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Study on Effect of Vehicle Side Mirror Base Position on Noise

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Abstract

The position of side mirrors is crucial in ensuring optimal visibility and safety during vehicle operation. Additionally, the design and placement of side mirrors can significantly impact aerodynamic and wind-induced noise generation and propagation. This study uses ANSYS, a powerful engineering simulation software, to investigate the relationship between side mirror base positioning and noise generation. The study utilizes computational fluid dynamics (CFD) simulations within the ANSYS platform to analyze the aerodynamic performance of angular and horizontal side mirror positions. By considering different mirror angles, the research aims to identify the optimal side mirror base position that minimizes noise generation while maintaining adequate visibility. To prepare for this research, a model was scanned using a 3D scanner, and the base was modified using the SolidWorks software, and the simulation ran using the ANSYS software. The ANSYS software will specify the boundary condition to execute a test with specific conditions for the new model. Three streamline velocity values (80 km/h, 100 km/h, 120 km/h) were chosen as references. The analysis results included the side mirror's acoustic contour and sound pressure level. The horizontal base produces a maximum acoustic power level of 103.41 dB when traveling at a high speed of 120 km/h. The maximum acoustic power level for the angular base, which travels at 120 km/h, is 101.48 dB. The horizontal base side mirror has a higher acoustic power level than the angular base side mirror.

1. Introduction

Side mirrors play a crucial role in safe driving, as they help drivers see vehicles and objects in blind spots. However, side mirrors can also generate noise, which can cause discomfort to passengers and affect the overall driving experience. The noise generated by side mirrors is often caused by wind turbulence around the mirror, which dominates when traveling at high speeds. A major contributor to the interior noise of a vehicle is the high-speed airflow separation from the mirror surface, which causes severe pressure fluctuations on the side window. The study of acoustics produced by air interacting with an object is known as aeroacoustics. Laminar airflow striking an object causes it to become turbulent with air vortices [1]. Due to the fluctuating pressure created by the vortices, nearby objects shake and produce noise. Additionally, noise is produced by the airflow vortices [2] and is transferred through various passageways and areas of the structure; it may also pass through cracks and leaks in sealings and openings [3]. Vehicles include sound absorption packages to lessen interior noise. However, these packages are hefty and can only tolerate a limited number of frequencies or amplitudes. The A-pillar and side mirrors, which are positioned closest to the driver, are the most significant noise sources [4]. The A-pillar and side mirrors form a turbulent wake structure that causes the surrounding vehicle windows to vibrate, which causes noise that is quite close to the driver's ears and detracts from the comfort and quality of the ride. Even though the wheels generate loud noise levels, they are far away from the passengers in most vehicle designs, which negates the effect [5].

2. Methodology

The methodology involved a multi-step process starting with the 3D laser scanning of the vehicle's original side mirror Mazda 3 2012. The data was then integrated into SolidWorks to modify the mirror's angle base. The redesigned mirror was analyzed using ANSYS software to simulate noise generation. Through meshing [6], setting appropriate boundary conditions [7][8], and running simulations, we were able to observe variations in sound pressure levels and frequencies around the mirror. This comprehensive process enabled us to identify the design that most effectively minimizes noise for vehicle passengers.

2.1 Side mirror base model on SolidWorks

In this project, there are two types of side mirror bases that need to be compared for the test and analysis. Figure 1 and Figure 2 show the design of the side mirror base model horizontal and base model angular, respectively. The side mirror is modeled according to actual dimensions. The side mirror base is designed using the advantage modeling technique in SolidWorks software [9].

Fig. 1 *Side Mirror Base Model Horizontal in SolidWorks*

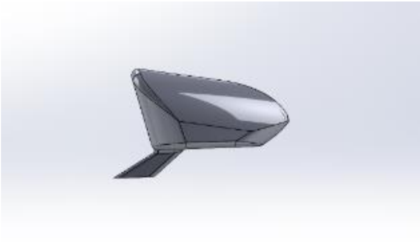


Fig. 2 *Side Mirror Base Model Angular in SolidWorks*

2.2 Geometry Model

The current optimization study used An enclosed computational domain to mimic airflow distribution across the mirror. The airflow simulation process is performed in the computational domain in Fig. 3. The airflow on the stationary mirror model and fluid flow are simulated in this optimization analysis. The mirror model is positioned 0.5 m from the air inlet in a computational domain to improve the streamlined flow visualization.

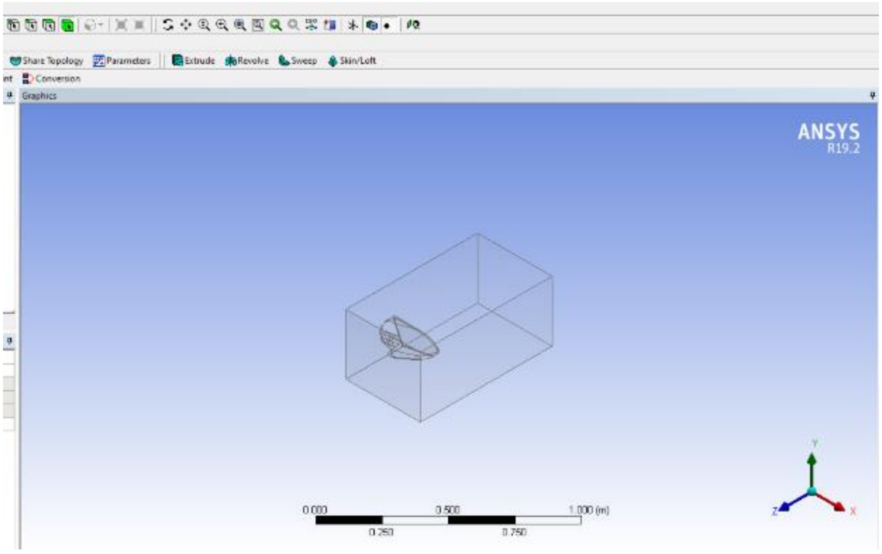


Fig. 3 *Enclosed computational domain*

2.3 Meshing

Meshing can be defined as the process of dividing the entire component into several elements. When the load is applied to the model, the load is uniformly distributed as meshing. The accuracy of the meshing quality can be achieved by setting the meshing parameter to the smaller surface. During the meshing process, the position of the model's inlet, outlet, and wall must also be determined. Fig. 4 shows the model that was applied to the mesh before running the simulation and details 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 that the mesh is low-quality (Lanfrit, 2005).

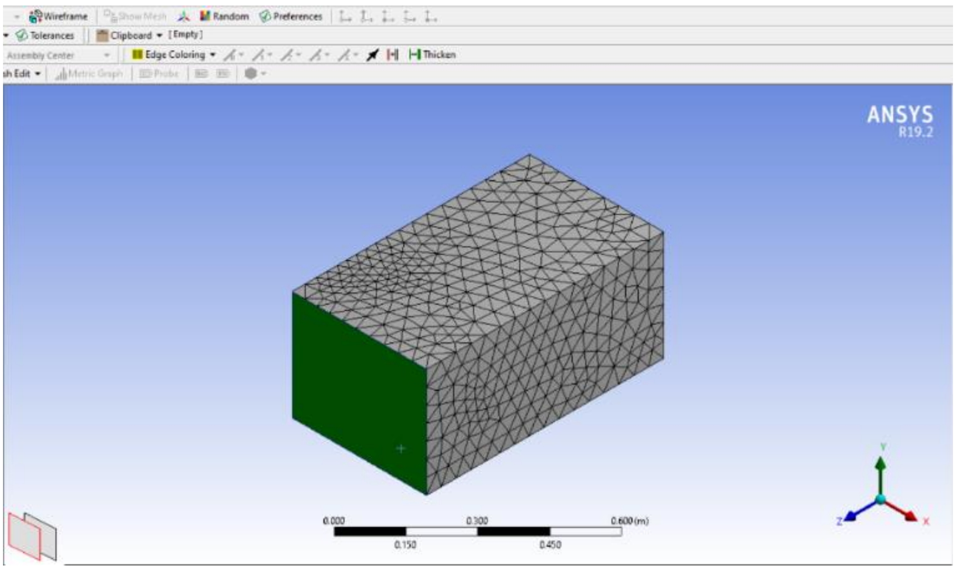


Fig. 4 *Meshing process on Ansys software*

2.4 Setup

Three different inlet velocities (80, 100, and 120 km/h) will be evaluated to determine the maximum sound generated on the side mirror at each velocity. We used the K-epsilon model for this simulation, which is better for the flow away from the wall. Additionally, we used the Ffowcs-Williams & Hawkings model to perform a decibel-level acoustic study. The decided-upon parameters are displayed in Table 1.

Table 1 *Detail for Parameter Setup*

Parameter	Description
Velocity Inlet	80km/h, 100km/h, and 120km/h
Model	
Viscous	K-epsilon
Acoustic	Ffowcs-Williams & Hawkings
Material	
Fluid	Air
Solid	Aluminum
Method	
Scheme	Simple
Gradient	Least Square Cell-Based
Pressure	Second Order
Momentum	Second Order Upwind
Turbulence Kinetic energy	Second Order Upwind
Turbulence Dissipation Rate	Second Order Upwind
Monitors	
Iteration	1000
Initialization	
Methods	Hybrid

3. Result and Discussion

Table 2 *Sound Pressure Distribution at Velocity 80 km/h*

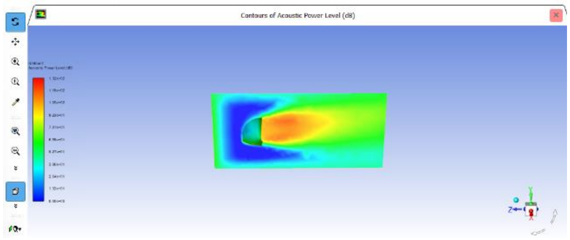
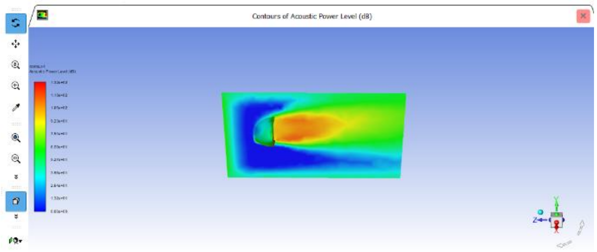
 Result for horizontal base	 Result for angular base

Table 3 *Sound Pressure Distribution at Velocity 100 km/h*

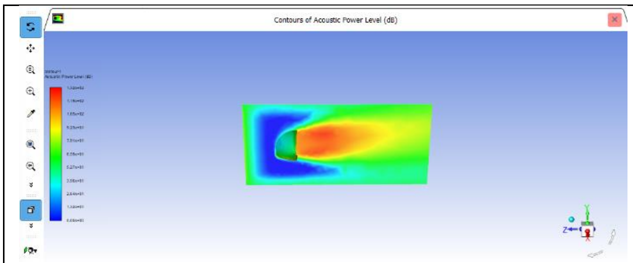
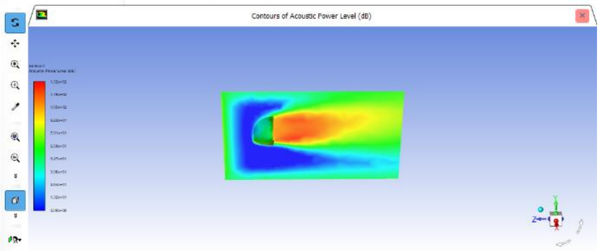
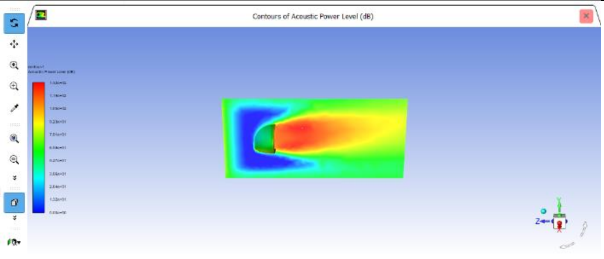
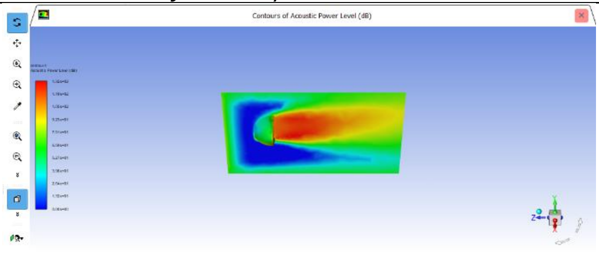
 Result for horizontal base	 Result for angular base

Table 4 *Sound Pressure Distribution at Velocity 120 km/h*

 Result for horizontal base	 Result for angular base

The contour diagrams illustrate how sound pressure spreads for each base model. Tables 2, 3, and 4 show simulation results for sound pressure distribution at a velocity of 80, 100, and 120 km/h for both horizontal and angular base models. The contour diagram for the horizontal base likely shows a pattern of sound pressure distribution. Typically, in horizontal base models, sound pressure might spread uniformly across the base, with higher intensity near the source and gradually decreasing as it moves away. The contours are expected to be more concentrated near the source, indicating higher pressure levels, and become sparser as distance increases, showing a decrease in sound pressure. For the angular base, the contour diagram showed a different pattern. The angular design might cause the sound to spread asymmetrically or be more focused in certain directions. The sound pressure contours in an angular base model could be denser in specific areas, indicating that the sound is being directed more efficiently in certain directions than others. The angular base shows a more targeted distribution, potentially making it more suitable for applications where sound directionality is important where max point on sound pressure level at angular is 97.05 dB at 80 km/h, 100.3 dB at 100 km/h and 101.48 dB at 120 km/h while max point on sound pressure level at horizontal is 100.03 dB at 80 km/h, 101.74 dB at 100 km/h and 103.41 dB at 120 km/h.

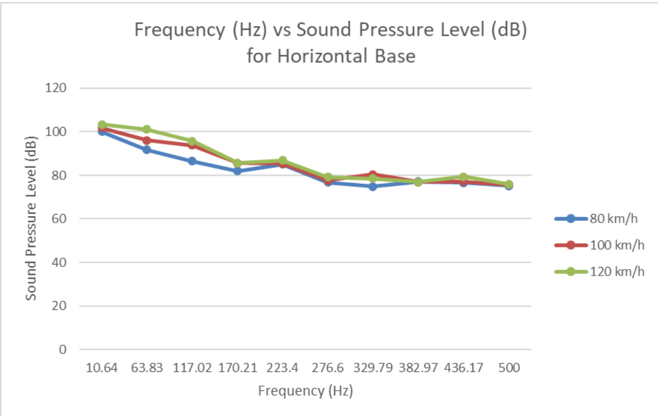


Fig. 5 *Sound Pressure Level (dB) vs Frequency (Hz) for horizontal base*

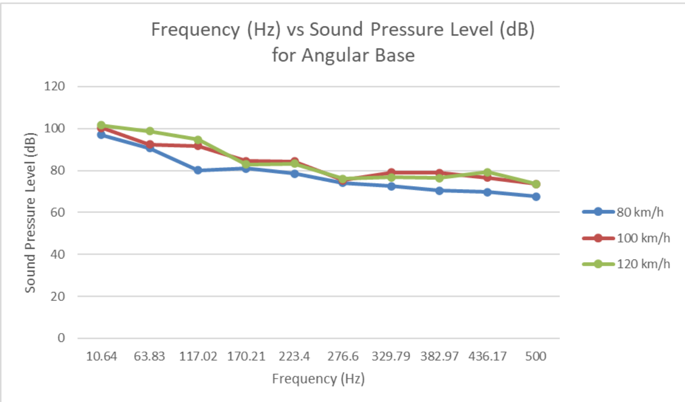


Fig. 6 *Sound Pressure Level (dB) vs Frequency (Hz) for angular base*

Figures 5 and 6 show the result data from ANSYS simulation and plotted into a graph relationship between frequency and sound pressure level in a horizontal base and angular base model at various vehicle speeds. As observed in the graph, the sound pressure level tends to decrease with the increase in frequency, although this trend is accompanied by some fluctuations. This indicates that both models produce higher sound pressure levels at lower frequencies, which gradually diminish as the frequency rises. However, the decrease is not entirely consistent. At some points, the sound pressure level stabilizes or slightly increases before continuing its downward trend.

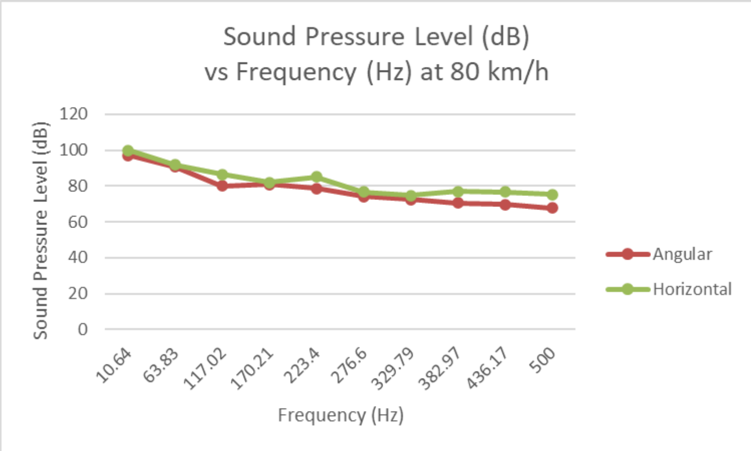


Fig. 7 *Sound Pressure Level (dB) vs Frequency (Hz) at 80 km/h*

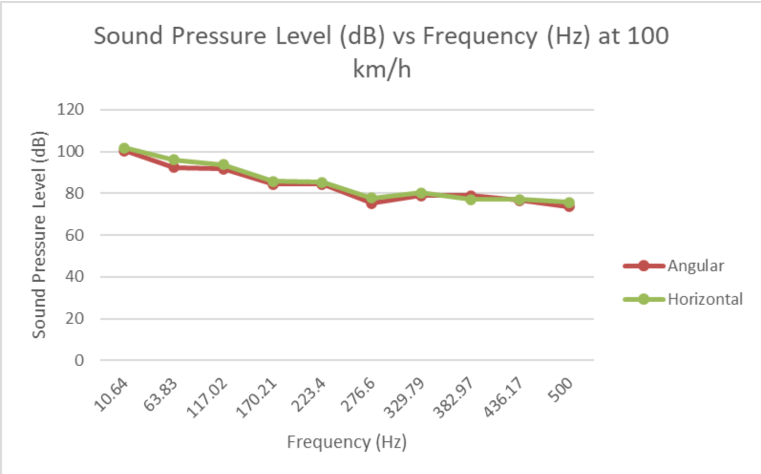


Fig. 8 *Sound Pressure Level (dB) vs Frequency (Hz) at 100 km/h*

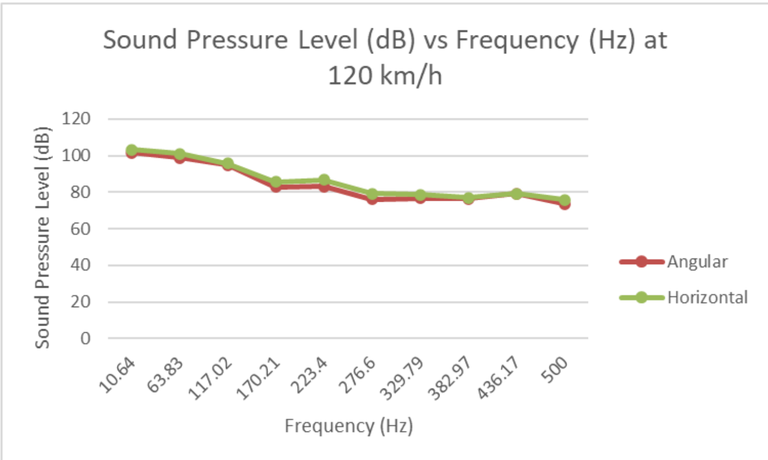


Fig. 9 *Sound Pressure Level (dB) vs Frequency (Hz) at 120 km/h*

Figures 7, 8, and 9 show comparison sound pressure levels (SPL) for vehicles with different side mirror bases (angular and horizontal) at different speeds (80, 100, and 120 km/h) across a frequency range of 10 to 500 Hz. It reveals that horizontal bases tend to have higher SPLs at lower frequencies. A key observation is the peak SPL at the lowest frequency (10.46 Hz), where horizontal bases consistently show higher levels than angular ones.

Table 4 *Value Sound Pressure Level for Horizontal and Angular Base*

Base Model	velocity (km/h)	Frequency (Hz)	Maximum Sound Pressure Level (dB)
Horizontal	80	10.64	100.03
	100	10.64	101.74
	120	10.64	103.41
Angular	80	10.64	97.05
	100	10.64	100.3
	120	10.64	101.48

Table 4 shows the difference in the maximum sound Pressure Level model with different velocities. The horizontal base side mirror exhibits the highest velocity, while the angular base side mirror displays the lowest velocity. For the horizontal base, the sound pressure level was measured at 100.03 dB at 80 km/h. The sound pressure levels increased to 101.74 dB and 103.41 dB, respectively, at 100 and 120 km/h. So, from 80 km/h to 100 km/h, it increased by 1.71%, and from 100 km/h to 120 km/h, it increased by 1.64% for the horizontal base. For the angular base, the sound pressure level was measured at 97.05 dB at 80 km/h. The sound pressure levels increased to 100.3 dB and 101.48 dB, respectively, at 100 and 120 km/h. So, from 80 km/h to 100 km/h, it increased by 3.35%, and from 100 km/h to 120 km/h, it increased by 1.14% for the angular base. This suggests that, in the horizontal model, there is a direct relationship between the vehicle's speed and the sound pressure level, with faster speeds translating into higher sound pressure levels (Nik Muhammad Jafni Jamaludin, 2022).

4. Conclusion

In conclusion, the objective of this simulation study was to evaluate the study that was carried out to assess how side mirror base orientation affects noise generation. With the aid of computational fluid dynamics (CFD) analysis using ANSYS software, the study successfully analyses the aerodynamic performance of angular and horizontal side mirror arrangements. The results show that side mirror location and angle significantly impact the production and spread of wind- and aerodynamic-induced noise. According to the study, the angular base usually produces lower noise levels than the horizontal position, and clear differences in noise levels were found between the two orientations. According to this, improving side mirror design can significantly lower vehicle noise and enhance vehicle performance and passenger comfort. In addition, this work establishes a foundation for future investigations into aerodynamic vehicle design solutions, highlighting the significance of side mirror placement in automotive engineering.

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