5$. Afterbody rounding is found to have an adverse effect on the aerodynamic performance. In particular, the model with afterbody rounding exhibits a higher $C_d$ and $C_l$ due to the drop in the surface pressure of the rounded part of the roof and the slanted end. However, the application of spoiler could prevent such pressure drop. Therefore, the use of rear spoiler is crucial as it reduces the drag coefficient ($C_d$) and lift coefficient ($C_l$) by as much as 4% and 563%, respectively.

**Keywords:** *CFD; aerodynamics; automotive*

## 1. INTRODUCTION

Afterbody rounding is a common geometric feature of hatchbacks. Such feature is perceived as of higher aesthetic value, and arguably provides better aerodynamic performance because the rear section of the roofline resembles the streamline body shape. However, the study of Rossitto et al. [1] reported that while the rounding of the trailing edge of the roof has resulted in a lower $C_d$, it has generated a higher $C_l$. Nevertheless, the rounding feature of their study which is made of a filleted edge is not a good representative of the roofline profile found in hatchbacks in practice. Therefore, the aim of the present study is to reproduce roofline profile typically found in practice to investigate its effect on the aerodynamic performance of hatchbacks. In addition, the influence of rear roof spoiler which is commonly found in hatchbacks is also studied.

## 2. METHODOLOGY

The simplified hatchback model is based on the Ahmed body [2]. The trailing edge of the roof was rounded in such a way that the roofline is of a streamline profile and that the ratio of the height of the rounded part to the model height (i.e. h/H) was 0.09, which is according to the typical ratio found in hatchbacks in practice as according to the authors' observation across several hatchback models (Figure 1). In Figure 1, the roofline for both the rounded (black line) and angular (green line) rear-roof corners were superimposed for the purpose of comparison. The slant angle of the Ahmed body was 35˚.

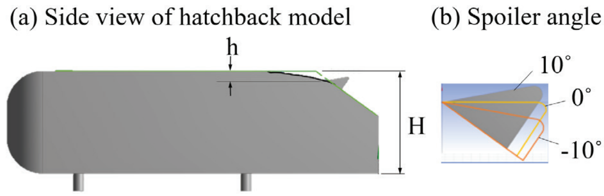


Figure 1 Geometric configuration of vehicle model

The study investigated the effect of rear spoiler by employing the strip-type rear spoiler used in the study of Cheng et al. [3]. In total, 5 cases were tested with the baseline case being the one without the afterbody rounding and spoiler. Table 1 summarizes the test configurations of each case.

Table 1 Test configurations of each case.

| Case | Afterbody rounding | Spoiler angle |
|---|---|---|
| 1 | No | Without spoiler |
| 2 | Yes | Without spoiler |
| 3 | Yes | 10° |
| 4 | Yes | 0° |
| 5 | Yes | - 10° |

In the CFD, the continuity and momentum equations were solved by the commercial CFD package Ansys Fluent v16. The Reynolds number of the flow based on the model length was 5.25 x $10^5$. The computational domain was rectangular with the inlet boundary located at five times the model length (L) upstream. A uniform velocity of 40 m/s was prescribed for the inlet boundary condition. The outlet boundary was at 15L downstream and set as pressure outlet. The lateral side boundaries and the top boundary were respectively 2.5L and 5L from the model, and set as free-slip walls. Finally, the model and ground surfaces were set as noslip walls. The study employed an unstructured grid with tetrahedral and prism cells. The total element number was around 1.3 million.

## 3. RESULTS AND DISCUSSION

Figure 2 compares the $C_d$ and $C_l$ of all the cases. As shown, case 2 exhibits the highest $C_d$ and $C_l$. Figure 3 shows that the afterbody rounding produces a higher flow velocity near the roof end (marked A). Consequently, the surface pressure of the rounded part of the roof becomes lower (marked B). Low surface pressure on the top-facing and rear-facing surfaces is unfavorable as it contributes to higher $C_d$ and $C_l$. Figure 4 shows that the use of rear spoiler can modify the surface pressure of the rounded part of the roof. In particular, when the rear spoiler is applied, the surface pressure of the rounded part becomes higher. In addition, the surface pressure increases with the increase in the spoiler angle. As a result, cases 3, 4, and 5 exhibit lower $C_d$ and $C_l$.

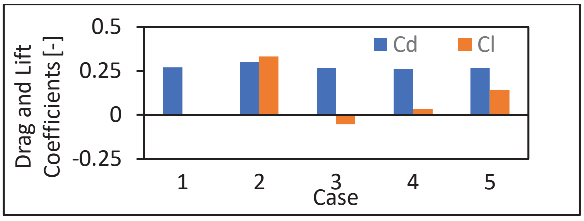


Figure 2 The drag and lift coefficient of all the cases

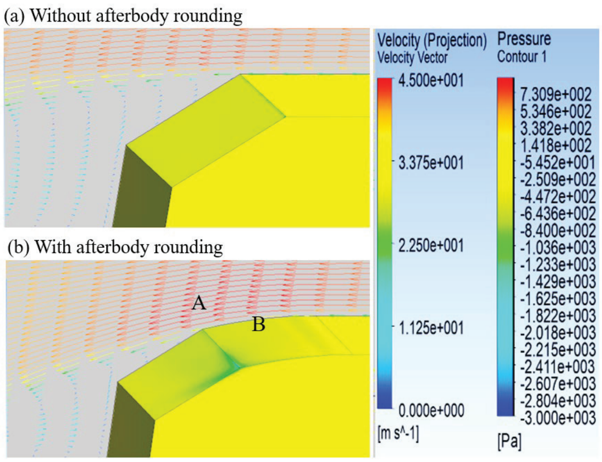


Figure 3 Streamwise velocity and surface pressure distribution of case 1 (a) and case 2 (b)

As for the $C_d$ performance, case 4 is found to be most optimum. Figure 4 compares the surface pressure of the upper side of the model between the with-spoiler cases. It reveals that the surface pressure of the rounded part in case 4 is higher than case 5, while it is comparable to case 3 (marked I). However, case 4 does not exhibit the high pressure region found in case 3 (marked II) which would contribute to higher $C_d$.

As for the $C_l$ performance, the reason for the relatively low $C_l$ in case 3 is due to the generally higher surface pressure at the rear upper side of the model due to the effect of the rear spoiler (Figure 4). Note that low $C_l$ is deemed favorable because it contributes to a better wheel traction and ride stability.

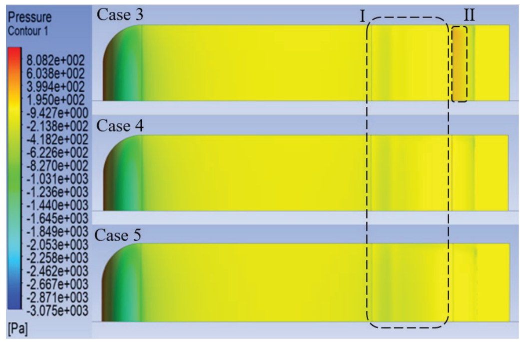


Figure 4 Surface pressure distribution of with-spoiler cases (Top view)

## 4. CONCLUSION

The study investigated the effect of afterbody rounding and rear spoiler on the aerodynamic performance of hatchback-type vehicle. Although the afterbody rounding modifies only a small geometrical part of the body, its negative impact on the vehicle's aerodynamic performance is pronounced. Hence, the use of rear spoiler is important for vehicles with such geometric feature for ensuring a good aerodynamic performance. The $C_d$ and $C_l$ for vehicle models of simple body shapes such as Ahmed model typically fall in the 0.26 – 0.28 and -0.03 – 0.04 ranges, respectively. Both the force coefficients obtained from the baseline case fall within these ranges (i.e. $C_d$ = 0.269 and $C_l$ = -0.008). In general, the spoiler angle has limited influence on the $C_d$ performance. However, the $C_l$ performs better with increase in the spoiler angle. In particular, an improvement of 563% is achieved at 10° spoiler angle as compared with the baseline case.

## ACKNOWLEDGEMENT

This project is supported by Universiti Teknikal Malaysia Melaka (UTeM) and Ministry of Higher Education under FRGS/2018/FKM-CARe/F00375.

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