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Production Two-Stroke Racing Motorcycle: Suter MMX 500

Introduction to Automotive Engineering ACHA4009

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Date 14/04/2022

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Chapter 1

Introduction

Motorcycle manufacturers are forced to develop new engine concepts to comply with today's increasingly strict emission requirements (Oswald, Kirchberger, and Krimplstatter, 2018). Especially for two-stroke engines which produce high hydrocarbon emissions due to scavenging losses. Modern road-legal two-strokes are equipped with after-treatment exhaust gas systems such as secondary air fitted with two or more catalytic converters in compliance with *Euro 4* homologation (Oswald, Kirchberger, and Krimplstatter, 2018). The additional units of a catalytic converter in an exhaust system led to a significant power loss for a two-stroke motorcycle and, therefore, gave a significant disadvantage compared to a four-stroke motorcycle (Oswald, Kirchberger, and Krimplstatter, 2018).

Two-stroke and four-stroke engine designs are air or liquid-cooled (Oswald, Kirchberger, and Krimplstatter, 2018). There are more rotating components inside a four-stroke engine, with its camshaft, crankshaft, clutch, and gears operating in an oil-filled crankcase, making it heavier and its lubrication system different to that of a two-stroke engine. On the other hand, only the gears and the clutch are drenched in oil on a two-stroke engine. It mixes fuel with two-stroke oil to keep the piston and crankshaft components lubricated and prevent them from grinding (Oswald, Kirchberger, and Krimplstatter, 2018). The burning of oil makes two-stroke engines fail the new and strict emission standards. However, there are still a few motorcycle manufacturers producing a production two-stroke racing engines that are being raced in competitive leagues mainly dominated by four-stroke motorcycles.

The vehicle chosen for this report is a Suter MMX 500, a modern production two-stroke racing motorcycle. Having only 99 units available globally, this 576 cubic centimetre (cc) V-four fuel-injected engine is a low-weight, weighing only 280 pounds (*lbs*), and a high-performance machine producing 195 horsepower is the epitome of a modern two-stroke GP motorcycle (SR Staff, 2015).

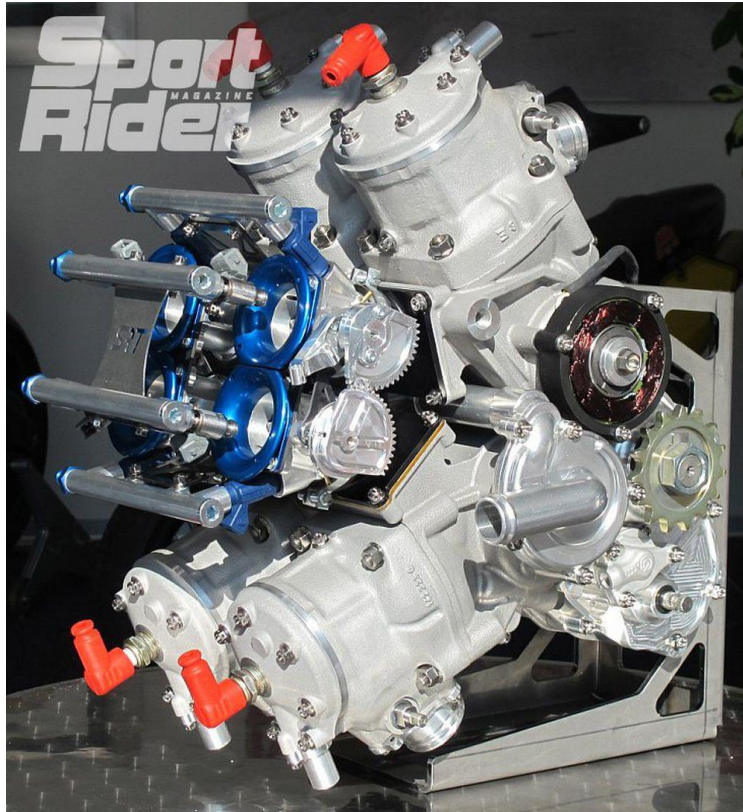


Figure 1: Suter MMX 500 90-degree V-Four Two-Stroke, Fuel-Injected Engine (SR Staff, 2015).

The Suter MMX 500 is equipped with the modern electronic technology equivalent to high-end four-stroke production superbikes and MotoGP race bikes (i.e., launch control, wheelie control, quick shifter, auto blipper, fully-active suspension). In addition, it is built with the industry's finest materials, such as full carbon fibre bodywork, aluminium chassis, forged magnesium wheels, and full titanium exhaust.



Figure 2: The Suter MMX 500 (SR Staff, 2015).

Aims

This report aims to determine if the chosen vehicle fits the industry's current state and how well it can perform against its competitors, specifically when considering the advantages/disadvantages of two-stroke engines against four-stroke engines.

Objectives

Eight topics will be investigated, discussing how they affect the chosen vehicle. As a result, a clear insight will be given into whether or not the Suter MMX 500 would suit the current industry requirements.

Chapter 2

Impact Of The 8 Topics

2.1. Materials

2.2. Automotive Manufacturing

2.3. Emissions

2.4. Aerodynamics

2.5. Internal Combustion Engine

2.6. Computational Method

2.7. Vehicle Automation

2.8. Full Electric and Hybrid Electric Vehicles

2.1. Materials

In automotive production, the adoption of alternative materials often instigates functional developments as well as weight reduction (Silvestre *et al.* 2015, pp. 10–20). Scaling down the weight of a vehicle is one of the simplest ways to enhance fuel economy.

Thus, the industry has focused on developing improved material grades with outstanding durability (Schauerte, 2003, pp.411-418). Furthermore, due to higher safety and performance efficiency requirements being embedded in the future production of automobiles alongside aerodynamics and many other mechanisms, the willingness to acknowledge the adoption of more expensive materials is expanding.

To name a few, here are some of the automotive industry's widely used materials (Schauerte, 2003, pp.411-418).

- Iron/Steel
- Aluminium
- Magnesium
- Titanium
- Carbon fibre composites
- Glass
- Plastic
- Rubber

2.2. Automotive Manufacturing

During the manufacturing process of the vehicles, materials such as steel, aluminium, magnesium or titanium undergo different shaping stages (Silvestre *et al.* 2015, pp. 10–20). As a result, manufacturers concentrated on developing methods to achieve precise predictions of the component's geometrical feature and post-forming attributes. Similarly, the estimation of potential errors and failures on the development parameters has also been examined. In addition, the Finite Element Method (*FEM*) is an effective numerical technique that is broadly used as a device for engineers to enhance the component design in consideration of process limitations (Silvestre *et al.* 2015, pp. 10–20).

Throughout the shaping stages of the materials, the metal sheets are commonly going through stretching, bending, and unbending procedures. In these circumstances, the material is forced upon obscure strain paths that make it hard to precisely anticipate the final form of the product after the shaping procedure, which also plays a role in the longevity of the material's life cycle (Silvestre *et al.*, 2015, pp. 10–20).

2.3. Emissions

One of the most noticeable problems humankind faces today is climate change, predominantly caused by anthropogenic carbon emissions (Böttcher and Müller, 2015, pp. 477–498). In the present day, 50 to 80% of all anthropogenic air pollution emissions are caused by automotive vehicles (Grechkin, Kotlyarenko and Kutenev, 2021, p. 12088). As a result of the current environmental problem, the United Nations (*UN*) and Government Organizations, as well as the automotive industry and other related businesses, are taking standardized resolutions to minimize the effect of automotive transportation on the environment and public health.

Looking at a more extensive timeline, between 1990 and 2050, the European Union (*EU*) attempts to minimize its greenhouse gas (*GHG*) emissions by at least 60% in order to fulfil the *EU*'s responsibility of the 21st Conference of the Parties to the United Nations Framework Convention on Climate Change that took place in Paris in 2015 (Gómez Vilchez *et al.* 2019, pp. 1–17). In 1990 the European automotive sector discharged 851 mega-tonnes of carbon dioxide equivalent (*MtCO₂eq*), which will convert into a peak value of 340 *MtCO₂eq* in 2050.

In plans for the mitigation process, vehicle transportation bears an essential role, considering that it accounts for 72.95% of transport *GHG* emissions and is a major source of Nitrogen Oxide (*NO_x*) in Europe. In addition, 44.4% of transport *GHG* are produced by cars alone (Gómez Vilchez *et al.* 2019, pp. 1–17).

2.4. Aerodynamics

In the early years of automobile development, the importance of aerodynamics was neglected and often considered an inconvenience by car designers (Schüetz, 2016, pp. 601-653). Only ten years later, the adoption of aerodynamic optimization became recognizable through the shape of its bodywork.

The drag coefficient significantly increased in the following years due to the eagerness to enhance handling by combining suspension, wider tyres, and a wider track (Schüetz, 2016, pp. 601-653). Another reason is that the demand for better ergonomics led to bigger interior space and increased frontal surface area.

The front and rear spoiler were introduced during the 1970s to decrease lift and drag in sports car production. Progressively, the recognition and application of aerodynamics to sports cars accelerated at the end of the 1980s (Schüetz, 2016, pp. 601-653).

Race cars and sports cars share similar disciplines to a certain extent, for which extreme aerodynamic application is required. Laminar flow over the most extended section of the body's top surface is necessary to attain the slightest resistance possible (Schüetz, 2016, pp. 601-653).

2.5. Internal Combustion Engine

Based on the current state of the automotive industry, the Internal Combustion Engine (*ICE*) will remain to be used in all sectors, i.e. land, sky, and sea, including energy and industrial production (Carlucci, 2019).

In the present day, *ICE* accounts for almost the entirety of the global transportation services (Kalghatgi, 2018, pp. 965–974). Liquid fuels became the leading choice for transport fuel because of their favourable characteristics such as high energy density, ease of storage, and shipment.

Because of the existing stringent emission standard regulations imposed on the automotive industry, higher demand for fuel efficiency and the reduction of exhaust emissions is nowadays the main focus of automotive manufacturers (Lee and Zhmud, 2021, p. 74). Aside from electrification of the powertrain, *ICE*'s efficiency has been continuously attempted to be improved by automotive manufacturers. Scaling down the engine size and boosting became the popular choice in engine design. However, this leads to wear problems because of higher power density and increased torque output of modernized boosted engines, combined with extremely low viscosity engine oils resulting in higher engine stress (Lee and Zhmud, 2021, p. 74).

2.6. Computational Method: Computer-Aided Engineering

During product development, automotive manufacturers aspire to bring the cost of a product to a minimum and design an improved product within a shorter period (Ryberg, Bäckryd and Nilsson, 2014, pp. 711–728). These challenges address continuous advancements in techniques and procedures.

Automobile designs are currently being refined through Computer-Aided Engineering (*CAE*) and Computer-Aided Design (*CAD*). Traditionally, the aim throughout the development has been to come up with a suitable design that satisfies the requirements explicitly and find an optimal model in a single approach (Ryberg, Bäckryd and Nilsson, 2014, pp. 711–728).

The intensive application of software simulation during the development period has decreased the use of physical prototypes. Transitioning to *CAE*-based from a hardware-based development has significantly slowed the development cost and made it possible for a faster development period (Ryberg, Bäckryd and Nilsson, 2014, pp. 711–728).

2.7. Vehicle Automation

Vehicle automation technology has quickly progressed over the years (Morris *et al.* 2020, pp. 507–510). Automotive manufacturers now have the proficiency and competence to create a fully self-driving vehicle that does well enough to get around many traffic circumstances. However, more experiments are needed to completely assure the safety and reliability of self-driving vehicles.

Accessibilities such as Adaptive Cruise Control (ACC), parking assistance systems, blind-spot assistance, and lane-keeping assistance have become standard specifications on modern vehicles (Naujoks, Purucker, and Neukum, 2016, pp. 67–82). These advanced systems can give action suggestions and warning information or command the vehicle to perform linear or lateral functions.

Automation has lightened human manual tasks and other workloads during the driving period (Naujoks, Purucker, and Neukum, 2016, pp. 67–82). However, recent studies have shown adverse results, causing loss of situation awareness, loss of focus, and overreliance on the automaton.

2.8. Fully Electric and Hybrid Electric Vehicles

Due to the recurring toxic air pollutants caused by Internal Combustion Engines (*ICE*) and strict emission standard regulations, increased demand for more efficient, economical, and ecological transportation has been brought into consideration (Pereirinha and Trovão, 2012). Current relevant solutions such as Electric Vehicles (*EV*) and Hybrid Electric Vehicles (*HEV*) were deemed fit to mitigate the mentioned problems.

Undeniably, electrification of the powertrain could be the solution for sustainable and ecological transportation. In general, the electric motor (*EM*) is highly efficient, bringing approximately 70-90% efficiency compared to the *ICE* with only 10-30%. That enforces less “*Tank-to-Wheel*” energy consumption in automobiles driven by *EMs* when compared to *ICE* vehicles (Pereirinha and Trovão, 2012)

Chapter 3

Discussion

The presented topics are very closely related and are highly considered in motorcycle development and every aspect of automotive manufacturing. Heavy materials make the engine less efficient because it needs to run on a higher engine revolution, causing it to consume more fuel and produce more exhaust gases. Similarly, the material choice also contributes to the manufacturing process in which it dictates the cost and the reliability of the components. The aerodynamic design helps the driving stability of a vehicle in a high-speed operation and enhances the engine's cooling efficiency and drivability when exposed to crosswinds and severe weather conditions. Emission and *ICE* are always tied together because of the environmental problems currently experienced globally due to exhaust gases produced by vehicle transportation. The reduction of emissions can only be achieved with improvements in the *ICE*. The computational method significantly enhances the product designs by using modern software, testing the materials' rigidity fit for its purpose, and eliminating potential errors during manufacturing components. Vehicle automation is a clear indication of the advancements in the technology supplied to modern vehicles; it increases the ease of driving and the user's comfort during the driving period. Electrification of the powertrain is currently the automotive industry's solution to more economical and sustainable transportation regarding current environmental problems.

Chapter 4

Conclusion

In conclusion, as observed above, it is undeniable that the majority of the topics discussed are strongly leaning toward complying with emission regulations and aiming to find ecological and sustainable transportation advancements. This study has also evidenced that two-stroke motorcycles are less favoured in today's motorcycle industry due to the emission issues that they entail. Indeed, they are not the most practical choice of daily transportation because of today's increasing petrol prices and their shorter period of maintenance intervals due to their inefficient combustion design.

When assessing the topic from the racing perspective, modern production two-stroke racing motorcycles are still highly competitive. Their agile characteristic and high-power output can easily compete in modern race leagues mainly dominated by four-stroke motorcycles.

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