

MSc Motorsport Engineering

CFD and Emissions Modelling

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Introduction

In this assignment an engine specification will be proposed for use in L-class vehicles for 2035 and beyond, based on CFD engine data obtained from ANSYS forte and Ricardo WAVE. This means that the engine must comply with the incoming regulations proposed to come into effect in 2035, which includes the ban of sales of non-zero emission L-category vehicles from this time. This assignment will first discuss the proposed regulations and the current state of future developments in this sector, before proposing and justifying an engine specification for future use based on these challenges.

1: Emissions Regulations and Current Outlook

It is currently proposed that new non-zero emission L-category vehicle sales be ended by 2035 at the latest, with a view to bring this into effect as early as 2030 for some vehicles in this group (Department for Transport, 2022). The government states that it remains neutral on the issue of what to replace conventional petrol ICE engines with, which leaves the issue of with what to replace these fuels with open. Portions of the market are turning to battery electric vehicles, while others are beginning to use hydrogen, both in fuel cells and in ICEs, and the use of bio or synthetic fuels has also been proposed and is being considered by the government (Department for Transport, 2022).

Battery electric power has shown to be particularly popular in the car industry, although with less uptake for motorcycles and other L-category vehicles, with petrol engines still remaining the most popular. However, this class of vehicles is broad and thus a breadth of solutions are required for the sector. For example, 41.65% of L1 vehicles registered in 2021 were BEVs, compared to only 2.86% of L3s (Department for Transport, 2022). Thus, it is clear that while the industry is proving that a trend towards BEVs for mopeds, powered cycles, and small city cars appears to be effective, conventional motorcycles may require a new fuel solution for a carbon-neutral power source. With that being said, electric motorcycles are being designed and manufactured by big brands; Kawasaki's Ninja e-1 is one example of a fully BEV full-size motorcycle. In road mode, the bike has a reported range of only 41 miles at a top speed of 55mph with a boost taking this speed to 65mph, owing to the 12hp electric motor (Kawasaki, 2023). These specifications are a far cry from the ICE Kawasaki Ninja of a similar price point, which generates 67hp from a 649cc parallel twin (Kawasaki, 2025), and can reach twice the top speed. The size and weight of electric motors and batteries prohibit vehicles of a motorcycle's form factor from gleaning the same performance and range that can be found in many electric performance cars.

In order to meet the impending regulations of zero tailpipe emissions, vehicles will likely have to transition to BEV, hydrogen FCEV, or hydrogen ICE engines. However, efforts will still have to be made to reduce the carbon impact of existing conventionally fuelled vehicles, given the prominence of the second hand vehicle market and the age of the average vehicle on the road today. The average age of a motorcycle in the UK is 15.4 years as of 2020 (Department for Transport, 2020), and so synthetic or bio fuels and blends compatible with these engines should be investigated for this purpose. Synthetic fuels are gaining traction in the wider motorsport world, with top motorsports Formula 1 and the WRC following this route, with the WRC switching completely in 2022 (FIA, 2023) and F1 set to make the move next year (Benson, 2022). This will draw greater research towards this fuel technology, which may result in greater cross-pollination for this technology between the motorsport and automotive sectors.

2: Proposed Engine Configuration

The alternative fuel proposed here is a blend of synthetic ethanol and synthetic diesel, sourced from reclaimed carbon from the atmosphere in order to create a carbon-neutral fuel solution. This configuration could be further iterated upon to add exhaust gas recirculation, which would ensure that the combustion process is more complete, resulting in less harmful carbon, and carbon monoxide, and NOx, common in many diesel vehicles due to their predisposition to create NOx.

2.1: Methodology

Firstly a sector mesh was created for use in the ANSYS forte simulation from the following sketch.

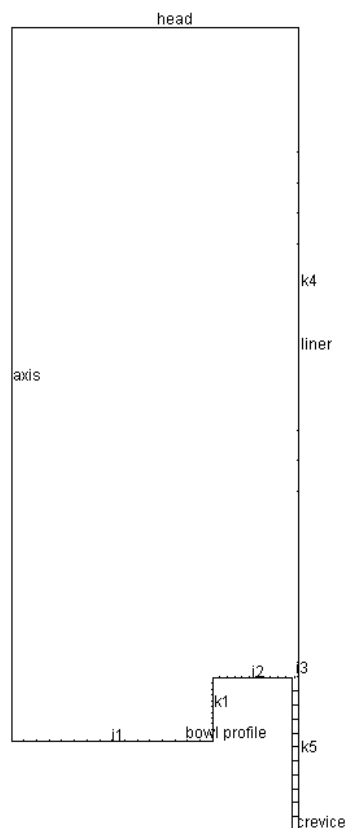


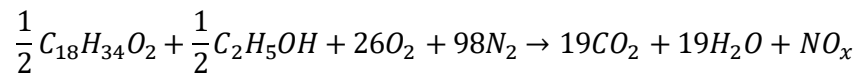
Figure 1 - Sector mesh sketch

A sector mesh was used as a means to cut down on the simulation time by only carrying out a computational flow dynamics simulation on a sector of the full cylinder, and extrapolating this data to form the full simulation. This significantly cuts simulation time while preserving data accuracy (Manoj, Pandurangadu, Prasad, & Reddy, 2013).

2.2: Chemistry

The below equation represents the combustion of 50-50 synthetic diesel and synthetic ethanol, with the biodiesel simplified into a methyl ester, and air containing oxygen and nitrogen. The below equation

shows complete combustion, where the true equation would likely release carbon monoxide and solid carbon.



2.3: Results Analysis

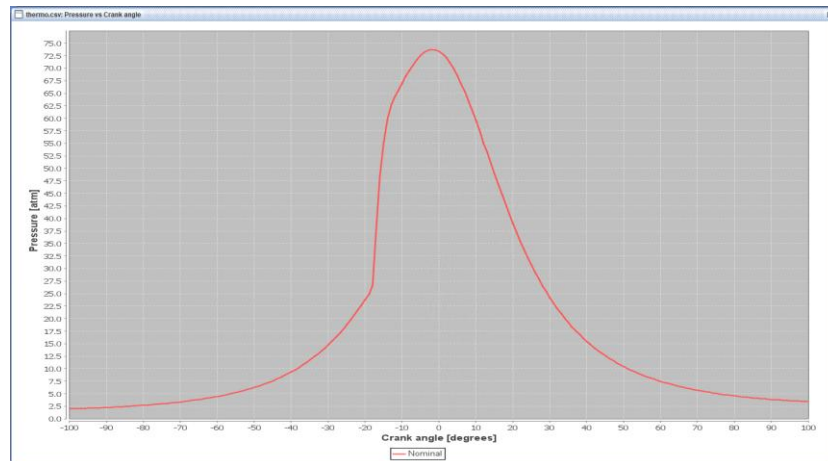


Figure 2 - Pressure plot

Above is the pressure trace. The initial increase can be observed owing to the compression stroke of the engine, before the fuel is injected.

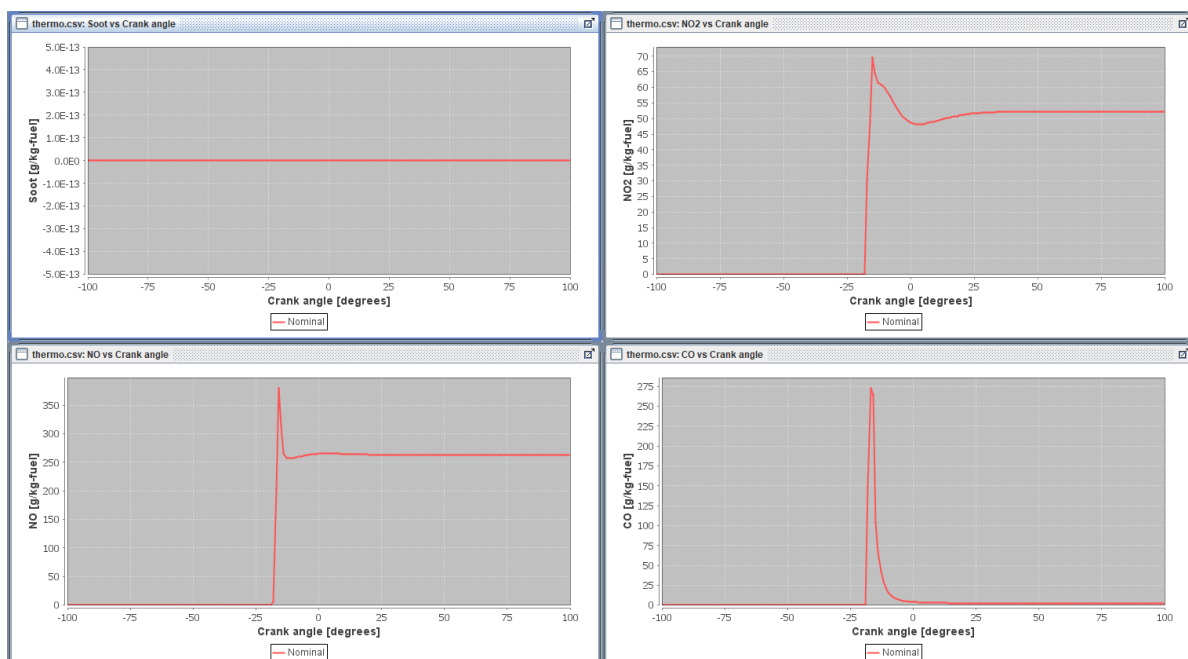


Figure 3 – Emissions Output

These graphs show the emissions output from the sector simulation. The soot stays at zero throughout the simulation as soot was not modelled during this simulation. This can be further investigated in

further testing. NO_x emissions can be seen to be produced from the simulation, with significantly greater NO production than NO₂, at roughly 5x greater NO than NO₂. Carbon monoxide production is very low in this model, stabilising after combustion at around 2.5 g/kg.

Based on these simulations, the engine configuration is functional, and given the synthetic nature of these fuels, net zero carbon. This can serve as a configuration to be used to reduce emissions of the large second hand vehicle market and of the motorsport industry, which is likely to remain with ICE engines for the foreseeable future.

Conclusion

The current state of alternative and low emission fuels and powertrains were analysed for class L vehicles, and an engine configuration was investigated based on these regulations and technologies. A blend of 50% synthetic ethanol and 50% synthetic diesel was selected for further analysis, and the emissions data from this was analysed. While the configuration obviously does produce carbon emissions, it is a net-zero emission solution, and synthetic fuels are often able to be used with existing engines, thus reducing the carbon impact of these vehicles.

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