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# Optimizing the Performance of SI Engine with Velocity Stack

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## ABSTRACT

*Improving the performance of a spark ignition (SI) engine aims to enhance the efficiency of the engine through various modifications or changes. One way to enhance the performance of an SI engine is by modifying the air intake system with the addition of a velocity stack to increase the airflow into the engine. This study conducted direct experiments on a 150cc SI engine, measuring power and torque, to examine the effects of using a velocity stack. The research results indicate improvements in engine performance with the use of a short velocity stack, resulting in a 6.2% increase in power and a 6.4% increase in torque. Meanwhile, the use of a long velocity stack increased power by 9.3% and torque by 11%. The characteristics of using a long velocity stack provide rapid acceleration and high torque at low to mid-range RPM compared to using a short velocity stack, which is more responsive to torque at higher RPM, enabling the engine to reach its maximum top speed. The use of a velocity stack improves volumetric efficiency, thus significantly influencing engine performance enhancement.*

***Keyword:*** *SI engine, Performance Improvement, Velocity Stack*

## INTRODUCTION

Enhancing the performance of spark ignition (SI) engines is a widely pursued goal that can be achieved through various approaches. Among these techniques are alterations to the cylinder diameter [1] and the incorporation of fuel additives that impact both exhaust gas emissions and volumetric efficiency [1][2][3][4], and the substitution of traditional fuels with alternative substances such as gas or liquefied petroleum gas [5]. It is essential to note, however, that these modifications can have significant effects on the engine, including increased temperatures, adjustments to the fuel system configuration, and possible performance decreases if not implemented properly. In addition to these more complex modifications, there are simpler ways to improve engine performance, such as installing an open filter or modifying the induction system. The purpose of such modifications is to maximize the engine's volumetric efficiency [6].

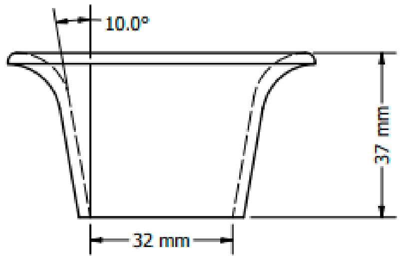
Modifying the air intake is an effective way to enhance a vehicle's performance during dynamic events. Air intake systems deliver air to the throttle body, where it is mixed with fuel and directed to the combustion chamber [7][8]. Among the crucial components for optimizing performance in a gasoline engine is the intake manifold. This manifold ensures the delivery of fresh air to the internal combustion engine, significantly impacting both engine performance and emissions. Uneven distribution of air leads to uneven power production, resulting in increased engine vibrations [9]. In the design of commercial engines, an airbox is commonly integrated to draw air from the atmosphere. This airbox consists of an air filter, intake pipe, plenum, and intake runners. Within the engine, the inlet manifold is responsible for supplying the fuel/air mixture to the cylinders. Its essential function is to equitably distribute the air-fuel mixture to each cylinder head intake port. Obtaining uniform gasoline distribution is crucial for optimizing engine performance and efficiency. In addition, the intake manifold can accommodate additional engine components such as the carburetor, throttle body, and fuel injectors [10][11]. Flow within the intake manifold, which includes compression waves, has a significant impact on engine performance and permits empirical estimation of the desired torque curve. The amount of air and fuel entering the cylinder has a direct effect on engine performance, with a higher air mass flow rate enhancing the engine's volumetric efficiency and resulting in increased torque and output power. Consequently, optimizing the intake manifold's design and airflow characteristics is essential for maximizing engine efficiency and attaining superior performance. By assuring proper distribution of the air-fuel mixture and capitalizing on compression waves within the intake manifold, engineers can enhance the engine's breathing capabilities and optimize its torque and power output.[12][13][14].

The volumetric efficiency of an engine is a performance metric that measures its ability to draw in air. It is frequently referred to as the engine's lung capacity. The amount of air-fuel mixture that can be inducted into the cylinders of an engine directly impacts the power generated by the engine. A plate restricts the ventilation at the intake during throttling, resulting in a decrease in pressure. In standard spark ignition (SI) engines, the throttle-based air control system utilizes approximately 10 percent of the input energy to pump air [15]. The enhancement of volumetric efficiency has been pursued through several approaches, such as modifying the geometry of the intake valve [15], adding intake tromp cyclones with computational analysis [16], and utilizing them as references in a study focused on improving the performance of SI engines through the addition of a velocity stack to the throttle body air intake [16]. Several researchers have also analyzed the structure of the intake pipe in automobiles and the airflow[17][18][19], which is used as a reference in this investigation. The objective of the conducted research was to investigate the effects of employing velocity stacks with different dimensions on the torque, power, and volumetric efficiency of SI engines.

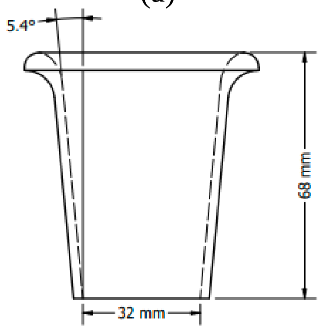
## MATERIAL AND METHODS

### *Preparation*

In this research, two different types of velocity stacks were utilized to compare the engine performance outputs. The velocity stacks used in the study are shown in Figure 1, with (a) the short velocity stack (Velo S) and (b) the long velocity stack (Velo L). The objective of this comparison is to analyze and evaluate the impact of these distinct velocity stack designs on the overall performance of the engine.




(a)




(b)

*Figure 1 (a) The short velocity stack (b) the long velocity stack*

The short velocity stack features an inlet diameter of 32 mm and a length of 37 mm, with an outlet inclination of 10˚. In comparison, the long velocity stack has an inlet diameter of 32 mm, a length of 68 mm, and an outlet inclination of 5.4˚. The velocity stack designs were created using CAD software, ensuring that the dimensions and sizes were tailored to match the diameter of the throttle body used in the engine under testing. The ABS material was chosen for constructing the velocity stacks, taking into consideration its strength and low cost material, utilizing the 3D printing technique [20]. This enabled precise fabrication of the velocity stacks according to the specified dimensions and ensured their suitability for the experimental setup.

A motorcycle engine manufactured by a renowned Japanese company was carefully chosen for evaluation. The specific engine model utilized in the research is identified as the K56, with a displacement capacity of 149.16 cc. It is crucial to emphasize that the engine employed for this study is meticulously maintained, ensuring its optimal performance and reliability. Detailed information regarding the essential characteristics of the engine is comprehensively presented in Table 1, offering a comprehensive overview for reference and analysis.

*Table 1 Engine Specification*

| NO | ITEM | SPECIFICATION |
|---|---|---|
| 1 | Stroke Type | 4 Stroke, DOHC – 4 Valve |
| 2 | Engine Volume | 149.16 cc |
| 3 | Fuel System | PGM-FI |
| 4 | Bore x Stroke | 57.3 x 57.8 mm |
| 5 | Transmission Type | Manual, 6 Speed |
| 6 | Compression Ratio | 11.3 : 1 |
| 7 | Power | 15.8 HP / 9000 RPM |
| 8 | Torque | 13.5 Nm / 6.500 RPM |
| 9 | Coolant System | Liquid Cooled with Auto fan |

The engine is a single-cylinder sport-type engine featuring a DOHC 4-valve mechanical cylinder head system. According to the manufacturer's specifications, the K56 engine demonstrates notable attributes such as swift acceleration and the ability to generate substantial torque at lower to medium engine revolutions per minute (RPM).

***Measurement Tools***

A dynamometer is a precision instrument designed to accurately measure the torque, force, or electrical output generated by a rotating shaft. The rotational speed of the shaft is typically determined using a tachometer, while the turning force or torque exerted by the shaft is quantified through the use of a scale or other measurement techniques. The power output, either directly observed through the instrumentation or calculated based on the combined measurements of shaft speed and torque, provides valuable insights into the performance characteristics of the system under analysis. Primarily employed for the measurement of force or power, particularly in the context of mechanical power, such as that produced by a motor, a dynamometer plays a vital role in assessing and understanding the operational efficiency and capabilities of various engines and machinery. Its versatility extends beyond mechanical power, as it can also be utilized to measure and analyze electrical power and other relevant parameters. The utilization of a dynamometer in research, experimentation, and performance evaluations ensures accurate and comprehensive assessments, facilitating advancements and optimizations in diverse fields of engineering and technology [21]. The dynamometer utilized depicted in Figure 2 below.


*Figure 2 Dynamometer*

An anemometer can be utilized to determine the air velocity and volume entering the intake manifold. Anemometers are frequently employed for measuring the velocity of air or gas at room temperature and calculating the volumetric flow rate in a wide range of applications, including ventilation systems in mines, air or gas control systems in factories, intelligent agricultural systems, and meteorological measurements. The sensing element of an anemometer is a rotor with vanes whose rotational speed is directly proportional to airflow velocity. This form of anemometer is characterized by its portability and user-friendliness in comparison to other models. In physics classrooms and laboratories, it is useful for demonstrating the principles of Bernoulli's theorem and conducting experiments involving the measurement of wind velocity [22]. The type of anemometer used in this research is indicated by Figure 3.


*Figure 3 Vane Anemometer*

***Formulations***

To determine the effect of the penstock angle on the power and efficiency of the turbine is to use several equation solutions. To find the power on the generator, use the following equation.

$$P = \frac{2\pi . n . T}{6000} \quad \text{.....(1)}$$

Where $P$ is power of performance (HP), $n$ is the revolution of engine speed (RPM), and $T$ is Torque of engine (N.M).

$$T = F \times s \quad \text{.....(2)}$$

Where *T* is torque of engine (N.m), *F* is Centrifugal force (N). *s* is adistance (m).

$$\eta_v = (m_{af} \cdot nr) / (\rho_a \cdot V_d \cdot N_e) \text{…..……..(3)}$$

in which ηv is volumetric overall performance (%), maf is mass air glide (g/s), ρa is consumption air density (kg/m3), Vd is amount of the engine (cm3), Ne is the revolution engine speed (RPM).

## RESULTS AND DISCUSSION

The primary aim of this study was to evaluate the effects of velocity stack on the overall performance characteristics of the K56 engine. This investigation employed direct experimental techniques conducted directly on the engine itself to gather empirical data and assess the direct influence of the velocity stack. The research sought to determine how the presence and design of the velocity stack affected various performance metrics, including power output, torque generation, and overall engine efficiency. Through the utilization of rigorous experimental methods, this study aimed to provide valuable insights into the optimal implementation of velocity stacks in the K56 engine for enhanced performance and improved overall functionality.

### *Engine Performance*

Using a dynamometer, the power generated by the K56 engine when various velocity stacks are utilized was determined. Figure 4 depicts the power output attained with the implementation of a short velocity stack during the testing phase.

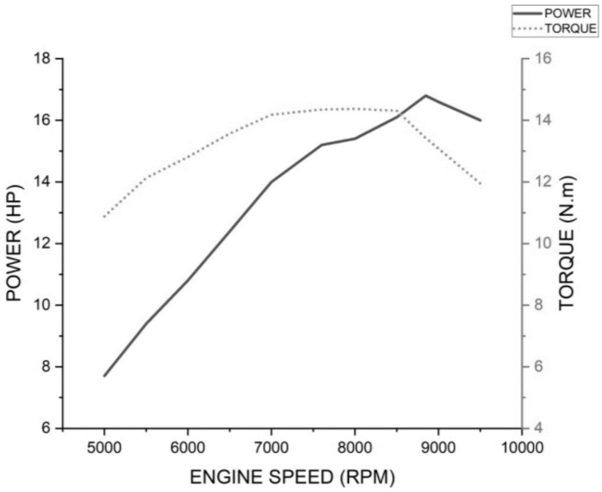



*Figure 4 Engine Performance using a Velo S*

The output of the dynamometer has been recorded with the results of power and torque testing utilizing a brief velocity stack between 5000 and 10,000 RPM. There is a significant increase of 16.8 HP and 14.37 Nm of torque at 8847 RPM and 7600 RPM, respectively. Compared to the conventional specifications, the utilization of the short velocity stack results in a notable increase in power and torque. The torque and power are increased by 6.2% and 6.4%, respectively, compared to the standard spec.

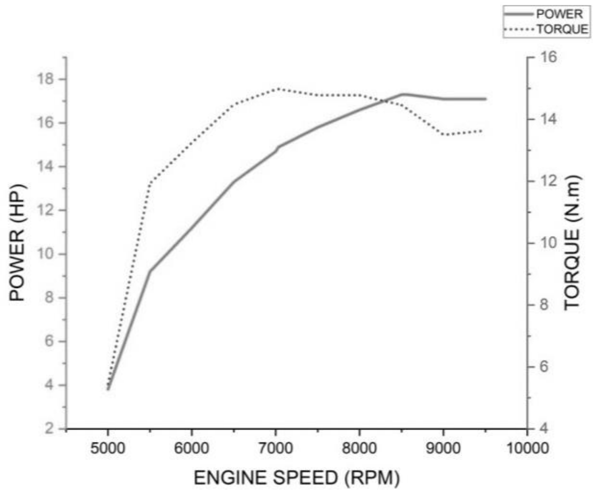



*Figure 5 Engine Performace using Velo L*

In figure 5, the results of tests conducted with an extended velocity stack demonstrate a distinct performance enhancement compared to those of previous tests. At 8565 RPM, there is a 17.3 HP increase in power, and at 7033 RPM, there is a 14.98 Nm increase in torque. Compared to the short velocity stack, the long velocity stack offers superior efficacy in terms of power and torque. In comparison to the conventional specifications, the long velocity stack increases power by 9.3% and torque by 11%. These results indicate that the use of a long velocity stack has a greater impact on enhancing engine performance in terms of power and torque than the use of a short velocity stack. This research substantially advances our understanding of the effect of these two velocity stack types on SI Engine.

The utilization of both forms of velocity stacks demonstrates distinct performance characteristics. Figure 6 depicts a comparison graph illustrating the torque relationship between the short velocity stack (Velo S) and the long velocity stack (Velo L).

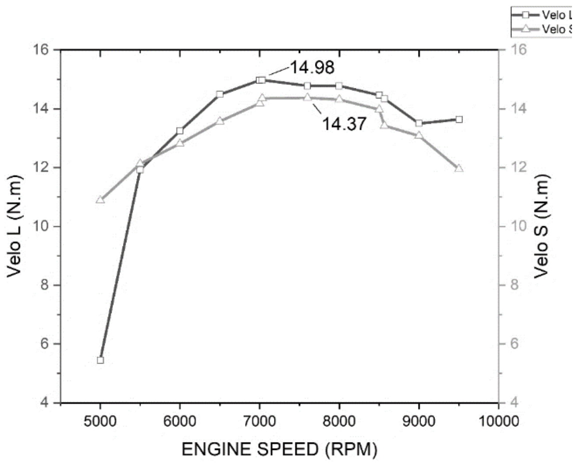



*Figure 6 The comparison of torque generated*

A shorter velocity stack exhibits a notable capability of generating substantial power output at lower engine speeds, specifically from idle up to 5000 RPM. This configuration yields a torque output of 10.8 Nm, which progressively increases with each revolution until it culminates in the maximum torque of 14.37 Nm at 7600 RPM. The implementation of a short velocity stack enhances acceleration performance, particularly during low-speed operations, owing to the considerable torque it delivers. Conversely, a longer velocity stack presents contrasting characteristics. According to the graphical representation, at 5000 RPM, the torque output merely amounts to 5.9 Nm. However, there is a significant upsurge in torque output at 5500 RPM, which further escalates during high-speed rotations. The maximum attainable torque is achieved at 7033 RPM, amounting to 14.98 Nm. In naturally aspirated engines, the point of maximum torque signifies the engine operating at its peak combustion efficiency. Consequently, lower engine speeds correspond to lower torque outputs, while higher engine speeds yield higher torque outputs [23].

The utilized engine has a high rotational limit, with a maximum speed of 10,000 RPM. During testing, it was determined that the use of a short velocity stack resulted in a significant power increase at 5,000 RPM, reaching 7.7 HP, whereas the use of a long velocity stack at the same RPM only produced 3.8 HP. Figure 7 depicts the graph illustrating the comparison of velocity stacks.

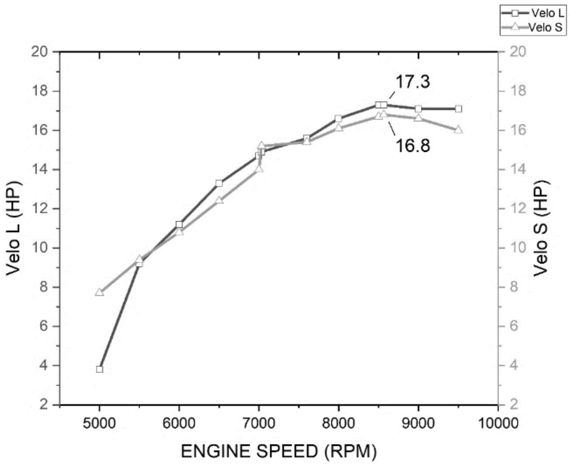



*Figure 7 The comparison of power generated*

Results from this research indicate that the utilization characteristics of velocity stacks vary according to specific requirements. By utilizing a short velocity stack, it is possible to accomplish high torque with maximum acceleration at low and mid-range RPMs. In contrast, the use of a long velocity stack is responsive to torque and power in the midrange and at high RPMs, making it suitable for attaining high maximum top speeds.

***Volumetric Efficiency***

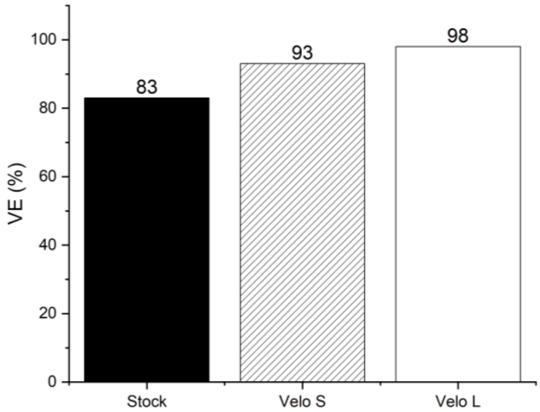



*Figure 8 Volumetric Efficiency*

Volumetric efficiency was measured under full throttle conditions. The volumetric efficiency of the standard engine without a velocity stack was found to be 83%. An increase in this value was observed when using the short velocity stack, reaching 93%, and the highest increase was achieved when using the long velocity stack, reaching 98%. The increase in air volume entering the combustion chamber is directly proportional to the generated torque [6]. The increase in volumetric efficiency observed in this engine results in high torque when using the long velocity stack, aligning with the obtained VE (Volumetric Efficiency) value. SI (spark ignition) engines, the intake airflow entering the combustion chamber often experiences fluctuations within the intake tract. The design of a velocity stack, resembling a trumpet shape, can help mitigate these flow fluctuations, thereby improving power and torque output.[24] The enhancement of volumetric efficiency is of paramount importance for modern combustion engines to achieve optimal performance, low emissions, and efficient fuel consumption [25]. Utilizing a velocity stack is equivalent to removing the air filter, resulting in a greater airflow than when using a motorcycle's conventional air filter. Eliminating the air filter significantly improves the vehicle's performance [26]. For instance, a velocity stack with specific dimensions and design can be optimized to improve airflow into the cylinder at certain RPM ranges, resulting in increased torque and power within that range. However, it's essential to note that such modifications may affect the engine's performance at other RPM ranges.

## CONCLUSION

The research findings suggest that incorporating a velocity stack can enhance the performance of a vehicle, particularly in terms of torque, power, and volumetric efficiency. When a shorter velocity stack is employed, the vehicle exhibits rapid acceleration, resulting in a 6.2% increase in power and a 6.4% increase in torque compared to the standard specifications. On the other hand, utilizing a longer velocity stack demonstrates superior engine performance at higher RPM ranges, leading to an 9.3% power and a 11% increase in torque. Furthermore, the implementation of velocity stacks improves volumetric efficiency, with the shorter stack achieving 93% efficiency and the longer stack achieving 98% efficiency when full throttle conditions. Selecting the appropriate velocity stack should be based on the specific requirements and characteristics of the engine to be used.

## DECLARATION OF COMPETING INTEREST

The authors counseled no capability conflicts of hobby.

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