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Ducati V4

Introduction to Automotive Engineering (ACHA4009)

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1 Introduction

The automotive industry is in part indistinguishable from engineering. For any modern vehicle to be produced it of course must first be designed, simulated, built and tested.

The Ducati V4 makes an interesting case study when looking at some of the facets of engineering owing to the fact it is both at the pinnacle of technology as well as the fact the variations between and the criterium of each design.

Through this variation it is clear to see where compromises were made in order to meet with cost, the expectations of consumers and regulations, either emissions or homologation requirements.

2 Topics and their impact

2.1 Control Systems.

Control systems are becoming abundant on motorcycles. Features such as electronic fuel injection and Anti-lock brakes have already been required by law to be present on any road legal vehicle conforming to euro 4 emissions and traction control commonplace amongst most motorcycles. In addition, Ducati have introduced an Inertial measuring unit (IMU) (Ducati editorial 2022). This allows for the addition of wheelie control, cornering ABS and slide control.

The wheelie control and slide control are fundamentally the same system. Ducati uses a Bosch IMU which incorporates a 3-axis gyroscope and a 3-axis accelerometer, to measure yaw, pitch, roll and its relative acceleration in each of these planes (Bosch 2015). This works in conjunction with the front and rear wheel speed sensors to give the required information to the ECU.

The TCS system has maps to allow for a given amount of variation between front and rear wheel speed and will begin to cut engine power if the difference becomes too high, further to this the IMU measures the rate of yaw, in the case of wheelspin and again will cut power if this value becomes too high. Different maps can be selected by the rider to allow the rear wheel to spin more or less depending on preference.

2.2 Aerodynamics.

Motorcycles have on the whole left aerodynamics un-developed for the last 60 years. Fairing design has largely been based around the concept of reducing drag as much as possible.

In the last decade, Ducati have pioneered the development of motorcycle wing design since their brief introduction in 2008 and re-appearance in the 2015 season in MotoGP. The V4 was the first road legal Ducati to feature such devices.

The primary advantage of winglets is twofold. Firstly, they counter the effects of aerodynamic lift, described as the lift centre of pressure is forwards of the centre of gravity, creating a moment on the motorcycle rotating it backwards around the rear axle, in turn unloading the front wheel at high speeds. (Tony Foyle, 2002)

They also reduce the effect of wheelie when the motorcycle is accelerating, which is often more of an issue than lack of grip when on corner exit.

The design of the winglets and fairing also offer advantages in other areas.

Through the use of winglets, Ducati were able to produce an additional net downforce of 275.56N at 168mph. (Ducati, 2019) Wings have also led to performance increases in other areas, in the same example it was found to have increased flow through the radiator by 2% and the oil cooler by 10%. (Ducati, 2020).

2.3 Emissions.

The Ducati V4, being a road legal vehicle has to comply with euro4 emissions standards. Several devices have been implemented in order to meet the requirements.

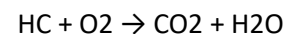
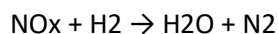
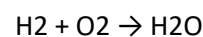
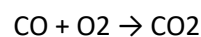
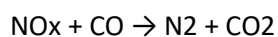
The use of catalytic converters has become increasingly important. The concept behind catalytic converters is exhaust gasses are passed through a ceramic structure formed in a honeycomb type shape, this is to maximize total surface area. This honeycomb is lined with metals such as platinum, palladium and rhodium. Catalytic converters also increase in efficiency as the temperature increases, this is advantageous due to exhaust gasses at the converter are typically in the region of 300 degrees or above.

In this system keeping the engine at or near stoichiometric air/ fuel ratio is also advantageous due to the fact in lean burn conditions the oxygen rich and typically hotter combustion temperatures increase levels of NO_x and decrease the conversion rates. Rich conditions does not have an issue with NO_x however there is a higher number hydrocarbons and carbon oxides (Nettinc 2022).

Three way catalytic converters are now used in motorcycles including the Ducati V4 with exception to the superlagerra.

Three Way catalytic converters reduce levels of Nitrous oxides, Carbon mon/di-Oxide and hydrocarbons within the exhaust system. The major reactions that take Place are Listed below;

FOR OXIDES OF NITROGEN (NO_x): FOR CARBON MONOXIDE (CO): FOR HYDROCARBONS (HC):



(Umicore, 2022)

2.4 Materials.

The V4 superlagerra is a good showcase of the impact materials can have on a vehicle. The V4SL is 152.4kg dry (with the optional Abramovic exhaust) , this is 22.6kg less than the base models.

A large portion of this is due to the use of materials such as carbon fiber, magnesium and titanium.

The exhaust system is made from almost solely of titanium and in its self 6.6kg lighter than the standard system. Titanium is is stronger when compared with density then other common materials such as aluminium and steel, as an example when comparing the ultimate tensile strength of titanium Ti-15V-3Cr-3Sn-3Al against 304 stainless there is a 30% increase. Crucially for this application has a higher fatigue temperature then both materials (AMT, 2012).

Titanium comes with its drawbacks when it comes to production vehicles. Firstly, the initial cost of titanium is in the region of three times that of steel. Additional care must also be taken when fabricating parts from titanium. Extra care must be taken during welding processes due to oxidation when molten will significantly increase the brittleness of the material. Machining processes are also more difficult as the due to its relatively higher tensile strength and low elasticity modulus (Adam Pochopin, 2022)

2.5 Interpretation of Rules.

The V4R is a limited production run of the standard V4 with noticeable changes such as a reduction in engine size.

The reason behind the numerous differences lies within the homologation rules for WSBK.

The FIM specify a minimum of 250 units must be produced with controlled items such as crank shaft weight, conrod length and frame dimensions in order to be eligible to race in WSBK, (FIM, 2021)

These rules are put in place in order to prevent one off prototypes similar to MotoGP machinery.

This, and for the series to be grounded within the consumer market which is why the V4R was produced to a limited of 1500 units, balancing homologation requirements to demand.

Ducati have undoubtable drawn inspiration from the engine used in the MotoGP Desmosedici which also uses a 90 degree 998cc V4 which has been heralded as the most powerful engine in the Motogp. The bore of each of the V4 models the same as the Desmosedici (Ducati, 2019) and with the reduction of engine size in the V4R this theoretically brings the stroke to a similar dimension.

The bore is one of the few similarities between the models, with generally less expense spared throughout the rest of the engine, one of the most restricted components.

2.6 Manufacturing.

The V4 in its various forms shows how varied manufacturing processes can be. The base V4 and V4s are both mass produced vehicles and as such must be made on such a way that compromises profit with quality and performance and delivers on the expectations of customers. For example, comes equipped with premium components such as tyres and brakes. The V4R being a homologation model and a limited production run differs from the base with engines being blueprinted and hand built at great expense to Ducati as well as differences in design in terms of aerodynamics, engine capacity etc.

For every part not shared across models there also comes an additional manufacturing process, for example the V4/S shares the same crankcases, however with the V4R the decreased cylinder size means the entire crankcase is different. Requiring at least additional machining on each crankcase or separate dies for casting.

The Superleggera takes this to another extreme, with its own parts such as forged magnesium front stays and different subframe.

In balance the R and Supperlagera also omits certain parts such headlights and electronic suspension options owed to the fact these are typically sold for use on track.

2.7 Data Systems.

The base V4 and V4s Can be fitted optionally with the Ohlins EC model suspension. (Ducati 2019)
This fork and shock integrated with the standard dash in order to give the user control over the preload and damper settings through the use of servo motors controlling the input to each of the adjustment screws

Having the settings of the suspension controlled electronically has allowed Ohlins to combine a data system in order to have semi- active suspension.

Through the use of an internal stroke potentiometer the suspension ECM can log multiple times per second the position of the shock and its velocity. Combined with other variables such as power maps, rider inputs and recorded data used to predict riding style the suspension is able to self-adjust in real time in order to maximize grip and feedback, ultimately improving performance. (Ohlins 2018)

The Ohlins system also builds in a guide to suspension setup within the user interface.

The ecu on the Ducati will also log various elements such as throttle usage, speed and lean angle due to euro emissions requirements.

2.8 Internal combustion engine.

The engine used in the Ducati is a 90 degree V4 in either 1100cc or 1000cc form.

The two engines are both tailored for their purpose, the 1100cc from the base models produces more torque and bhp lower in the rpm range as apposed to the 1000cc, this is done due to the 1100cc being primarily a road vehicle. The 1000cc being designed to comply with SBK regulations and as such is tuned for peak toque to be higher in the rpm range, as well as an increase in maximum rpm resulting in higher total bhp.

To achieve the increase in maximum rpm Ducati used the same bore dimensions but shortened the stroke, reducing CC to the desired amount as well. The advantage of using a shorter stroke in regards to RPM is the piston speeds are reduced, 23.183m/s average for the 1100cc at 13000rpm compared to 20.975m/s at 13000rpm for the 1000cc. In turn there is a reduction in piston acceleration experienced by the piston, pistons which also differ between the two engines although no data is provided on how these have been changed. It would be reasonable to assume that due to the higher rpm limit and average speed they reach (25.76m/s) a reduction in weight and/or increase in strength would be achieved owing to the fact

3 State of the Industry and Conclusion

The unfortunate reality of the motorcycle industry is that time is limited, through increasing emissions regulations some models have been discontinued, such as the CBR600rr, where in its final iteration it made less power than the previous model. Or in the case of the YZF R6 where it is only sold for track use only.

The V4 is no exception, with exhaust systems that reduce power figures in aid of emissions for road use.

With the UK government stating there to be no tailpipe emissions by 2030 the use of modern and more environmentally friendly fuels may not be permitted.

The search for an alternative is perhaps one of the most pressing issues for the motorcycle industry in current times and the need for innovation in engineering more important than ever.

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