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CO2 Emission Reduction Synergies of Advanced Engine Design and Fuel Octane Number

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ABSTRACT

Engine downsizing is a key approach employed by many vehicle manufacturers to help meet fleet average CO_2 emissions targets. With gasoline engines in particular reducing engine swept volume while increasing specific output via technologies such as turbocharging, direct injection (DI) and variable valve timing can significantly reduce frictional and pumping losses in engine operating areas commonly encountered in legislative drive cycles.

These engines have increased susceptibility to abnormal combustion phenomena such as knock due to the high brake mean effective pressures which they generate. This ultimately limits fuel efficiency benefits by demanding use of a lower geometric compression ratio and sub-optimal late combustion phasing at the higher specific loads experienced by these engines. The lower expansion ratio and retarded combustion in turn increase the exhaust gas temperature, which often leads to a need to add extra fuel that cannot be fully combusted in order to cool and protect engine components from thermal damage. Optimizing the engine design for use with a fuel with an increased research octane number (RON) allows the adoption of a higher compression ratio. This gives thermodynamic efficiency benefits at lower loads whilst mitigating the compromise in combustion phasing at high loads and reducing the requirement for over-fuelling. These synergies allow reductions in CO_2 emissions and fuel consumption in both legislative drive cycles and real world driving.

To quantify the benefits of such an approach a prototype 1.2l 3-cylinder turbocharged gasoline engine with a maximum BMEP of 30 bar was installed on an engine test bed and its operation optimised across a range of compression ratios and fuel octane numbers. For each combination of compression ratio and fuel octane number full operating area maps of fuel consumption, key combustion parameters and exhaust emissions were developed and are analyzed here.

The key findings were:

- Simultaneously increasing the compression ratio from 10.2:1 to 12.2:1 and fuel octane number from 95 RON to 102 RON resulted in BSFC improvements of between approximately 4% and 15% depending on operating point.
- Increasing the compression ratio from 10.2:1 to 12.2:1 on 95 RON fuel could reduce BSFC by approximately 4% at loads up to around 10 bar BMEP. However, at full speed and load BSFC was increased by over 30%.
- Operating the engine at 12.2:1 compression ratio and with 95 RON fuel required that engine be de-rated by ~10% beyond 4000 rpm to avoid exceeding the maximum turbocharger speed.
- Increasing the fuel octane number from 95 RON to 102 RON at a compression ratio of 10.2:1 greatly expanded the region where optimal engine operation was not limited by knocking combustion. However, in some knock limited regions the design maximum cylinder pressure and rate of pressure rise limits were reached before the knock limit.