

Influence of Oil Drain Holes on Oil Emission of a Turbocharged Gasoline Engine

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ABSTRACT

The oil emission of a combustion engine has a direct influence on CO₂ and particulate emissions. The focus on reducing oil emission is thus particularly growing in the context of stricter emissions limits for the automotive industry. To reach this goal requires a deeper understanding of the mechanism behind the genesis of oil emission in a combustion engine. In order to determine oil emission caused specifically by the piston group, part of the exhaust gas flow is taken and analyzed using a mass spectrometer directly downstream of the exhaust valve in the exhaust manifold. In the process, the mass spectrometer is operated in high-pass filter mode to detect long-chain hydrocarbons associated with the lubricating oil. In order to make differentiated and detailed statements about oil emission mechanisms, oil emission and blow-by in steady-state and transient engine operation are determined for specific design parameters of the piston group. A highly transient test cycle developed specially for this purpose is used when investigating transient engine operation. Using a standardized and fully automated evaluation tool, characteristic key figures can be calculated for oil emission and blow-by. They reflect the influence of various piston and ring designs on oil emission. This article describes the measurement system, the proprietary test cycle, and the influence of piston designs, such as oil drain holes in the area of the oil control ring and breaks along the third piston groove lower flank on oil emission and blow-by. A better understanding of mechanisms can contribute to more effectively minimizing oil emission and consequently CO₂ emissions.

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INTRODUCTION

The term "oil consumption" generally refers to the amount of engine oil by which the amount of oil in the engine is reduced over a specified period of time. Generally, over 90 % of oil consumption ends up in the form of unburned hydrocarbons in exhaust gas and is characterized as "oil emission" [1]. The measured CO₂ emissions after the catalyst are mainly formed by the burned fuel. However, the CO₂ formation due to oil emission is not negligible [2] and must be addressed in modern engines. It is also not uncommon that engines, which do not show any oil consumption problems during conventional steady-state bench testing experience increased oil emission in normal everyday operation, i.e., in transient engine operation (real driving lube oil consumption). A frequent simple

solution is to increase the tangential load on the oil control ring in order to reduce oil emission. However, this inevitably leads to increased engine friction and thus CO₂ emissions due to higher fuel consumption [2]. Furthermore, by increasing the tangential load in the steady-state operating ranges, lubricant quantity is frequently reduced to such an extent that it leads to inadequate lubrication conditions of the piston or piston ring package. This absolutely must be avoided. Accordingly, for transient, everyday use a reduction in oil emission needs to be achieved by influencing other parameters. Therefore, the focus in this article is less on steady-state oil emission than on an attempt to minimize the so-called dynamic oil emission through suitable piston design parameters. [Figure 1](#) shows schematically four piston variants of this parameter study.

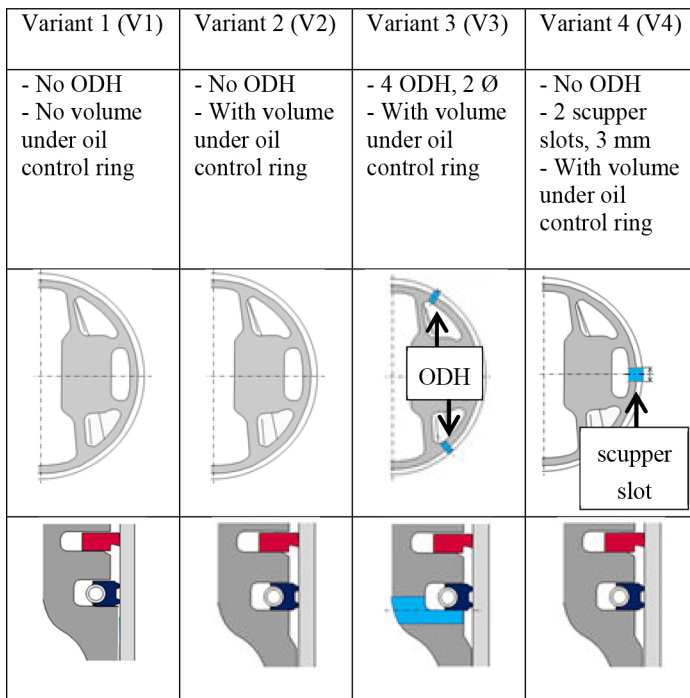


Figure 1. Schematic diagram of the four investigated piston variants with a horizontal section in the third groove (above) and a vertical section (below)

In this article, the oil drain cross-section area is defined as the cross section of the oil drain holes (ODH) in the third groove and the cross section of the break in the third piston groove lower flank, which is characterized as a scupper slot (sc). It focuses on actions that influence oil drainage in the area of the oil control ring. In variants 3 and 4, the oil drain cross-section area is varied, while variants 1 and 2 do not have any oil drain holes. In addition, variant 1 is the only variant that has no relief volume under the oil control ring in the form of a surrounding groove (missing J groove).

Measurement System (Quadrupole Mass Spectrometer)

Depending on the required scope of work and the problem description, various methods can be used to measure oil emission. Mass spectrometry has proven particularly effective to measure highly transient load and speed changes as well as for fast, reproducible online measurements of the entire engine map. Figure 2 shows the oil emission measurement system [3] for conducting measurements on the turbocharged passenger car gasoline engine.

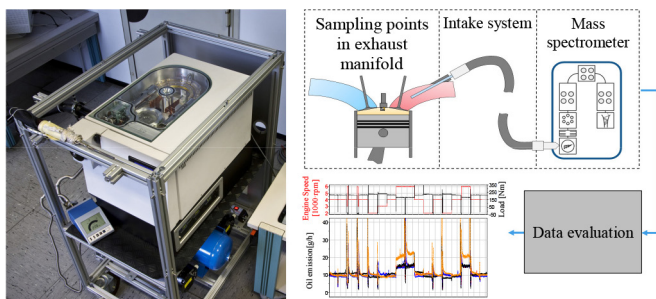


Figure 2. LUBRISSENSE 1200 mass spectrometry measurement system-schematic test setup and transient test cycle for measuring oil emission

The unburned oil molecules contained in the exhaust gas are detected directly. The measuring unit continuously samples a defined, cylinder selective, amount of exhaust gas using a heated sampling system consisting of a sampling probe, a short transfer line, and a pressure-controlled inlet body. The sampling system transfers a portion of the exhaust gas to the ion source of the mass spectrometer. Using electron impact ionization, the sampled exhaust gas molecules are ionized and fed through a hexapole to the mass filters (quadrupole). The various exhaust gas components are separated based on their molecular mass. The volatile content from the combustion process as well as short-chain hydrocarbons from the fuel are separated by the quadrupole mass filters from the long-chain hydrocarbon content of the lubricating oil, which has a higher molecular mass [4]. As a result, only hydrocarbon molecules from the lubricating oil are detected and converted into an electrical signal at the detector. Based on this signal, the concentration of oil in the exhaust gas is determined. With the exhaust gas mass flow, which is determined in real time from the amount of air and fuel consumed by the engine, oil emission is calculated from the oil concentration. While oil emission is being measured, blow-by is also captured simultaneously and evaluated.

Exhaust Sampling Points Application

For the implementation of oil emission measurements, the exhaust manifold is equipped with exhaust sampling points (Figure 3). The exhaust sampling points are positioned as close as possible to the middle of the respective exhaust manifold, while the distance from the exhaust valves is held constant. This ensures comparable thermodynamic and flow dynamic influences on the measurement result for all cylinders.

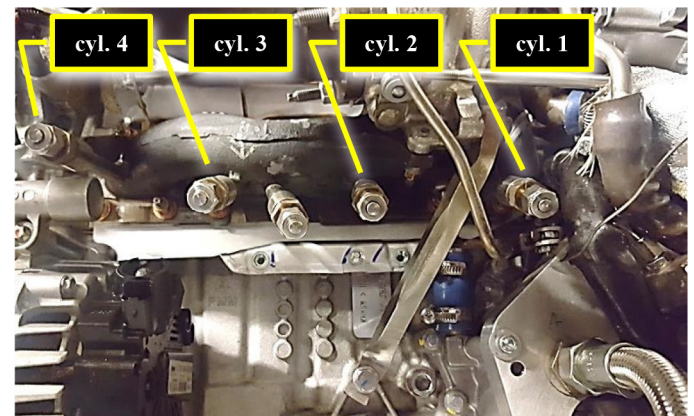


Figure 3. Exhaust sampling points in the exhaust manifold for cylinders 1 to 4 on a turbocharged gasoline engine

TRANSIENT TEST CYCLE

A specifically designed transient test cycle consisting of 25 operating point changes is used to perform a detailed analysis of oil emission mechanisms [5, 6]. Figure 4 shows a schematic diagram of the speed-load sequence of the test cycle in an oil emission map.