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Motorcycle exhaust system.

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Abstract

This report examines the effects of exhaust system on motorcycles. It highlights how these modifications can improve engine efficiency, power, and sound, but also alter back pressure, exhaust flow, and emissions. The role of modern technologies, such as servo motors and exhaust valves, in meeting performance and noise regulations is also discussed. The report emphasizes the need for ECU recalibration following exhaust modifications to ensure optimal engine operation and compliance with environmental standards.

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1. Introduction

The exhaust system is the main component used in vehicles to reduce the toxic exhaust gas, noise, and vibration generated from the engine. In various vehicles mass-produced in recent years, the exhaust system is appropriately tuned to improve the exhaust sound and performance of the engine, according to their characteristics. The owners of older vehicles also attempt to tune their exhaust systems to arouse emotions and express their personality.

In the exhaust system, various elements, such as the manifold, catalyst, resonator, and muffler, are connected to the exhaust pipe. During the tuning of the exhaust system, the outer diameter of the pipe is increased, or its geometry is changed naturally, while each element is modified according to tastes and purposes.

For tuning, however, the pressure of the exhaust gas that flows in the exhaust system should be considered. This is because the backpressure change caused by modifying the exhaust pipe size and geometry of the exhaust system affects the power, exhaust emissions, noise, and vibration of the engine. (Kang, 2022)

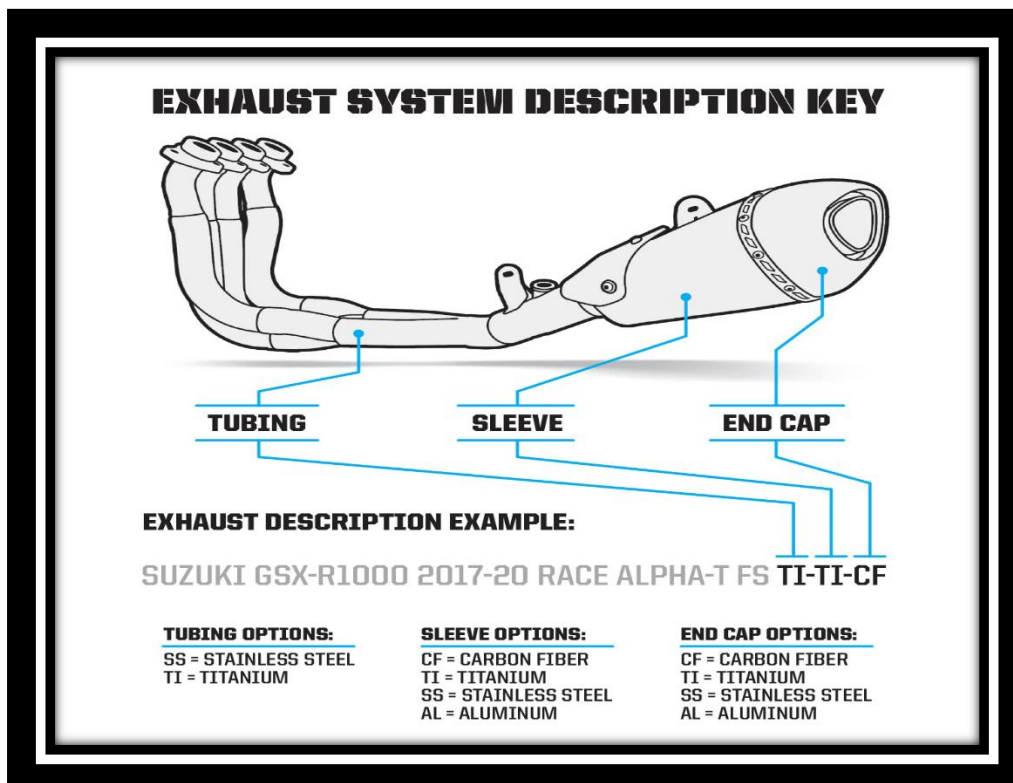


Figure 1 - Exhaust System Layout (Yoshimura , 2024)

Contextual\Background

In most [motorcycles](#), all or most of the exhaust system is visible and may be [chrome plated](#) as a display feature. Aftermarket exhausts may be made from stainless steel, aluminium, titanium.

Motorcycle exhausts come in many varieties depending on the type of engine and its intended use. A twin-cylinder bike may have independent exhaust sections, as seen in the [Kawasaki](#) EX250 (also known as the [Ninja 250](#) in the US, or the GPX 250), or a single exhaust section known as a two-into-one (2-1). Four-cylinder machines, super-sport bikes like Kawasaki's ZX series, [Honda](#)'s CBR series, [Yamaha](#)'s YZF series, latterly titled R6 and R1, and [Suzuki](#)'s GSX-R, often have a twin exhaust system. A "full system" may be bought as an aftermarket accessory, also called a 4-2-1 or 4-1, depending on its layout. In the past, these bikes would come as standard with a single exhaust muffler. This practice lasted until the early 2000s when EU noise and pollution regulations effectively forced companies to use other methods to increase the motorcycle's performance. Tube length and diameter are critical factors in exhaust design. As a general rule, if you're tuning for low-end torque, you want longer tubes of a smaller diameter, while an exhaust tuned for peak power will have shorter, larger-diameter piping. Equal pipe length on all cylinders is almost always desired.

In a [two-stroke engine](#), such as that used on [dirt bikes](#), a bulge in the exhaust pipe known as an [expansion chamber](#) uses the pressure of the exhaust to create a [pump](#) that squeezes more air and fuel into the cylinder during the intake stroke. This provides greater power and fuel efficiency. See [Kadenacy effect](#). (Wikipedia, 2007)

Modern Exhaust technology

2. An exhaust servo motor is one component of the exhaust valve system (sometimes called the ex-up or power valve system) found on almost every modern sportbike including all Honda, Kawasaki, Yamaha, Suzuki, BMW, Ducati, Triumph and a few others. The system consists of a few parts, the first is the valve assembly inside the exhaust pipe. This is a simple butterfly valve that can open or close to change the amount of exhaust flow. Connected to this valve is a set of cables that run to the other part of the system, the servo motor. This motor, which is controlled by the engine control unit, has a pulley on top that rotates the cables to open and close the valve in the exhaust, similar to the way electronically controlled throttle plates are used to meter intake-air velocity to match engine speed. The cables are used to isolate the motor from the hot exhaust and allow it to be placed in a more convenient place on the bike.

3.

The purpose of this system according to the motorcycle manufacturers' marketing departments is to create back-pressure at lower RPMs to increase torque. Unfortunately, this probably isn't the real reason; the true purpose of the exup valves is to meet noise regulations. The exhaust valves are partially closed at idle and low rpm to reduce noise and closed again at the upper RPMs to meet peak noise regulations. The proof of this has been shown on the dyno where removing the valves and retuning the engine creates a flatter better torque curve. Additionally, in the USA, most bikes close the valve again at the upper RPM range, but in Europe they do not (different regulations) and the European bikes typically create a few more HP on the top end as a result. (Parts, 2024)



Exhaust Valve Cables Servo Motor (Parts, 2024)Figure 2

Changing the motorcycle exhaust

Replacing the exhaust to an aftermarket end can or full system (including headers and often removing the catalytic converter) generates more power, weight reduction, better sound by improving exhaust flow. Lighter materials like titanium and carbon can also increase the motorcycles handling, acceleration and reducing the stopping distance.

Impact of Exhaust Replacement on Motorcycle Performance

A more free-flowing aftermarket exhaust can reduce back pressure, potentially increasing engine efficiency and power output. However, this modification also changes the exhaust gas composition, which can impact how the ECU interprets sensor data and adjusts the air/fuel ratio.

Why Tuning is sometimes mandatory After Exhaust Replacement

Given the ECU's reliance on sensor data to optimise engine performance, any modification that alters exhaust gas flow or composition necessitates a revaluation of these parameters.

Adjusting to New Exhaust Characteristics: The ECU needs to recalibrate its air/fuel mixture settings based on the new exhaust system's characteristics to avoid running too lean (not enough fuel) or too rich (too much fuel), both of which can lead to suboptimal performance or even engine damage.

Optimising Performance: Proper tuning ensures that the motorcycle takes full advantage of the aftermarket exhaust system's potential benefits, such as improved throttle response and increased power output.

Ensuring Environmental Compliance: Adjusting the air/fuel ratio is also crucial for minimising harmful emissions, ensuring that the motorcycle remains environmentally friendly and complies with emission standards. (Team, 2024)



Figure 3 :Aftermarket exhaust (Team, 2024)

Dyno testing

These Slip-Ons on a Yamaha R1 2007 models. They feature 304 series stainless steel mid-pipes with swaged inlets (no welds) and exit into 12" dual mufflers. Available with 2.0", 2.25" or large 2.5" cores. With the muffler lengths being fairly short, sound levels are slightly elevated, but the tonal quality is awesome. The polished muffler body clamps are laser cut from 304 series stainless steel with extruded rubber insulators. Stainless steel T-Bolt clamps is utilized on the mid-pipes and muffler inlets. The mufflers are available in Carbon Fiber or lightweight 304 series Stainless Steel.

This bike was brand new. We put 10 miles on it (on the dyno) before taking our readings. We gained 6.04 hp and 4.19 tq at peak horsepower and torque readings. The chart shows runs with the 2.25" cores. The 2.0" cores put out slightly less from mid range on up to peak. The larger 2.50" cores were very similar to the 2.25", with slightly more mid range and peak power. The power will continue to improve with more break-in miles. The power band was significantly improved as well. Horsepower and torque start increasing from 2800 rpm on up to peak (12600 rpm). There is a torque increase of 10 foot pounds between 3000 – 4000 rpm. From 7000 rpm to 9500 rpm there is an increase of almost 10 horsepower. The stock fuel curve was improved (slightly flatter, slightly leaner), but within specs up to the soft limiter (13650 rpm). The addition of a PC3 with proper map will further optimize performance.

(areapnolimits, 2007)

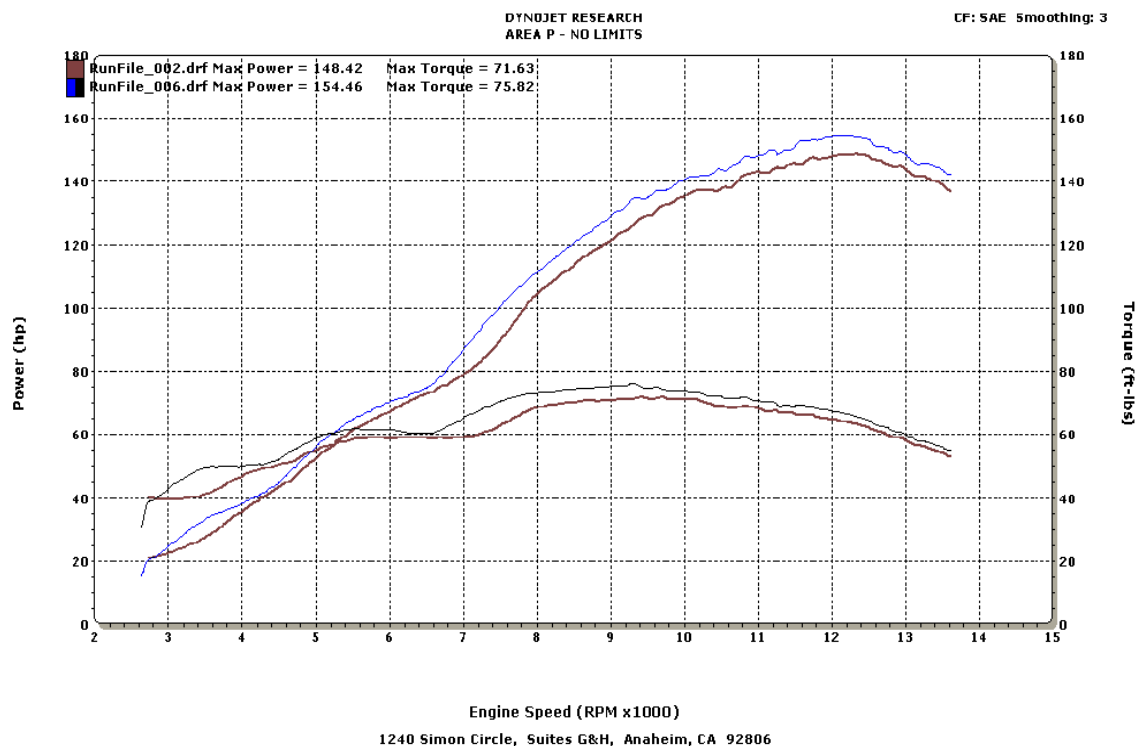


Figure 4 Yamaha R1 Dyno chart (areapnolimits, 2007)

Conclusions

The exhaust system is critical for vehicle performance, emissions, and user experience. This report demonstrated how modifications, such as geometry changes or advanced components, impact backpressure, torque, noise, and emissions.

For motorcycles, replacing or upgrading exhaust systems enhances performance and reduces weight but requires proper ECU tuning to ensure efficiency and compliance. Dyno testing confirmed that aftermarket systems, like those tested on the Yamaha R1, can significantly improve power and optimize the power band when properly calibrated.

Future advancements in materials and intelligent systems will further enhance performance while minimizing environmental impacts, keeping exhaust systems vital in vehicle engineering.

4.

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