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Honda CBR1000RR

Introduction to Automotive Engineering

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1 Introduction

The automotive industry is rapidly evolving due to a combination of technological advancements, shifting consumer preferences, and political pressures. In recent years, environmental and ethical concerns have become major drivers of change in the industry, with many governments and regulatory bodies implementing stricter standards for emissions, safety, and sustainability. In this report, we will examine the current state of the automotive industry and how certain political pressures are pushing the automotive engineering industry.

Based on various topics covered in second-semester level 4 lectures, we will explore how these pressures have influenced the design and development of Honda's CBR1000RR (CBR), having been manufactured from 2004-present, the CBR has moved with the rapidly evolving industry whilst remaining a fan favourite.

2 Impact of the topics

2.1 Emissions

Euro 2 regulations were implemented in 2004 for two-wheel vehicles to reduce harmful by-products emitted by internal combustion engines. In 2006, more stringent Euro 3 regulations were introduced (Transport Policy). Honda's CBR was released in 2004 and complied with the regulations using several exhaust gas recirculation and cleaning technologies.

To prevent the discharge of crankcase emission into the atmosphere, the CBR's crankcase is equipped with a closed system. The emissions are returned to the combustion chamber through the air cleaner housing and throttle body.

An evaporative emissions control system is also in place to draw fuel evaporation gases from the fuel tank and introduce them into the combustion process. Moreover, the CBR features a secondary air supply system that pulses fresh air into the exhaust port to promote the burning of unburned exhaust gases.

Finally, a 3-way catalytic converter filters the remaining exhaust gases, further purifying the final emissions (Honda, pg 1-112 – 1-114).

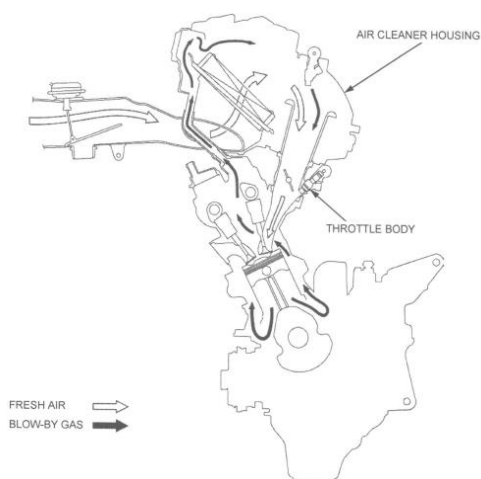


Figure 1: Crankcase emission control system. (Honda)

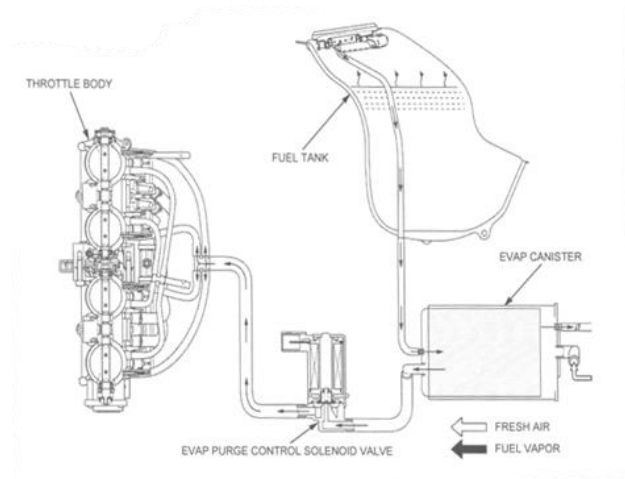


Figure 2: Evaporative Emission Control System (Honda)

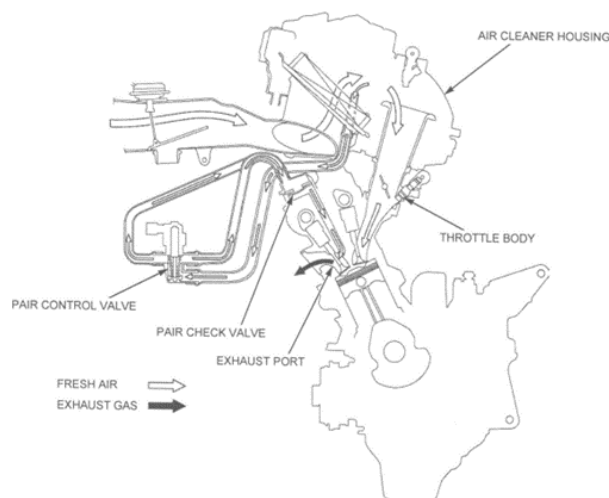


Figure 3: Secondary air supply system (Honda)

2.2 Aerodynamics

Honda's 2004 CBR release boasted several technologies from the world of racing. Among powertrain advancements the bike included a full race fairing kit which guides air over and around the rider when in full tuck position. Figure 4 shows the fairings, that include strategically placed vents to enable maximum airflow to assist with cooling around the engine area (circled in green).

Since 2004 Honda have improved the fairing design and in more recent models have incorporated front winglets that assist with wheelie control by utilising downforce. This can be seen, circled, on the 2019 model (figure 5) and has been further improved in subsequent releases. "It started in the beginning of 2017 when we were asked for ideas for controlling wheelies of the MotoGP machines." (Yokokawa, S.).



Figure 4: 2004 CBR1000RR (Honda Global)



Figure 5: 2019 CBR with front wings (Honda Global)



2.3 Materials

The advancements in metallurgy over the production lifetime of the CBR has allowed Honda to experiment year on year with varying changes made to the frame, subframe, wheels and even the fuel tank to assist with weight reduction, part longevity and reliability.

In 2004 Honda released the CBR with a lightweight twin-spar aluminium frame, borrowing technology used from their RC211V model (Torrance, C.). The twin-spar frame design is still used to date but has received technological advancement and refinements. The 2019 model introduced optimised frame-wall thickness to improve weight and flex characteristics (American Honda Motor Co. 2018) (Figure 7).

The 2019 model also introduced the world's first titanium fuel tank for a mass-production road bike (Figure 6), manufactured using a deep drawing process. "When deep draw stamping titanium, a metal blank punches down into a series of hardened steel dies. Once the deep draw process is complete, the fully formed part is structurally stronger than the original metal part." (Jones Metal Products, 2013).



Figure 6: 2019 CBR titanium fuel tank (surreymcparts)



Figure 7: 2004 CBR twin-spar frame (left) 2019 CBR twin-spar frame (right) (American Honda Motor Co. 2004) (Bennetts. 2019)

2.4 Computer-Aided Engineering

In 2007 Honda entered a CBR into the Suzuku 8-hour endurance race, their research and development team set about preparing the bike for the race and produced a technical report outlining the changes they made. The team found that “Torque fluctuations during acceleration and reducing engine braking during deceleration were issues”. Regulations prohibited the modification of the crankshaft mechanism, however modification to the Alternator Circuit Generator (ACG) rotor was allowed. The team increased the inertial mass of the ACG rotor by 256% (Figure 8) which helps prevent sudden increase in engine speed due to throttle operation, therefore assisting with torque fluctuations (Kanda, et al. 2008).

As mentioned earlier, Honda’s CBR design is heavily influenced by that of motorsport, from powertrain technology to aesthetics. It would appear that computer aided engineering (CAE) has played a massive part in the production and testing of the CBR during its timeline. CAE allows engineers to prototype and test designs at a much quicker and cheaper rate than physically producing and testing components (Noble, A. 2023), keeping costs to a minimum but also enabling the rapid advancement in vehicle technology that has been seen over the last 20+ years.

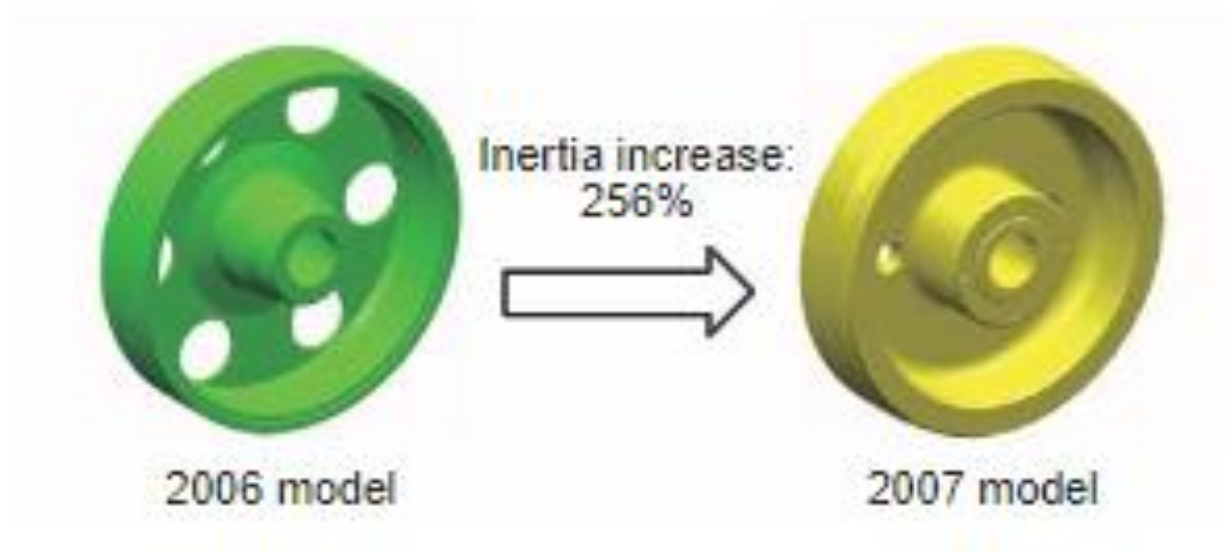


Figure 8: ACG rotor inertial mass increase

2.5 Data Analysis

Steering dampers are used to slow or stiffen steering action to aid with control of speed wobble at high speeds. Calif, 2004, states that “In general, Honda avoided installing these devices on motorcycles because all existing designs included inherent drawbacks that compromised the benefits.” This meant that steering dampers set to reduce wobble at high speeds had an adverse effect on handling at low speeds, something that was not ideal for a consumer market vehicle.

Honda designed a product to alleviate the issues and in 2004 released their Honda Electronic Steering Damper (HESD), subsequently installed on all CBR1000RR to date. HESD works in conjunction with the Engine Control Unit (ECU) to provide differing levels of dampening depending on vehicle speed and acceleration over a wide range of riding conditions.

Honda has released a multitude of ECU controlled advancements that assist the rider. One example is wheelie control, added to the 2019 model, that limits engine speed when the front wheel is detected as leaving the ground. Another technology included is Honda Selectable Torque Control (HSTC) which measures wheel speeds and body roll angle to assist with control of rear wheel slip in corners and moments of acceleration by minutely controlling throttle body opening (Okoshi, S).



Figure 9: HESD on 2004 CBR1000RR (American Honda Motor Co.)

2.6 Calculus in Automotive Systems

Calculus is used throughout vehicles, especially those controlled by an Electronic Control Unit (ECU). The HESD system mentioned in paragraph 2.5 uses calculus to control the steering damping relating to vehicle speed.

Calculus can be described as the study of change (Sutton, R. 2023) and in damper systems is related to the change in damping action and can be identified as one of three types, over, critically, or underdamped. An example of overdamping can be seen in soft close doors or cabinets and applies to the HESD system when the motorcycle is travelling at higher speeds to provide stiffer handling and prevent unwanted movement. Critical damping can be used in the same applications but can be described as a faster initial displacement, as seen in figure 10.

Underdamping can be shown in objects such as pendulums using air resistance and spring masses. Figure 10 shows the underdamping with oscillations that reduce in size as the mass loses energy. This would more likely be used by HESD at lower speeds where quick and frequent turning of the steering assembly may be required and there is a low risk of this action causing an unwanted reaction.

An oil filled chamber is divided into two sections using a vane connected by a linkage arm to the steering assembly. The damping force can be adjusted accordingly using a main valve controlled by a linear solenoid that receives its control from the ECU (Torrance, C. 2004).

In calculus, damping force is identified using c and holds the value of $\frac{\text{force}}{\text{velocity}}$ these values are continuously updated with information received via sensors.

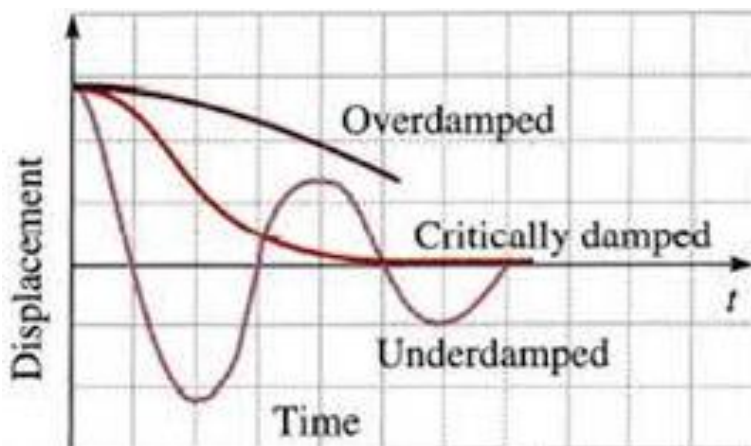


Figure 10: Graph of damp types (labman.phys.utk.edu)

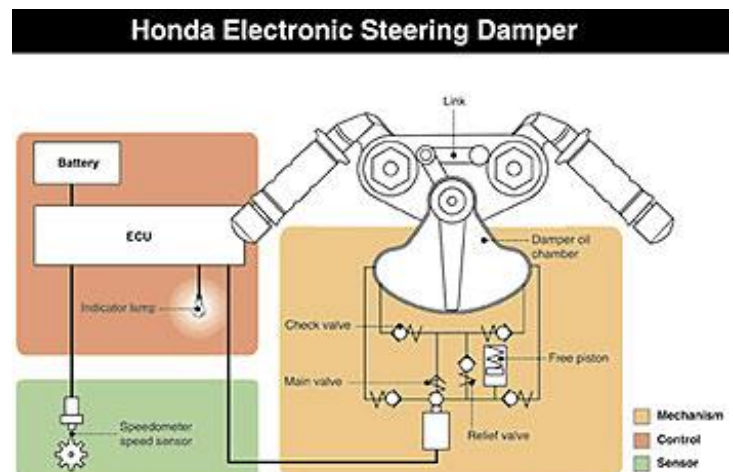


Figure 11: Honda HESD overview (motorbiketoday.com)

3 Current State of the Industry

In recent years, the importance of addressing environmental impact has become increasingly clear, with global concerns about climate change and pollution driving major policy changes. For instance, the European Union (EU) has set a goal of achieving climate neutrality by 2050 and has implemented measures such as banning combustion engines to reduce road transport's contribution to CO₂ emissions. In June 2022, the EU Parliament “backed the European Commission's proposal of zero emissions from new cars and vans by 2035.” demonstrating a strong commitment to promoting sustainable transportation.

The move to electric vehicles seems like the most obvious solution to reducing vehicle emissions, but this brings its own set of unique environmental and moral issues. Kaunda, 2020, describes the current demand for efficient battery production as the “battery boom” and estimates “the demand for lithium-ion batteries to reach 2.2 million tonnes by 2030”. Kaunda touches on environmental impacts of lithium extraction and processing, stating that “The environmental concerns are especially related to air, water and soil pollution, as well as the depletion of water resources upon which many local communities in these lithium mining regions are dependent.”. They then go on to mention the biophysical consequences which “could adversely impact human metabolism, neuronal communication, soil ecology, and aquatic life.”.

Biodiesel and alternative fuels are another option for automotive manufacturers to consider. Biodiesels produce on average less PM, CO, and THC but a slight increase in NO_x emissions when compared to fossil fuel-based diesels (Knothe et al. 2005). This of course would not comply with zero emissions policies; however technological advancements could further refine biodiesels to produce less emissions. This, combined with vehicle emissions control systems touched on in paragraph 2.1, could greatly reduce the number of emissions released by combustion vehicles.

Hydrogen powered vehicles are an exciting and potentially promising advancement. The Toyota Mira, introduced in 2014 was the first production hydrogen powered car and produced zero tailpipe emissions. Hydrogen is a clean and safe alternative that is readily available, making up 70% of the matter of the universe, hydrogen can be locally sourced and carbon free if renewable energies are used in the extraction process (Toyota).

The automotive industry is at a turning standpoint and needs to think carefully about the future of vehicles as well as the current infrastructure available for consumers. Electric vehicles might seem like a quick and easy way to meet emissions standards, but a huge amount of infrastructure work needs to be completed for consumers to rely on their electric vehicles. Alternatives that use the current fuel transfer infrastructure and allow manufacturers to use existing powertrain designs allowing them to run on biodiesels or hydrogen fuels seem like a more realistic achievement.

4 Conclusion

The CBR1000RR has remained a popular choice in sports bike since its first release despite increasing regulatory pressure. The CBR is a great example of how engineering is used to overcome these pressures whilst still maintaining the image it first portrayed. It also provides a great example of the rise in engineering possibilities with a huge range of new and ever improving additions that have been affected by the introduction of new tools within the industry.

The CBR is a perfect example of an engineering task that has grown and developed with the industry and provides an interesting area to follow for years to come, with Honda's incredible R&D Team continuously working to improve and expand. The zero emissions regulations, although not yet applied to motorcycles, will be Honda's next hurdle for the CBR, with no current electric model it will be interesting to see if the team decide to move the combustion classic to an electric powertrain or decide to move towards clean combustion alternatives.

Either way, now is an exciting time to see the automotive industry change in response to massive political pressures and will hopefully bring rise to a wave of ground-breaking technologies.

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