Motorbike Designing and the Optimization of the Motorbikes

Ran Sun *

GuangQuMen high school, Beijing, China

* Corresponding Author Email: sunran6666@outlook.com

Abstract. This essay provides a comprehensive introduction to motorbikes, tracing their development and historical evolution from early prototypes to modern high-performance machines. The discussion is organized into four main sections, each focusing on a critical aspect of motorbike design and technology. The first section examines the engines used in both cars and motorbikes, highlighting advances in engine efficiency, power output, and fuel consumption that have driven performance improvements over time. The second section explores the importance of lightweight design in motorbikes, including the selection of materials such as aluminum, carbon fiber, and advanced alloys, which contribute to reduced weight, enhanced maneuverability, and overall energy efficiency. The third section, a central component of the essay, introduces computational fluid dynamics (CFD) methods and basic principles, emphasizing their role in optimizing aerodynamics, minimizing drag, and improving stability at high speeds. Finally, the essay concludes by analyzing current trends and projecting future developments in motorbike technology, including innovations in materials, propulsion systems, and smart control mechanisms, which collectively shape the trajectory of modern motorbike design.

Keywords: Motorbike, CFD, Engine, Trend, Development.

1. Introduction

Motorbikes are highly efficient, flexible and sensually attractive transportation. It is important to people’s life, from satisfying the basic need for traportation for people to purse the extreme sport, like motogp. Motorbikes play a very significant role in life. Motorbikes have a crucial role in developing countries and specific industries. This type of transportation is becoming the livelihood of some Southeast Asian countriesn 2017, there are roughly 1.13 million of motrobikes in Indonesia, and motorbikes account for 43% of the total population of 2.64 million of people. There are lots of motorbikecommunities. Motorbikes are also playing an important role in entertainment. For example, MotoGP, WSBK, Motorcross, Rally represent the most top races in the world. Motorbikes are also becoimg a type of lifestyle and a spiritual pursuit. Such as motorcycle touring. Mmotrobikes are a classic element on the filming screen, creatingcountless beloved characters. For instance, the motorcycle in the TERMINATOR. These cultural symbols have deeply influenced the public longing for motorbikes. This essay aims to summarize the motorbike design and how to optimize the design of the motorbike and also give some updating progress of the motorbike. This essay first introducts some lightweigtht design for cars or motorbikes, since carsand. Motorbikes have some same properties to design.The lightweight materials include high-strength steel, aluminium alloy and some high polymer material and non-metallic material. Second the essay introduces some structural design and methods. Such as topology optimization, topography optimization, size design and shape design. Then we will talk about the engine system. For instance, we will talk that in stable working condition how does the flow change in the engine. The tyres of motorbikes are also very important to design. This part will include the material of the tyre, the research on tyre dynamics and the friction forcetyre, thedesign of the tyre for the professional race. The most important part is to consider the aerodynamics to design a motorbike and a car for either industry or top race. The essay will introduce the basic knowledge of the aerodynamics in designing cars and also some method to imitate the flow for desgining, such as CFD and wind tunnel test.The essay will give the overview on how the cars or motorbikes impact the environment and how to minimize the impact. The last part is to introduce the development tendency of motorbikes and the green energy development.[1]

2. Engine Designing and the Improvement the Efficiency of the Combustion

In the global world, scientists are trying to find a way to replace the traditional fuels. For instance, biothanaol, hydrogen cells. Like solar energy, which is still not market adaptive, because it needs more dedicated designs. A lot of scientists have the question about why hydrogen is not best alternative fuel, consisting of safety, cost and efficiency. On the contrary, biodiesel and bio ethanol require no engine modification, but they create lots of problems in long run. Also, these are strongly critizied for its environmental impact and the threat to the food. Saidur and some scientists try to estimate natural gas to replace the part of the effect of the partial substitution of the diesel fuel, such as methyl and ethyl and so on. From this study, researchers on CNG (compressed natural gas) fueled engines are progressing throughout the world due to its potential as alternative fuel. There are some comparisons for the traditional one and CNG. As a type of gas, CNG needs a different type of combusting mechanism in the condition of the normal temperature and normal pressure. This makes people more interested in CNG using as the internal combustion engine. CNG can be used as the great fuel for almost every type of car. The experimental devices demonstrate testing engine is consisted by the bi-fuel natural gas engine from an Si engine [1]. For the result and discussion. CNG can produce lower brake power than gasoline. Retrofitted car engine runs on lower BSFC when using CNG than on gasoline. CNG has an advantage of higher brake thermal efficiency on an average of 1.1% and 1.6% than that of gasoline. The engine exhaust gas temperature produced by the CNG burning is always higher as compared with that of the gasoline. There are some comparisons of the different types of the engine. SI (spark-ignition) engine: the SI engine has the almost most complicated combustion process than other engines. The combustion is driven by the interaction between the gas-heat-chemical reactions. The most confusing thing is why SI engines can work in a speed range from hundreds up to tens of thousands of revolutions per minute. Diesel engine: because of the demand of reducing Co2 emission and the efficiency of this type of engine, the motorbike combustion is more efficient than the gasoline one. Advanced low-temperature engine: HCCI (homogeneous charge compression ignition) is a type of prospective engine, because the engine exhaust gas temperature produced by the CNG burning is always higher as compared with that of gasoline. Because the dilute homogeneous charge can avoid high temperature in the chamber. The scientists are trying to determine region to try to mitigate the transportation problems and contaminant problems. For the racing motorbike, the output properties are very important, and it depends on the velocity, the atmosphere condition and the ingredients which are mixed with the air. And if the burning velocity are keeping in same level, it can improve the output power for the engine. The chamber of the displacement can impact the shape and distribution of the flame. It is important to consider friction and power losses. The scientists show a tridimensional CFD analysis of the lubrication circuit oil pump of a modern high-performance engine manufactured by Aprilia. In recent years one-dimensional and three-dimensional codes have been used to mimic the oil circuit way. The essay will show a high-performanced motorbike engine oil pump. There are 4 air cylinders in this engine.[2] Its maximum speed is 14000r/min as shown in **FIG.1**.

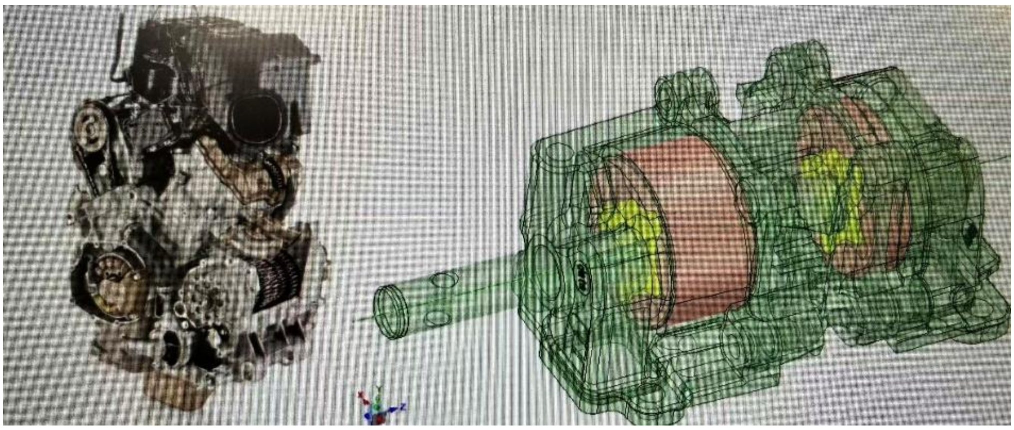

FIG.1. Engine Structure.

Introduction of the engine and rotors: The operation of this pump relies on the precise coordination of a 4-tooth outer rotor and a 5-tooth inner rotor. When the inner rotor is driven, its rotational speed is 1.25 times that of the outer rotor. This speed difference causes the volume of the sealed spaces formed between the rotors to constantly change, driving the oil to complete the processes of suction and discharge. The entire system integrates two such oil-pumping mechanisms, functioning as a compact dual-pump to provide power for the oil cooling circuit [3]. It is important to hybridize the road motorcycle, because there are some restrictions on weight, dimensions and cost, so it is necessary to have innovative solutions ro tailor the motorcycle. One study focuses on a stock motorbike with a 54kw engine and 200kg curb weight. The aim of this study is to reduce the fuel consumption and emission of Co2 without impacting on the property and the quality of cars. The most innovative thing is that there are an extremely small thermal engine and a compact axial flux electric motor. The study demonstrates some keys findings: 1. reducing the size of the engine can extremely minimize the whole size of the motorbike mixed power train system.2.the hybridization can reduce27% in fuel consumption and in decreasing totally 45% co2 emission. 3.the downsized engine can minimize the combustion time of the catalyst by 20%.4. The hybridization motorbike can provide 24km full-electric range at 100% charging condition.6. Full performance parity with stock motorcycles is achieved only with a fully charged battery, though the thermal engine alone can still meet standard performance levels, including the WMTC velocity schedule.

3. Lightweight Design

For the lightweight design for cars or motorbikes, there are lots of similar points to discuss. The essay will mention some innovative materials appropriate for the manufacturing of low carbon vehicles. For instance, high-strength steel, aluminum alloys, magnesium alloy. As well as novel composite materials commonly used for lightweight construction. High-strength steel: high modulus of elasticity, strength formability weldability, crashworthiness, low cost. The HSS, AHSS can be used for cars and motorbikes. AHSS has the feature of high tensile strength of 550Mpa.

Aluminum Alloys: the density of aluminum is one to three of the steel. Aluminum is a type of material that is very lightweight. A competition to "lighten" car materials is underway. It is predicted that by 2025, the average aluminum usage in European cars will approach 200 kilograms. In the high-end market, brands like Jaguar and Land Rover have pushed this figure up to 500 kilograms. And electric vehicles like Tesla Model S also optimize their performance by extensively using aluminum body chassis (with a total aluminum weight of 190 kilograms). It's worth noting that aluminum is not a new material. After its brief appearance in the Ford Model T era, it was outperformed by steel in terms of cost, but now it is experiencing a strong comeback. On the other hand, the "electrification" of automobiles has opened up a new battlefield for polymer materials. The special plastics developed to withstand high-temperature engines may be challenged. Instead, materials such as polyamide, polycarbonate, and polypropylene are widely used in the batteries, sensors, and interior and exterior components of electric vehicles. [4] Polymer-based composite materials are even regarded as one of the key materials that will determine the performance of future automobiles as shown in **Table 1**.

Table 1. Comparison of different types of materials.

materials	density	strength	elasticity	Corrosion resistance	Heat resistance
steel	7.85g/cm3	high	Extremely high (elasticity modulus about 200Gpa)	bad	Excellent (melting point above 1500 degrees)
aluminum	2.7g/cm3	median	Low (about 70Gpa)	Good (can form oxidation film)	good
polymers	1.0-1.6g/cm	Depend on materials	Low (need fiber to enhance the strength)	Excellent	bad

4. The Aerodynamics for the Vechicles

In recent years, aerodynamics is very important for designing motorbikes and cars, especially for racing. In the past ten years, the CFD has become the main method to calculate the data of vehicles, but the CFD of motorbikes are quite different from cars, because the motorbike and the person consist of a complex entirety. The essay will demonstrate the holistic of the CFD of motorcycles. The front fairing, the front wheel and its suspension are identified as the main contributors to the aerodynamics drag of the motorbike and its rider. It is also important to study the turbulent model for motorbikes. And the essay will show some Navier-stroke equations.

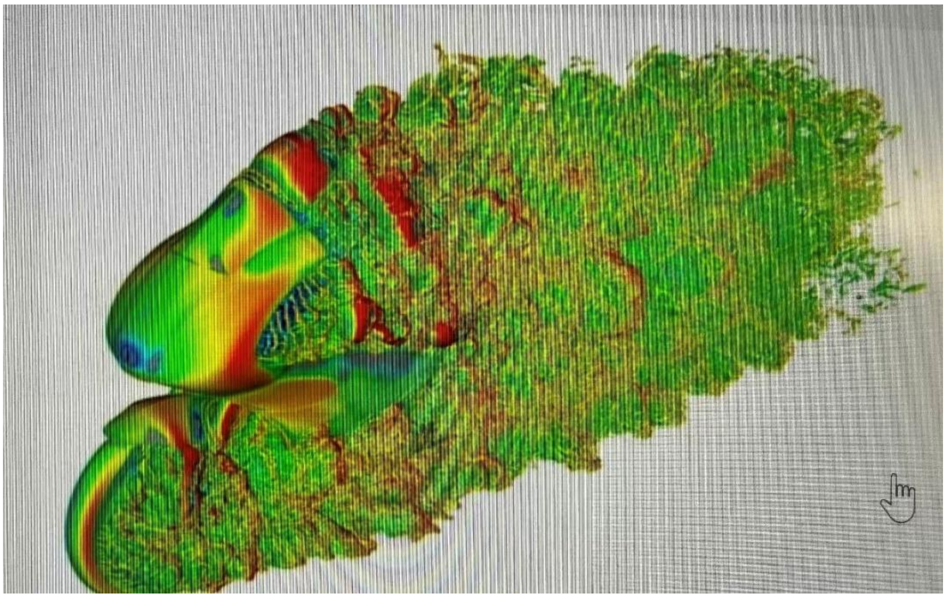

FIG. 2 CFD simulation result for motorbike

The study will some CFD to calculate motorbikes as shown in **FIG. 2**, although the CFD is the main method for aerodynamics study, but its accuracy may influenced by some factors: detail of the geometric, choice of the turbulent model, data internet. The essay will show the CAD model of a motor student class motorbike designed at the Warsaw University of technology. The most part of the motor body have been imitated by the researchers. The whole length of the motor is 2076mm,and the wheel base is 1495mm.The height of the car body is 1224mm,and the widest part is 740mm.For the computational range, it is need some preliminary conditions: the inlet velocity should be on the inlet surface of the domain , the outlet surface pressure should be equal to the atmosphere pressure. In the inlet domain: velocity is25m/s, turbulent intensity is 4%,the turbulent length scale equal to 5mm.The corresponding Reynolds number based on the height of the studied geometry(H1) and the inlet velocity is Reh1=2.09x106.These values correspond to the value obtained in the wind tunnel at the Warsaw university of technology when it is operating close to full power. Mesh: the study prepare lots of mesh. In order to resolve the thin boundary layer that occurs near the motorbike and rider surface, 26 prism cells were created with a first cell height of 29. 2um. So, choosing the first cell height value of 1.46mm. solver: There are three making turbulent methmethodsNS DDES and SAS. In the initial stage of this research, the aerodynamic characteristics of motorcycles and riders in the low drag posture were systematically simulated using the RANS method. In terms of the solution strategy, the pressure-velocity coupling was achieved through coupling algorithms. The calculations also compared the performance of various two-equation turbulence models, including: shear stress transfer k-ω (k-ω SST), Menter baseline k-ω (k-ω BSL), Spalart-Allmaras (S-A) model, the achievable k-ε model combined with standard wall functions (RKE-SWF), and the achievable k-ε model with enhanced wall treatment (RKE-EWT). [5]

In terms of spatial discretization, the gradient calculation is based on the least squares method for elements, and the pressure term uses a second-order interpolation scheme. In the convection term, the momentum equation is discretized using a second-order upwind scheme, while the turbulence equation employs a first-order upwind scheme.[6]

Some research will not introduce same aspects of this study: Flow Analysis around the Motorbike and the Rider, The Effect of the Rider’s Position on the Aerodynamic Properties of a Motorcycle. And for the result: 1the front fairing, the front wheel and its suspension are the main contributors for the aerodynamics drag force.2. All the value of the drag force are between8.3% in all turbulent models.3. The geometric shape of the riders and the posture have a significant impact on the function of the aerodynamics.

5. The Impact of the Motorbikes to the Environment and the Control of the Noise

The causes of photochemical smog can be traced back to research conducted in the 1960s. At that time, the scientific community confirmed that it originated from the photochemical reaction of hydrocarbons (HCs) and nitrogen oxides (NOx) under atmospheric conditions. The smog contains ozone, nitric acid peroxyacetyl (PAN), and other trace secondary pollutants. Although the concentrations are not high, they are all strong irritants and pose significant threats to human health and the environment. In terms of control technology, gasoline oxidation catalysts based on non-precious metals (such as nickel, copper, cobalt, and iron) have attracted much attention. [7]However, such catalysts have obvious limitations in practical applications: on one hand, they are prone to poisoning and deactivation due to the presence of residual sulfur, lead and other components in the fuel; on the other hand, their own thermal stability is poor, making it difficult to meet the requirements for continuous high-temperature operation. Environmental problems always confused the scientists and researchers. Catalyst substrate types: From the 1970s, people started to use monolithic substrate instead of ceramic material. It has lots of advantages: liable to connect pipe line, large surface area. Conclusion: PGM catalysts (Pt, Pd and Rh) can effectively avoid massive contaminants coming to the air. It is important to accelerate the green development of motorbikes. And the core development : 1.technology-driven:battery technology: improving the power density, the solid battery can totally solve the problem of safety.[8] electric engine can make it more effective and lighter.2.product diversification: commuting type: These are mainly economical practical ,small, and flexible, serving as the main means of short-distance urban travel. Performance and entertainment type: high-performance electric motorcycles meet the needs of cycling enthusiast providing the instantaneous acceleration and quiet driving pleasure .[9]Cross-border functional type: electric off road motorcycles ,electric ADV ,and other specialized markets are beginning to emerge.3.intelligent cockpit : features such as large TFT LCD displays, mobile phone connectivity ,navigation, music, and voice ,control will become standard equipment for the mid to high end vehicles.4.Advanced driver assistance system: the gradual introduction of ABS and TCS has become a trend . In the future, we may see more advanced functions such as blind spt monitoring, front and rear collision warning, lane departure warning, etc, which will significantly enhance safety.[10]

6. Conclusion

With the deepening of the global technological revolution and the advancement of the "dual carbon" goals, the motorcycle industry is now at a historic turning point. Its future development will no longer focus solely on performance and cost, but will increasingly integrate intelligent and electric technologies, actively contributing to the broader vision of sustainable urban transportation. This chapter presents a perspective on the future of motorcycles through three key dimensions: technological integration, energy transformation, and urban synergy.

The design and manufacturing of motorcycles are evolving from traditional mechanical engineering toward “software-hardware integrated” intelligent mobility platforms. Electronic control systems are no longer exclusive to high-end models; they are becoming essential for redefining the riding experience and enhancing safety.

Advanced sensors and Electronic Control Units (ECUs) now allow power output to be regulated beyond simple throttle input. Smart transmission systems—such as bidirectional quick-shifting gearboxes and adaptive clutches—enable millisecond-level gear changes, eliminating power interruptions and improving both smoothness and efficiency. Variable valve timing and lift technology are increasingly applied to motorcycles, intelligently adjusting intake volumes to balance low-RPM fuel efficiency and high-RPM power output, optimizing performance across the entire operating range.

Mechanical suspensions and braking systems are transitioning into intelligent, active safety platforms. Semi-active and fully active electronic suspensions monitor vehicle dynamics in real time (e.g., acceleration, tilt angle, and pitch) via Inertial Measurement Units (IMUs) and adjust damping within milliseconds. While motorcycles and cars share many underlying technologies, aerodynamics presents a key difference: motorcycle designers must account for rider posture, which significantly impacts airflow, making aerodynamic optimization more complex than in car design.

This work is divided into six parts. The first part introduces motorcycles. The second part focuses on the engine — the core component of motorcycles and cars alike — and explores optimization strategies to enhance acceleration, reduce fuel consumption, and improve overall efficiency. The third part discusses lightweight design, which is crucial for vehicle speed, presenting and comparing different materials. The fourth part examines motorcycle aerodynamics, comparing them with cars, and provides a brief introduction to Computational Fluid Dynamics (CFD). The fifth part addresses emission challenges, proposing effective methods to minimize pollutants and improve system efficiency. The final part explores future trends, including advancements in electric vehicle systems and intelligent technologies.

To develop more advanced motorcycles and cars, engineers must also conduct fundamental research in areas such as aerodynamics, materials science, and chemistry. This multidisciplinary approach is essential to push the boundaries of performance, efficiency, and sustainability in the next generation of vehicles.

References

[1] Proceedings of the 2nd International symposium on Transportation Studies in developing countries (ISTSDC 2019).

[2] Comparative engine performance and emission anlysis of CNG and gasoline in a retrofitted car engine M. I. Jahirul, H. H. Masjuki, R. Saidur, M. A. Kalam.

[3] Lubrication, emissions, and performance analyses of LPG and petrol in a motorbike engine: a comparative study. Muhammad Usman & Nasir Hayat

[4] Lightweight design A challenge for modern passenger car engines 2000-05-0051 power and propolsion, material and manufacturing.

[5] Comprehensive CFD Aerodynamic Simulation of a sport motorcycle byKrzysztof winski and Adam Piechna. The institute of Automatic control and Robotics, Warsaw University of Technology ,02-525 Warsaw, Poland Author to whom correspondence should be addressed.

[6] The Role of CFD on the Aerodynamic Investigation of Motorcycles Mario Angeletti, lucia Scla fani, Gino Bella and Stefano Ubertini.

[7] History-California Air Resources Board-CA.gov ww 2. arb. ca. gov.

[8] Photochemical oxidant air pollution: A historical perspective Arthur Davidson

[9] Automotive Exhaust Catalyst for Clean Air: Progress of the Three-way Catalyst and Supporting Catalyst Technologies Hirofumi Shinjoh

[10] Simulation Analysis of a Motorcycle with Passive, Idealized Semi-active and active Suspension systems Stefan Segla and Sayantan Roy,2021