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INTAKE MANIFOLD DESIGN: A KEY FACTOR IN OPTIMIZING SPARK IGNITION ENGINE PERFORMANCE

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ABSTRACT
This review investigates the influence of intake manifold design on spark ignition (SI) engine performance. Minimizing pressure drop within the manifold is crucial for efficient combustion and improved power output, torque, and fuel economy. Studies confirm the effectiveness of design strategies like increased valves per cylinder and multi-point fuel injection systems. Beyond pressure drop, runner length, diameter, and angle are key design considerations. Strategically designed runner lengths and larger diameters enhance performance, while variable-length intake manifolds offer an intriguing approach for optimization across engine speeds. The intake manifold angle significantly impacts performance in port-fuel injection systems, with a 150-degree angle demonstrating improvements over a standard 90-degree configuration. Overall, this review emphasizes the importance of optimizing intake manifold design configurations to achieve peak engine performance and lays the groundwork for future research into the combined effects of these design elements and the exploration of novel materials and manufacturing techniques.

KEYWORD
spark ignition (SI) Engine Performance, intake manifold, pressure drop

INTRODUCTION
The spark ignition (SI) engine remains a cornerstone of modern transportation, renowned for its efficiency in converting fuel combustion into mechanical work. This intricate system's intake manifold is critical, directly influencing engine performance, fuel consumption, and emission characteristics. Acting as a conduit for air, the intake manifold channels air from the engine's filtration system toward the cylinders. However, the design of this passage is not merely a passive pathway; it significantly impacts the pressure and flow behaviour of the incoming air charge.

An optimally designed intake manifold minimizes pressure drop throughout the system. This ensures a consistent and sufficient air supply for efficient combustion within the cylinders, directly translating to improved engine performance metrics such as power output, torque, and fuel economy. Prior research has established the intricate relationship between intake manifold design and engine performance. Studies have explored the correlation between intake manifold runner length and volumetric efficiency, a key parameter influencing engine power (Milkweed & Khalane, 2015). Furthermore, investigations into intake manifold angle for port-fuel injection (PFI) systems have revealed the potential for substantial gains in power output, fuel efficiency, and emission characteristics (Faisal Hushim et al., 2016; Hushim et al., 2015).

Despite these valuable contributions, a gap remains in our understanding of optimizing intake manifold design to achieve peak engine performance. This review aims to address this gap by examining the impact of intake manifold design on engine performance, with a particular focus on pressure drop and configuration. By analysing the existing literature and recent advancements in intake manifold design, this review seeks to provide an understanding of how different design parameters influence engine performance metrics such as power output, torque, fuel economy, and emissions. The insights gained from this analysis will contribute to the development of more efficient and high-performing spark ignition engines.

IMPACT OF PRESSURE DROP ON ENGINE PERFORMANCE

Pressure drop within the intake manifold plays a significant role in engine performance. A well-designed intake manifold minimizes pressure drop between the throttle body and the cylinders, ensuring a consistent and sufficient air supply for efficient combustion. Studies have shown that a reduction in pressure drop can be achieved through various strategies, including increasing the number of valves per cylinder, employing multi-point fuel injection (MPFI) systems (Jagtap et al., 2011), and optimizing plenum design (Pranoto et al., 2022). These design improvements promote better volumetric efficiency across all cylinders, increasing power output and fuel economy. Research by (Dziubak & Karczewski, 2022) further highlights the importance of minimizing pressure losses. Their findings demonstrate that even a slight increase in air filter pressure drop can negatively impact engine performance by reducing power output and increasing fuel consumption.

Similarly, (Mamat et al., 2009) observed a decline in engine efficiency and higher fuel consumption for both biodiesel and diesel fuels when the pressure drop within the intake manifold increased. These studies collectively emphasize the importance of designing and maintaining an intake system that minimizes pressure losses to achieve optimal engine performance and fuel economy. Furthermore, investigations into alternative fuels by (Saaidia et al., 2024) and the impact of intake pressure on combustion characteristics by (Sarangi et al., 2020) suggest that a well-designed intake manifold can improve performance even for engines utilizing alternative fuels and those operating under high exhaust gas recirculation (EGR) conditions. These findings underscore the critical role of pressure drop in optimizing engine performance across various operating scenarios.

INTAKE MANIFOLD DESIGN CONFIGURATION THAT AFFECTS THE ENGINE PERFORMANCE

A well-designed intake manifold significantly influences engine performance by optimizing air-fuel mixture delivery. Studies have shown that a strategically designed runner length, like a 160mm configuration (Liang et al., 2024), can enhance brake power. Intake manifold diameter also plays a critical role, with larger diameters (up to 60mm) promoting airflow and boosting torque (Liang et al., 2024). Variable-length intake manifolds offer an intriguing approach, dynamically adjusting runner characteristics for optimal performance across various engine speeds (Talati et al., 2022). For port-fuel injection systems, the intake manifold angle significantly impacts engine performance. A 150-degree angle, compared to a conventional 90-degree configuration, has been shown to increase brake power and reduce emissions (Hushim et al., 2015). This is likely due to improved in-cylinder air-fuel mixture distribution. Research also suggests that larger bend angles (around 180 degrees) promote superior airflow velocity within the manifold (Faisal Hushim et al., 2016), potentially benefiting engine efficiency. In conclusion, optimizing intake manifold design through runner length, diameter, and angle is crucial in achieving optimal engine performance.

CONCLUSION

In conclusion, this review elucidates the critical role of intake manifold design in optimizing spark ignition (SI) engine performance. Significant improvements in power output, torque, fuel economy, and emissions can be achieved by strategically incorporating design features that minimize pressure drop and optimize runner length, diameter, and angle. Future research should focus on exploring the synergistic effects of these configurations and investigating advanced materials and manufacturing techniques for intake manifolds. This approach can unlock further performance enhancements, propelling the development of high-performance and fuel-efficient SI engines.

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