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Assessment of Power and Torque Delivery Profiles in a Small-Displacement Engine Following Bore Modifications

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Abstract

This project focuses on the repair, calibration, and performance evaluation of a motorcycle chassis dynamometer to ensure accurate and reliable engine testing, specifically for the Yamaha Y15ZR. The dynamometer initially exhibited mechanical wear, sensor malfunctions, and calibration drift, resulting in inconsistent torque, power, and RPM readings. Through systematic troubleshooting and covering mechanical realignment, electrical repairs, and sensor recalibration in the system was restored to proper working condition. A calibrated testing setup was then used to establish baseline engine performance data, followed by comparative tests using two different flat-top ceramic pistons (57 mm and 63mm). The use of ceramic pistons, known for high thermal resistance and low heat conductivity, allowed the study to examine variations in combustion efficiency, heat transfer characteristics, and emission behaviour across different piston sizes. Preliminary results show improved combustion stability and measurable changes in power output and exhaust temperature corresponding to piston diameter. Overall, this project provides a functional dynamometer platform and meaningful insights into how piston geometry and material influence motorcycle engine performance, supporting future tuning, research, and development efforts.

1. Introduction

Small-capacity spark-ignition engines have long dominated the motorcycle landscape across Asia, serving as the primary mode of personal transportation for millions due to their manoeuvrability and fuel efficiency. As global petrol prices continue to fluctuate and rise, the reliance on these economical personal vehicles has surged, making them an indispensable asset for daily commuting and commercial logistics. To enhance performance without the substantial financial burden of purchasing a new, higher-displacement motorcycle, many users have turned to the aftermarket for performance-enhancing modifications. Among the most prevalent of these upgrades is replacing the factory cylinder block and piston assembly with larger-bore variants to increase displacement and power. This study was specifically conducted to verify the efficiency and real-world performance gains of these common block and piston dimension modifications, utilizing chassis dynamometer testing to provide a data-driven assessment of their impact on engine output.

The differences in piston shapes—such as flat-top, dome-top, and bowl shapes—directly affect critical combustion variables, including air turbulence, flame speed, and heat transfer. These factors subsequently influence overall engine performance, fuel consumption, and emissions. While significant research has focused on improving fuels, injection technologies, and ignition systems, the relationship between piston geometry and the ignition process remains not fully understood. Additionally, the impact of piston size on heat transfer within the cylinder, which plays a crucial role in managing thermal losses and peak combustion temperatures, has received limited attention.

This study aims to repair and calibrate an existing chassis dynamometer to enable accurate motorcycle tuning. It also seeks to establish baseline performance testing for a stock Yamaha Y15ZR engine and identify how tuning affects engine behaviour. Through technical maintenance and hands-on performance testing, this research contributes to a better understanding of motorcycle optimisation, providing valuable insights for engineers and enthusiasts looking to enhance engine efficiency and reliability.

Accurate evaluation of motorcycle engine performance is essential for effective tuning and diagnostics. Unfortunately, many chassis dynamometers suffer from mechanical wear, sensor errors, and calibration issues, leading to inconsistent readings and unreliable data. For instance, the dynamometer used for testing the Yamaha Y15ZR has shown irregular readings and mechanical errors that compromise performance data, making it difficult to measure torque, horsepower, and engine speed. To resolve these issues, this paper focuses on repairing and calibrating the dynamometer for precise measurements. Once operational, a series of performance tests will be conducted on a stock Yamaha Y15ZR engine. These tests will establish baseline measurements and assess tuning changes, providing reliable data to support recommendations for performance enhancement and tuning accuracy.

With growing concerns about emissions and efficiency, a significant portion of global transportation and energy generation still relies on internal combustion engines (ICEs). Current gasoline engines achieve a brake thermal efficiency (BTE) of 30-36%, while diesel engines range from 40-47%. However, some specialised research engines have exceeded a BTE of 50%, and earlier this year, a record-setting diesel engine achieved a remarkable thermal efficiency of 53.09%. One of the main factors influencing the efficiency of an ICE is the compression ratio, which measures the difference between the cylinder's maximum and minimum volumes during combustion. This ratio directly affects the engine’s efficiency in converting fuel into energy (Urbański et al., 2019). Furthermore, mechanical factors, such as the degree of lubrication between the piston skirt and the cylinder liner, play a significant role, especially under varying loads and speeds (Sun et al., 2022). Due to the complexity of ICEs, sophisticated modelling methods are required to accurately predict their combustion processes to achieve optimal performance (Stepanenko & Kneba, 2019). At the same time, it is crucial to consider the environmental impacts of ICEs, as they remain a major source of harmful emissions from fossil fuel combustion. Consequently, there is growing pressure to transition toward cleaner alternatives (Van Den Hoed & Vergragt, 2005). Hybrid systems have been proposed as a potential solution, enabling the capture of energy that would otherwise be wasted in exhaust gases and enhancing overall engine efficiency (Rares & Chiru, 2020; Chiriac et al., 2020). Additionally, using alternative fuels, such as biodiesel, is being explored not only to reduce environmental impact but also to decrease wear and tear on engine components (Okokpujie, 2024).

2. Methodology

2.1 Overview

The methodology employs a fully experimental approach comprising four main phases (see Figure 1): troubleshooting and repairing the dynamometer, calibrating the measurement systems, conducting baseline performance testing, and performing comparative testing with ceramic pistons of two different diameters (57 mm and 63 mm). All procedures were conducted in a controlled laboratory environment to ensure accuracy and repeatability. Two flat-top ceramic pistons with diameters of 57 mm and 63 mm were installed sequentially for a comparative performance analysis. For each piston size, the engine was reassembled, warmed up, and subjected to identical test procedures under controlled conditions. The same testing parameters—torque, power, RPM response, exhaust emissions, and fuel flow rate—were recorded to compare performance variations attributed to piston diameter. Experimental data were processed and analysed using statistical comparison techniques. Torque and power versus RPM were plotted for each piston size. Differences between the baseline and modified configurations were examined to determine the effects of piston diameter on combustion efficiency, heat transfer, and emission behaviour. All results were validated by comparing trends with established combustion theory and existing literature findings.

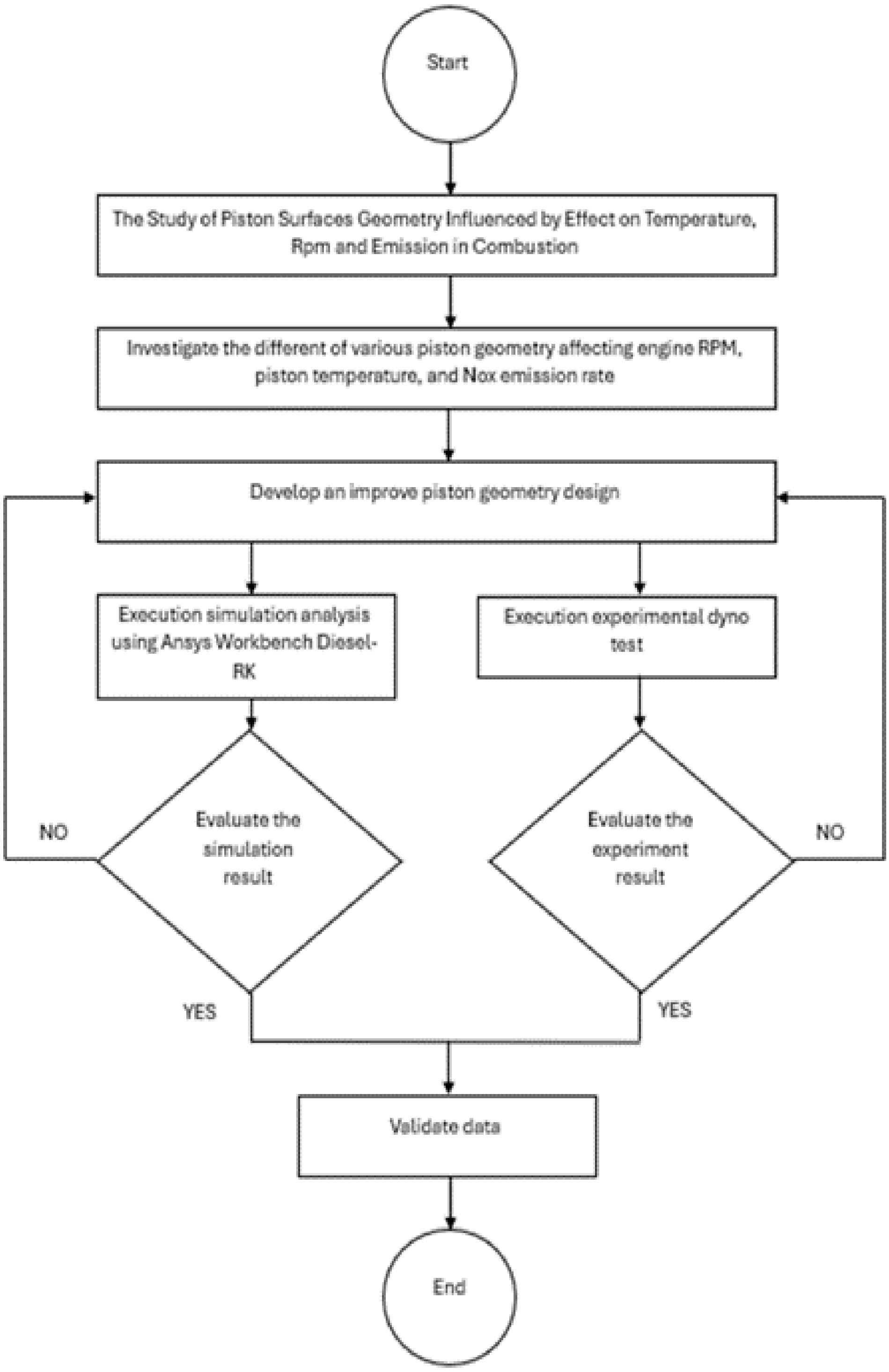

Fig. 1 *Methodology Flowchart*

2.2 Dynamometer Initial Inspection and Diagnosis

The process commences with a careful evaluation of the existing chassis dynamometer system. Manually examine mechanical parts, including rollers, shafts, bearings, load cells and belts, by sight, wear, corrosion, misalignment or damage. Electrical wiring, control units, and sensors (torque, speed, and load) are checked simultaneously using a multi-meter and diagnostic software to identify faults or abnormal signals. All abnormalities, including improper torque readings, RPM fluctuations, or software issues, are logged so they can be prioritised for repair.

2.3 Mechanical and Electrical Repairs

Based on the diagnostic results, necessary repairs are carried out. This includes replacing load cells suspected of malfunctioning. Electrical troubleshooting involves repairing or replacing faulty sensors, rechecking loose connections, and reconfiguring signal paths to eliminate noise or interference. All repairs are documented, and system safety is verified before proceeding to calibration.

2.4 Functional Testing and Data Validation

When the dynamometer is calibrated, it is tested under controlled conditions using a stock Yamaha Y15ZR motorcycle. Torque, horsepower, RPM, exhaust temperature, and emission levels are measured parameters as the vehicle makes several runs. The obtained data are then checked against established manufacturer standards to ensure that the dynamometer output is accurate. If differences occur, minor changes are made to the calibration settings.

2.5 Installation of Ceramic Pistons and Blocks

The installation of the ceramic piston and ceramic block was conducted through a fully controlled experimental procedure to ensure proper fit, alignment, and reliable engine operation during testing. The process began by allowing the engine to cool and disconnecting the battery before dismantling the Yamaha Y15ZR engine. This included removing the cylinder head, stock piston, connecting rod pin, and original block. Each ceramic piston (57 mm and 63 mm) and the ceramic block were carefully inspected for dimensional accuracy, piston-to-wall clearance, and surface integrity using precision tools such as micrometres and bore gauges. This step was crucial, as improper clearances could lead to seizure or excessive blow-by. The piston rings were then installed on the ceramic piston, with careful attention to the ring-end gaps and positioning. Next, the piston was mounted onto the connecting rod using a lubricated wrist pin and secured with circlips. The ceramic block was installed by lightly lubricating the cylinder wall and using a ring compressor to guide the piston smoothly into the bore. This ensured there was no resistance that could potentially damage the ceramic material. Once the block was seated onto the crankcase, a high-temperature gasket was fitted, and the cylinder head was reassembled using the correct torque sequence to prevent warping. The lubrication and cooling systems were refilled and checked, as ceramic components require stable thermal management. The engine was then started under controlled conditions, allowing the oil pressure to build before ignition, and a short break-in cycle was performed to ensure proper ring seating. Finally, a series of inspections, including compression testing, leak-down checks, and verification of idle smoothness, was completed before mounting the motorcycle on the dynamometer for performance evaluation.

4 Results and Discussion

4.1 Variation of the engine power with engine speed

One of the linear trends that is quite evident is that as the engine's power increased, there was a proportional increase in its speed – see Figure 2. This change in power from 7.9 kW to 8.5 kW widens the range of engine speed from 7200 RPM to 8800 RPM. That demonstrates a rather steady and expected correlation between the pair of variables.

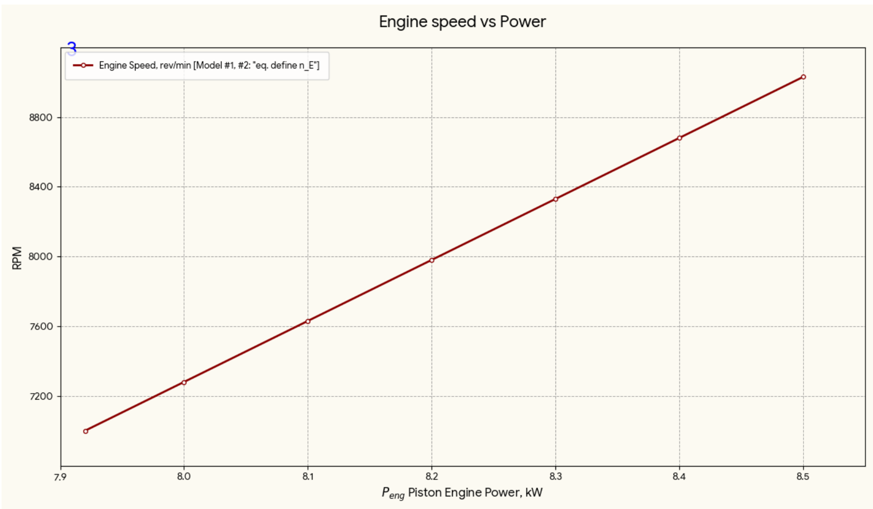

Fig.2: *Measured engine power variation against operating engine speeds*

4.2 Engine performance from both bore/piston dimensions

The measured power and torque curves from the 57mm piston-block assembly and 63mm piston-block assembly are shown in Figures 3 and 4, respectively.

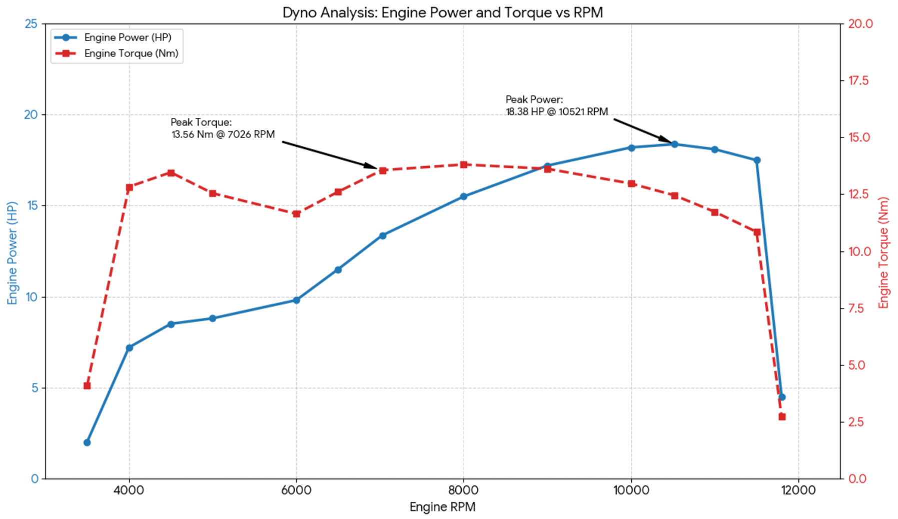

Fig.3: *Engine performance curves of the test motorcycle with the 57mm block assembly*

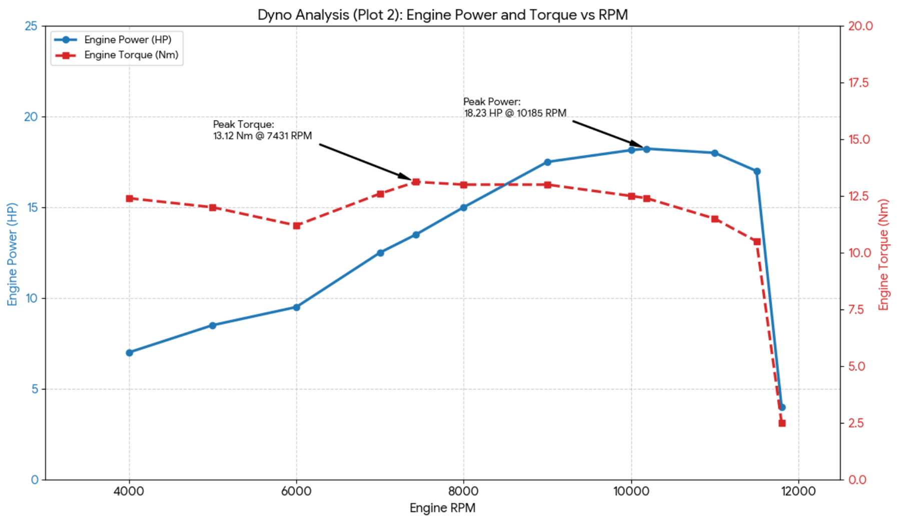

Fig.4: *Engine performance curves of the test motorcycle with the 63mm block assembly*

The data from the chassis dynamometer confirms that the 57mm block-piston assembly achieved higher peak performance, yielding 18.38 HP at 10,521 RPM. While the engine displacement is smaller in this configuration, the stock 57mm cylinder bore appears to be perfectly matched to the cylinder head's flow characteristics, maintaining high gas velocity and optimal thermal efficiency. The dyno graph illustrates a consistent power climb that sustains its trajectory well into the high-RPM range, peaking nearly 336 RPM later than the larger bore counterpart. This gain is attributed to superior volumetric efficiency, with the intake and exhaust ports correctly sized to fill the 57mm cylinder volume, allowing the engine to maintain a higher rate of work as it approaches the rev limiter. In contrast, the implementation of the 63mm block modification resulted in a slight reduction in peak output, producing 18.23 HP at 10,185 RPM and a peak torque of 13.12 Nm. Although the larger bore increases the theoretical displacement, the dyno data reveal a "bottleneck" effect, with the power and torque curves consistently sitting below the 57mm baseline across most of the rev range. This suggests that the 63mm configuration, despite its larger physical capacity, suffers from restricted airflow because the existing cylinder head and valve train were likely optimised for a smaller bore. Without a corresponding increase in port diameter or valve lift, the 63mm setup reaches a point of diminishing returns, where the engine is unable to ingest enough air to capitalise on the increased cylinder volume, resulting in the earlier power plateau and lower overall torque observed in the results.

4.3 Comparative analysis

The comparative plot from both assemblies is displayed in Figure 5.

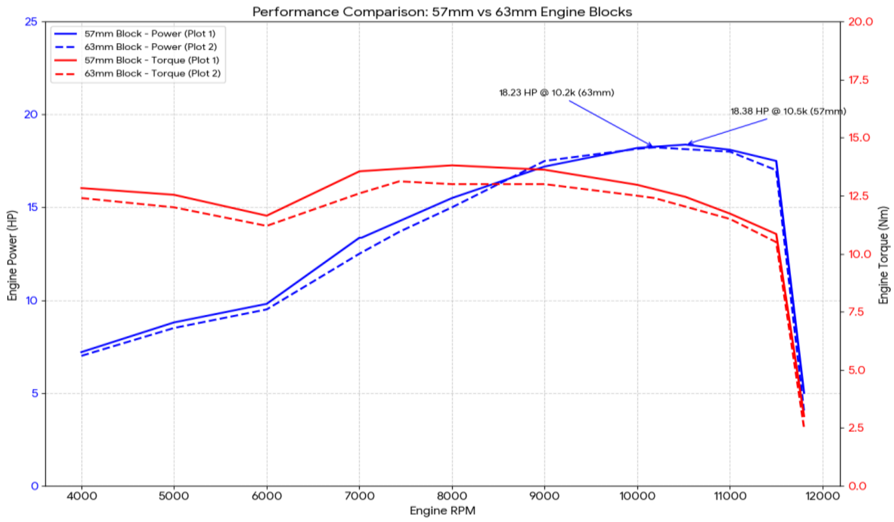

Fig.5: *Comparative plot for both block-piston assemblies*

The comparative analysis of the power and torque delivery profiles indicates that the 57mm assembly maintains a superior efficiency ceiling compared to the 63mm assembly under current testing conditions. While an increase in cylinder bore typically correlates with higher displacement and output, the dyno data demonstrates a marginal decline in both peak horsepower (-0.8%) and torque (-3.2%) following the 63mm modification. The 57mm setup shows a more aggressive power climb and sustains its peak at a significantly higher rev range (10,521 RPM), suggesting that the intake and exhaust gas velocities are optimally matched to the smaller cylinder volume. This high-velocity flow facilitates superior cylinder filling, allowing the engine to produce a higher rate of work as it nears the mechanical rev limit.

Conversely, the performance curve for the 63mm block shows a distinct plateau earlier in the RPM band. As the piston diameter increases, the demand for air increases proportionally; however, if the cylinder head ports and valve diameters remain unchanged, they act as a restrictive orifice. This bottleneck restricts the engine's volumetric efficiency, preventing the 63mm assembly from realising its theoretical displacement advantage. Furthermore, the shift of peak torque to a higher RPM (7,431 RPM) in the 63mm setup—coupled with lower overall values—likely indicates that the combustion cycle is struggling with either a lower effective compression ratio or inadequate air-fuel homogenization compared to the more optimised 57mm configuration. The summarised data is shown in Table 1.

Table 1: *Data comparison of 57mm and 63mm blocks of Yamaha Y15*

Parameter	57mm Block (Baseline)	63mm Block (Modified)	Difference
Peak Power	**18.38 HP** @ 10,521 RPM	**18.23 HP** @ 10,185 RPM	**-0.15 HP**
Peak Torque	**13.56 Nm** @ 7,026 RPM	**13.12 Nm** @ 7,431 RPM	**-0.44 Nm**
Max Engine Speed	~11,800 RPM	~11,800 RPM	0 RPM

5 Conclusion

In conclusion, the experimental results obtained from the chassis dynamometer challenge the conventional assumption that a larger cylinder bore automatically yields higher performance in small-displacement motorcycle engines. While the 57mm block-piston assembly demonstrated a highly optimised power-to-displacement ratio, achieving a superior peak of 18.38 HP, the 63mm modification resulted in a slight performance deficit, peaking at 18.23 HP. This outcome highlights a critical threshold in engine tuning at which volumetric efficiency is limited by ancillary components; the increased displacement of the 63mm block was likely undermined by the flow restrictions of a cylinder head and intake tract originally designed for a smaller bore. Therefore, while a 63mm piston provides a larger physical platform for power, these findings suggest that such a modification must be accompanied by comprehensive porting, larger valves, and precise induction tuning to prevent the engine from reaching a premature performance plateau.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The author confirms sole responsibility for the following: study conception and design, wind tunnel fabrication, data collection, analysis and interpretation of results, and manuscript preparation. All aspects of the project were carried out independently under the supervision of Prof. Dr Ahmad Jais Alimin. The author confirms sole responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

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