# Flow Visualization of Intake Manifold Aerodynamics

## Introduction

The efficient intake of air into an internal combustion engine is a critical factor influencing its performance and fuel economy. The intake manifold plays a pivotal role in this process by distributing the incoming air to the engine's cylinders. Understanding the complex flow dynamics within the intake manifold can lead to design optimizations that enhance engine efficiency.

This report presents a detailed analysis of a flow visualization experiment conducted on a 2D model of a car intake manifold. The experiment aimed to visualize the flow patterns and identify potential areas of flow separation and vortex formation. By employing a combination of physical modeling, flow visualization techniques, and video analysis, this study provides valuable insights into the intricate flow phenomena within the intake manifold. The resultant video of the experiment can be accessed through this link : https://vimeo.com/1024609135?share=copy

## Motivation

The primary motivation for this experiment was to gain a deeper understanding of the flow physics within a car intake manifold. By visualizing the flow patterns, we can identify potential areas of inefficiency, such as flow separation and vortex formation, which can negatively impact engine performance and fuel economy.

Specifically, the experiment focused on understanding the flow dynamics during the intake stroke when the intake valve opens, and air is drawn into the cylinder. By visualizing the flow patterns during this phase, we can identify potential areas for improvement in the design of the intake manifold, such as the shape of the intake ports and the length of the intake runners.

## Experimental Setup

## Model Construction:

A 2D model of a car intake manifold was constructed using wood and plexiglass. The model incorporated a single intake port and two cylinder ports. Two vacuum cleaners were connected to the cylinder ports to simulate the pressure differential between the intake and exhaust strokes.

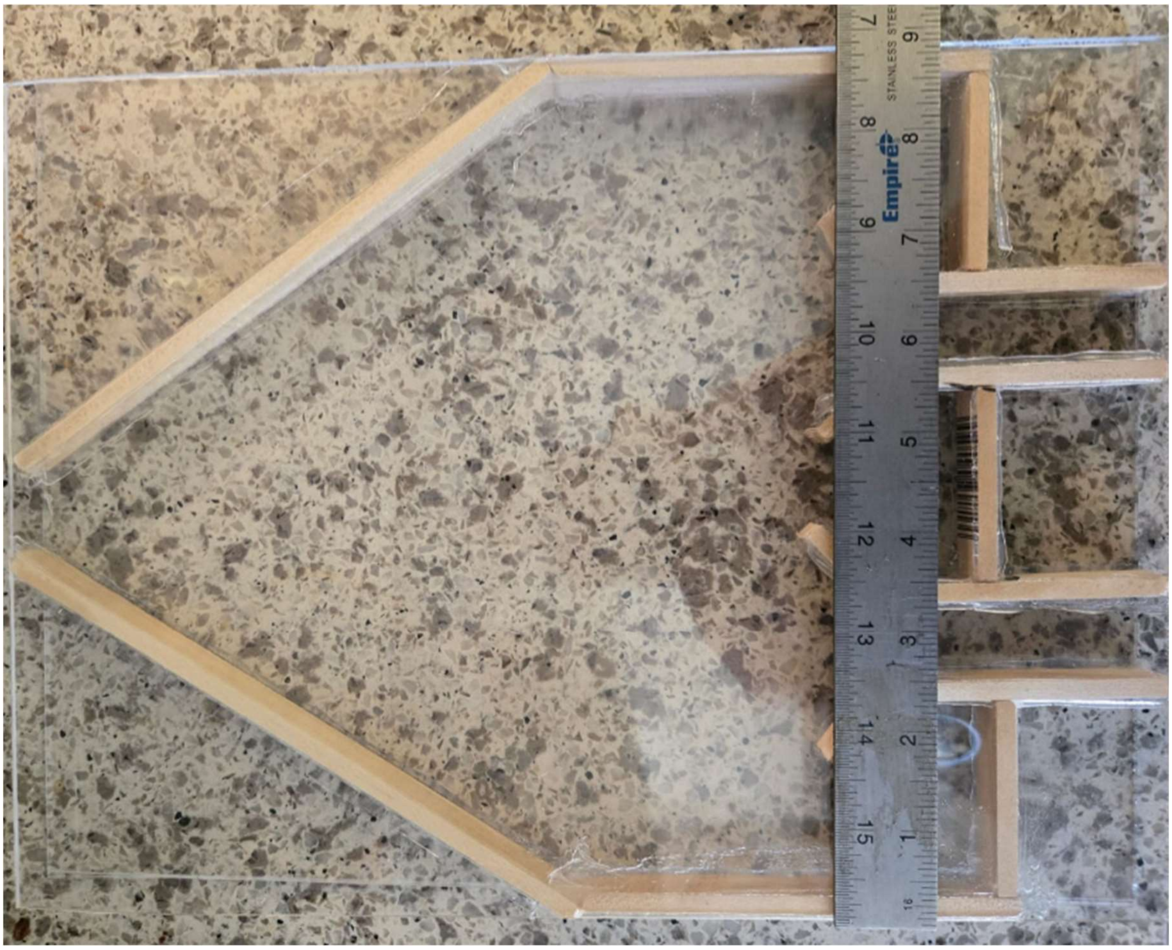

*Figure 1 Reference scale image*

## Flow Visualization Technique:

To visualize the flow patterns, the technique of smoke flow visualization was employed. Dry ice was used to generate a visible smoke that could be introduced into the intake manifold through the intake port. The smoke particles follow the flow streamlines, making the flow patterns visible to the naked eye.

## Video Recording:

A Canon M50 Mark I camera equipped with a Canon 50mm 1.8 prime lens was used to capture the flow visualization experiments. The camera was set to a high frame rate of 120 frames per second to capture the rapid changes in the flow patterns.

## Flow Physics and Observations

## Shear Flow and Vortex Formation:

One of the key phenomena observed in the experiment was the formation of shear flow and vortices. When one cylinder switches from the intake to the exhaust phase, a pressure differential is created between the two cylinders. This pressure gradient drives the flow of air from the high-pressure cylinder to the low-pressure cylinder. The rapid change in flow direction and velocity leads to the formation of a shear layer between the two regions of flow.

Within this shear layer, vortices can form due to the instability of the flow. These vortices can significantly impact the flow distribution within the manifold, leading to increased turbulence and pressure losses.

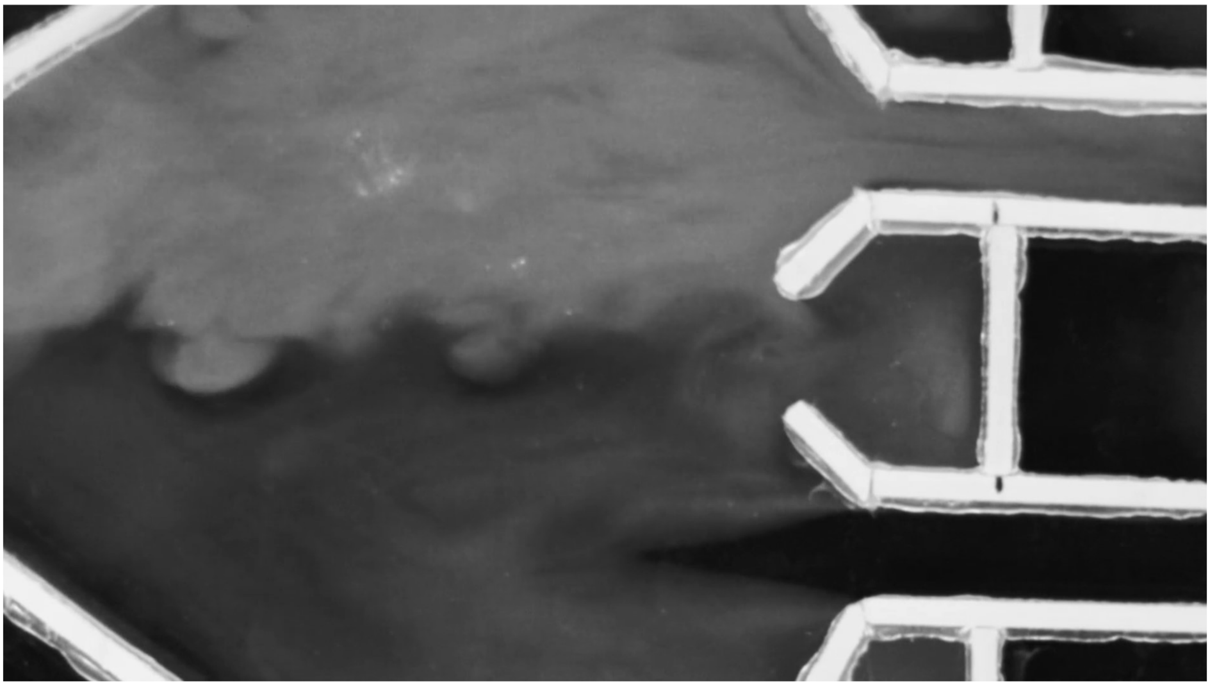

*Figure 2 Vortex formation in shear layer*

## Flow Separation:

Flow separation can occur at sharp corners and sudden changes in geometry within the intake manifold. This can lead to a reduction in flow velocity and increased pressure losses. By understanding the flow patterns and identifying regions of flow separation, designers can optimize the geometry of the intake manifold to minimize these losses.

## Post-Processing and Analysis

Post-production editing was performed using Adobe Premiere Pro. The videos were slowed down to 24 frames per second to facilitate detailed analysis of the flow patterns. Additionally, color grading was applied to the videos to enhance the contrast between the smoke and the background, making the flow patterns more visible.

Frame-by-frame analysis of the videos allowed for a quantitative assessment of the flow parameters, such as velocity and vorticity. This analysis can provide valuable insights into the underlying physics of the flow and help identify potential areas for improvement in the design of the intake manifold.

## Conclusion

The flow visualization experiment provided valuable insights into the complex flow dynamics within a car intake manifold. The formation of shear flow and vortices was observed during the intake stroke, which can significantly impact the efficiency of the intake process.

To optimize the design of intake manifolds, it is essential to minimize flow separation and vortex formation. This can be achieved by carefully designing the shape of the intake ports, the length of the intake runners, and the overall geometry of the manifold.

Future research could explore the impact of different intake manifold designs on flow patterns and engine performance. Additionally, computational fluid dynamics (CFD) simulations can be used to complement experimental studies and provide a more comprehensive understanding of the flow physics within the intake manifold.

## Acknowledgements

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## References

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2. **White, F. M.** (2011). Fluid Mechanics. McGraw-Hill Education.