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Aerodynamic Analysis on Noise Generated from Automotive Side Mirror Using CFD

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Abstract: The geometry of the car's side mirror influences the aerodynamic noise. This study will use computational fluid dynamics (CFD) to investigate the effect of aerodynamic analysis on noise from the side mirror. In this study, we will design two types of side mirrors using the Honda Civic EG9 for sedans and the Range Rover Evoque for SUVs. SolidWorks software was used for geometry modelling and the analysis was completed using the ANSYS software. Three streamline velocity values (80 km/h, 100 km/h, 120 km/h) were chosen as references. The results of the analysis included the side mirror's drag force, acoustic contour, and velocity streamlines. Design 1, produces a maximum acoustic power level of 77.21 dB when travelling at a high speed of 120 km/h. The maximum acoustic power level for Design 2, which travels at 120 km/h is 75.71 dB. In summary, Design 2's side mirror has a higher acoustic power level than Design 1's side mirror. Design 1 produces a drag force of 4.52 N at a high speed of 120 km/h while Design 2 results in a drag force of 6.36 N at a high speed of 120 km/h.

Keywords: ANSYS acoustic, side mirror, aerodynamic noise, computational fluid dynamics CFD

1. Introduction

Aerodynamically generated noise is generally the dominant noise inside a modern passenger car travelling at relatively high speed (> 100 km/h) In part this is due to the sensitivity of wind noise to flow velocity, which is related to the vehicle velocity through the air. However, at highway speeds wind noise is significant and is the focus of much attention by car companies [1]. Flow separation can cause strong pressure fluctuations, which generate aerodynamic noises and also impinge upon the side structures, causing them to vibrate and to radiate noise [2,3]. Other research also demonstrated that whistle noise is attributed to the considerable change in the A-piller vortex and increase in turbulent intensity [4,5].

To reduce the aerodynamic noise, the protruding mirror's design must be altered. There have been certain common methods used to reduce the side mirror's long-standing issues with noise and mirror surface vibration. Previous research have recommended aerodynamic optimization methods to reduce the strength of the intrinsic shedding vortex and suppress the generation of aerodynamic noise by changing the geometric shape of the mirror, such as its bracket height, the housing height and size, the bezel shape, the elimination of sharp edges on all of the corners, and the tube-type extension of the mirror housing [6,7].Because it also satisfies with the size restriction to ensure its visual angle, there are limitations on how much the geometry of the side mirror can be reduced for aerodynamic noise.

For vehicle designers, computational fluid dynamics (CFD) has proven to be a powerful resource. Tasks in CFD range from classical aerodynamics, like the computation of drag or lift forces, to interdisciplinary fields, like wind noise prediction. The goal is to simulate noise analysis and determine whether the vehicle's aerodynamics are affected by the basic geometry of the side mirror [9].

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The Broadband noise source model for acoustics makes it possible to identify the noise source across a wide frequency range in a steady state flow. Transient analysis, which consumes a significant amount of time and computing power to calculate the noise source and propagation, is not necessary for the broadband noise source model, in contrast to the direct method and integral method. The acoustic power is calculated in form decibel from the following formula:

$$Sound\ Power\ Level\ = 10 \log 10\left(\frac{W}{W_{REF}}\right) \tag{1}$$

where:

W= Acoustic Power associated with a sound source

WREF = References power level (W_REF=10^ (-12) W or 1 pW)

2. Methodology

In this research, the approach, simulation, setting, strategy, and mathematical formula are mentioned. ANSYS FLUENT software is used in this research to collect data and to perform computational fluid analysis about this research. The boundaries and limitations of the research study are very important to achieve the objective of the research and to obtain the best result of the research. The result of the study refers to the past research to be as a guide to complete this research.

To conduct the experiment, the geometry design used in this paper is a side mirror which having different parameters. Then, Ansys Fluent is used to start the simulation by setting up the parameter. Before proceeding to the next step, meshing sizes are set with the suitable size to make sure the result data obtained are acceptable. Then, the simulation is initialized and run to do a calculation. After that, the result is obtained, acoustic contour and the airflow pattern can be seen using the software.

2.1 Model design

In this project, there are 2 type of side mirror that need to compare for the test and analysis in Fig. 1 shows design 1 model reference Honda Civic EG9 category sedan car. as for Fig. 2 shows design 2 model reference Range Rover Evoque category SUV car. The side mirror is modelled accurately with actual dimensions. The models of side mirror are designed using the advantage modeling techniques in SolidWorks software [8].

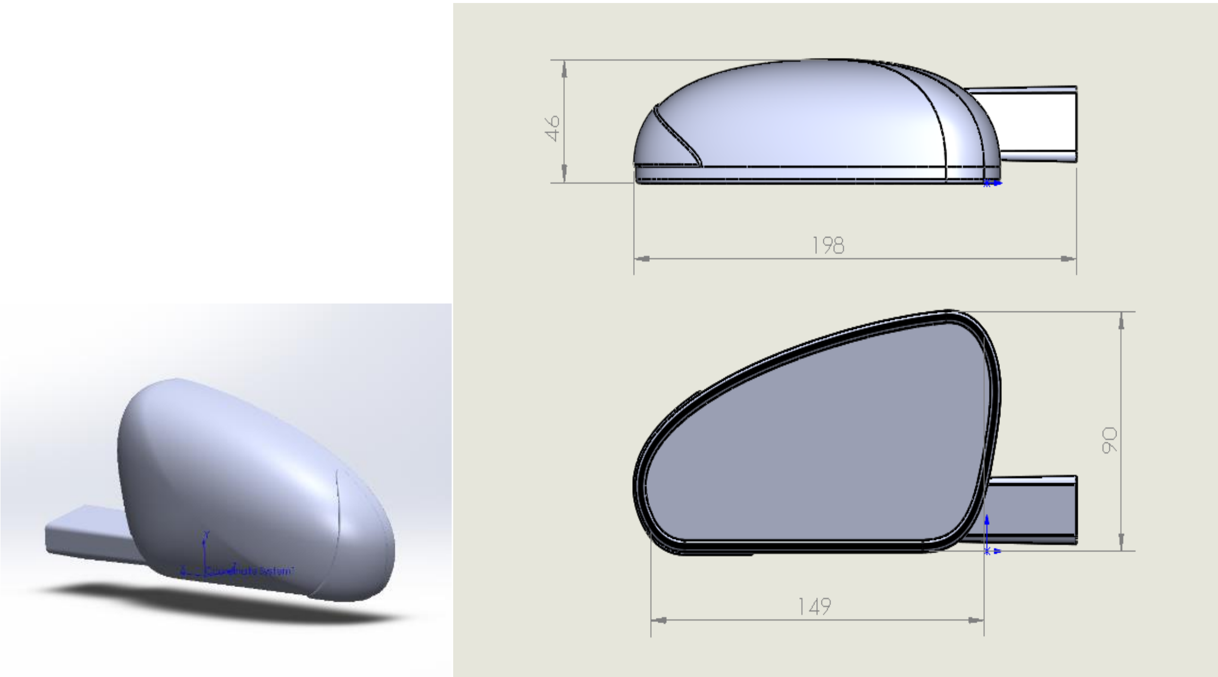

Fig. 1 - Design 1 side mirror overall dimension

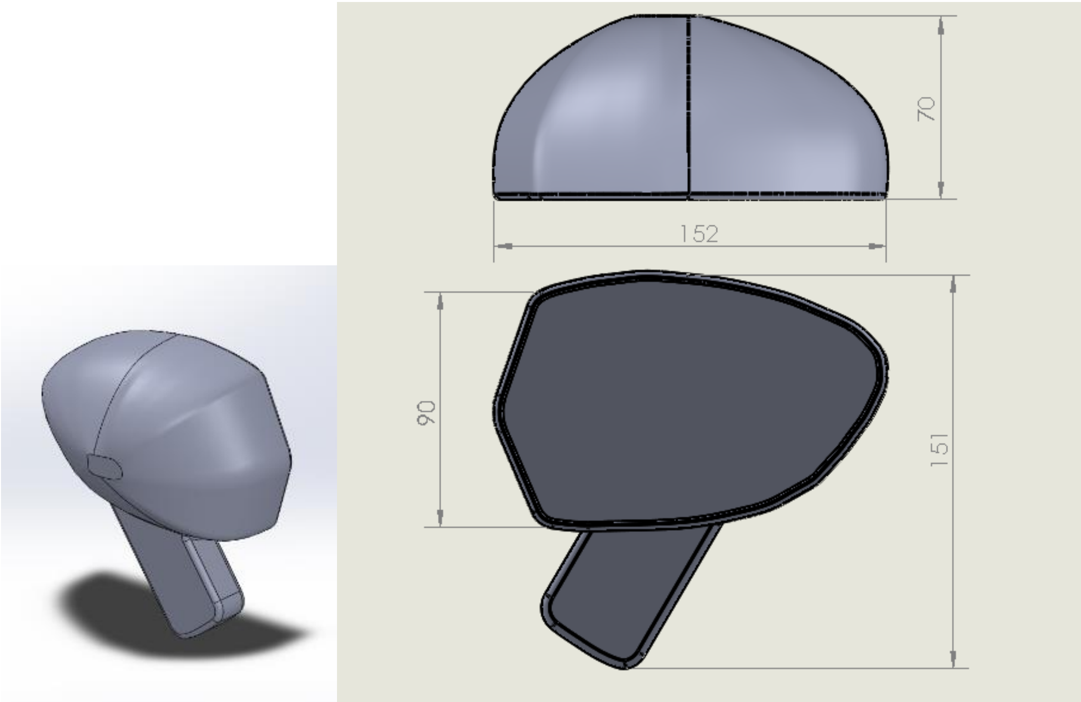

Fig. 2 - Design 2 side mirror overall dimension

2.2 Geometry Model

An enclosed computational domain was made in the current optimization study to simulate how the air flow was distributed over the mirror. The air flow simulation process is performed into the computational domain in Fig. 3. The width of the computational volume is 0.6 m, height is 0.6 m, and the length is 1.0 m. The air flow on the stationary mirror model is simulated in this optimization analysis along with the fluid flow. The mirror model is positioned in a computational domain 0.5 m away from the air inlet in order to improve the visualization of the streamline flow.

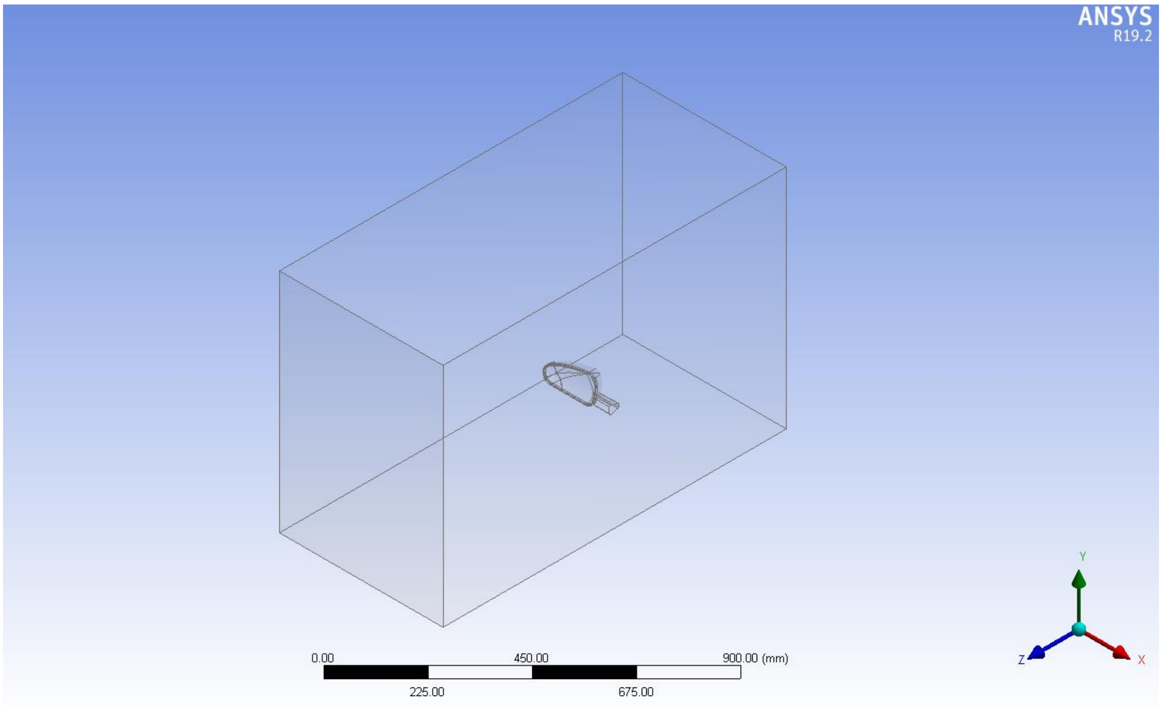

Fig. 3 - Enclosed computational domain

2.3 Meshing

The meshing used with water geometry workflow the Watertight Geometry workflow simplifies the mesh generation process, allowing all users to complete all stages of a CFD simulation, from meshing to post-processing, entirely within the same software session, in a single window user environment. A Polyhedral meshed were choose to the model. Plus, during the process of meshing, the position of inlet, outlet the wall of the model also must be determined. Fig. 4 shows the model been applied mesh before running the simulation and detail of this meshing. To get a high-quality mesh, mesh matrices must be addressed to eliminate numerical diffusion in Ansys Fluent. The incorrect answer is because the mesh itself is of low quality. Table 1 shows below, the solution's skewness and orthogonal quality for two designs. From result is may be considered good for skewness mesh and acceptable for orthogonal mesh.

Table 1 - Result skewness and orthogonal

Design	**Number of nodes**	**Skewness mesh metric**	**Orthogonal mesh-metric**
1	2555677	0.79	0.20
2	2454393	0.80	0.15

2.4 Setup

A total of three different inlet velocities (22.22, 27.79, and 33.33 m/s; 80, 100, and 120 km/h) will be evaluated to determine the drag force, maximum and minimum sound generated on the side mirror at each velocity. For this simulation, we used the SST K - Omega model, which is more appropriate for the flow region close to the wall than the K-epsilon model, which is better for the flow away from the wall. Additionally, we used the broadband noise source model to perform a decibel-level acoustic study. The decided-upon parameters are displayed in Table 2.

Table 2 - Detail parameter chosen

Parameter	**Description**
Velocity inlet, v	22.22 m/s, 27.78 m/s, 33.33 m/s
General	
Type	***Pressure- Based***
Velocity Formulation	*Absolute*
Time	*Steady*
Mesh	*Polyhedral*
Model	
Viscous	SST K-Omega
Acoustics	Broadband Noise Sources
Material	
Fluid	
Density of air,	1.225 kg/m^3
Methods	
Scheme	simple
Gradient	Least Squares Cell Based
Pressure	Second Order
Momentum	Second Order Upwind
Turbulent Kinetic Energy	Second Order Upwind
Specific Dissipation Rate	Second Order Upwind
Monitors	
Boundary walls	No slip condition
Time step	0.001
Iterations	1000
Initialization	
Methods	Standard
Turbulent Kinetic Energy	1.851482 m^2/s^2
Specific Dissipation Rate	12675 1/s

3. Results and Discussion

Validation is an important method for minimizing and measuring modelling errors and to ensure that the CFD model under consideration is a good representation of reality. Therefore, for this study, the past study was used as a guideline to validate this analysis is on the right path [10]. This study shares the same results as the new design side mirror which gave lower acoustic power level compared to existing model side mirror.

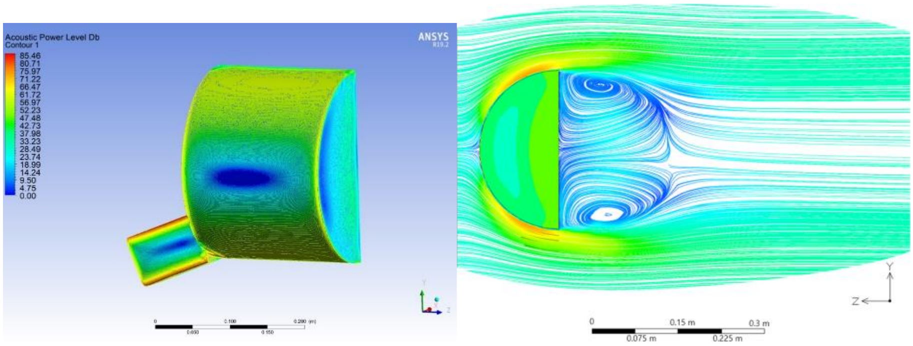

Fig. 4 - Acoustic power level contour actual model & velocity streamlines

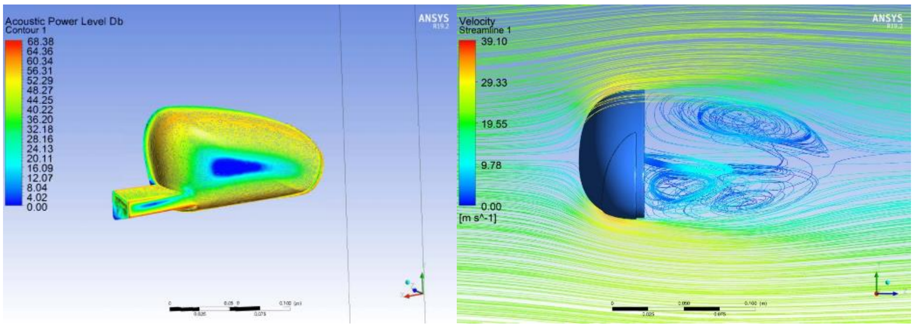

Fig. 5 - Acoustic power level contour & velocity streamlines design 1

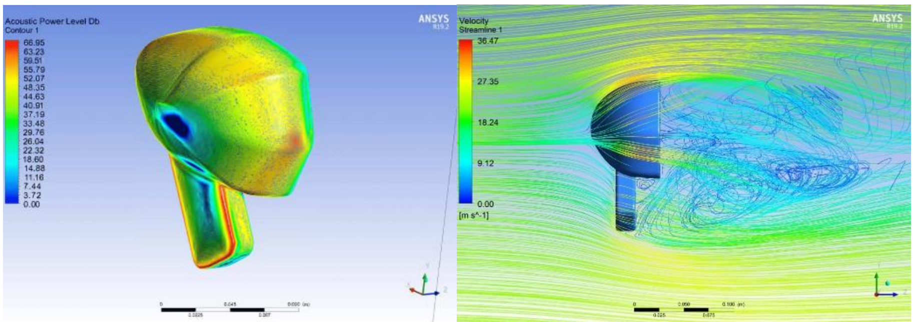

Fig. 6 - Acoustic power level contour & velocity streamlines design 2

Based on Fig. 4, Fig. 5, and Fig. 6 show CFD analysis result of the power level contour the high noise generates at the edges surface base holder part for each design this show when air flow on side mirrors the highest noise produce is at the base holder side mirror. From the velocity inlet which the fluid streamlines can be observed the streamline velocity drops abruptly on the back side of the mirror, causing a swirl. Due to the shape of the Fig. 4 actual modal and Fig. 5 design 1 has much more curvature housing compared Fig. 6 design 2 have vortex shape housing which is the stagnation points of the fluid are difference that led to the changes of velocity streamline pattern.

Table 3 - The value of acoustic power level for overall design

Design	Velocity(m/s)	Velocity(km/h)	Maximum Acoustic Power Level (dB)	Minimum Acoustic Power Level (dB)
Actual model	22.22	80	70.17	0
	27.78	100	76.62	2.34
	33.33	120	81.88	7.86
1	22.22	80	68.38	0
	27.78	100	73.80	2.27
	33.33	120	77.21	7.59
2	22.22	80	66.95	0
	27.78	100	72.20	2.15
	33.33	120	75.71	7.38

Table 3 shows the difference in maximum acoustic power level model by different velocity. Design side mirror 1 shows a middle position between the actual model being highest and design 2 being the lowest and it show for every velocity. From the result, actual model show increasing from 80 km/h to 100 km/h by 8.78% and from 100 km/h to120 km/h increasing by 6.64%. Design 1 also shows increasing from 80 km/h to 100 km/h by 7.62% and from 100 km/h to120 km/h increasing by 4.52%. This case same goes design 2 the percentage increasing from 80km/h to 100km/h by 7.55% and from 100 km/h to120 km/h increasing by 4.74%. It is seen that the air flow velocity increases gradually with increase acoustic power level. difference in minimum acoustic power level model by different velocity.

Design side mirror 1 shows a middle position between the actual model being highest and design 2 being the lowest and it show for every velocity. from the result, at 80 km/h the value of acoustic power level 0 dB for overall design because of the input air flow velocity in the study starts with 80km/h.at 100 km/h the difference minimum acoustic power level actual design model between design 1 is 3.03% and design model between design 2 is 3.50%. at 120 km/h show actual design model between design 1 is 8.46% and design model between design 2 is 6.30%. The highest acoustic power level means more noise generate as for lowest acoustic power level less noise generate.

Table 4 - The value of drag force for overall design

Design	Velocity(m/s)	Velocity(km/h)	Drag Force (N)
Actual model	22.22	80	2.49
	27.78	100	3.71
	33.33	120	5.14
1	22.22	80	2.06
	27.78	100	3.17
	33.33	120	4.52
2	22.22	80	2.91
	27.78	100	4.43
	33.33	120	6.36

Table 4 displays the result of drag actual model, design 1 and design 2 side mirror. From observation the value drag force increases gradually with air flow velocity. actual models show a middle position between design 2 being highest and the design 1 being the lowest and it show for every velocity. from the result, actual model show increasing from 80km/h to 100km/h by 39.35% and from 100km/h to120km/h increasing by 32.32%. Design 1 also show increasing from 80km/h to 100km/h by 42.44% and from 100km/h to120km/h increasing by 35.11%. This case same goes design 2 the percentage increasing from 80km/h to 100km/h by 41.42% and from 100km/h to120km/h increasing by 35.77%. it seen that the air flow velocity increase gradually with increase drag force. However, design 2 being the highest drag force course by shape design side mirror housing more width and larger compared to other.

4. Conclusion

The study focuses on CFD-based aerodynamic analysis of side mirror noise. The two types of side mirror, a Honda Civic EG9 category sedan and a Range Rover Evoque category SUV, have been compared in terms of noise using the two designs. Design 1, a sedan, produces a maximum acoustic power level of 77.21 dB when travelling at a high speed of 120 km/h. The maximum acoustic power level for Design 2 SUV cars travelling at 120 km/h is 75.71dB. In summary, design 2's side mirror has a higher acoustic power level than design 1's side mirror. The study also identifies drag force, which is the force that opposes the motion of a body that is filled with fluid. Design 1, a sedan, produces a drag force of 4.52 N at a high speed of 120 km/h. Design 2, an SUV, results in a drag force of 6.36 N at a high speed of 120 km/h. In summary, design 2's side mirror has a higher drag coefficient than design 1's side mirror. The model simulation was then examined using the Fluid flow mode of the ANSYS software. The results that can be produced by this simulation software include velocity streamlines, vector velocity, and acoustic power level, among many others. In conclusion, the sound power level can be used to predict the noise impact of a source in our new development before it is built without having to measure it. This includes sources like producing car side mirrors. If you are asked to provide noise data for something, the acoustician will always appreciate data that is provided as a sound power level.

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