Evolving HD Engine Efficiency to the next level

- A Pathway to 56% Brake Thermal Efficiency for Commercial Applications -

Th. Körfer[3)] U. Grütering[1)] L. Virnich[1)] J. Yadav[1)] J. Satyum[2)] S. Paul[2)]

1) 1)FEV Europe GmbH, 52078 Aachen, Neuenhofstrasse
2)FEV NA Inc., 4554 Glenmeade Lane, Auburn Hills, MI 48326
3)FEV Group GmbH, 52078 Aachen, Neuenhofstrasse

KEY WORDS: **Heat Engine, Compression Ignition Engine, Efficiency, Optimized Combustion, Hybridization, Advanced Crank Drive, Atkinson Cycle**

Modern Diesel engines represent even in today's fast paced world the workhorse for the modern society with all integrated industrial delivery chains. Reliable and versatile Diesel engine technologies are so ubiquitous in the broad field of applications, ranging from delivery trucks and vocational vehicles over agricultural and construction equipment up to rail applications and inland waterway ships and workboats. Even in stationary applications Diesel Engines play a major role ensuring electric power generation as emergency power generator. The refined Diesel engine will maintain to play a pivotal role in the mid-term future. This paper deals with the optimization and improvement of the thermal efficiency of Diesel engines According to recent testing reports in commercial vehicle magazines, new engine developments offer the most refined and enhanced combustion efficiency. The new engine types are positioned in the well-known straight-6 engine variants and offer significant fuel efficiency advantages vs. the established competition. The new engine features a 4-valve DOHC cylinder head with refined port geometries and incorporates as well also a cam phaser for active management of the applied valve timings. The technical approach to the base engine architecture in this study starts on the base of an earlier engineering campaign, aiming to achieve the best BTE figure of 51,4% by conventional refinement and optimization on classical parameters. According to the recent trends in CV propulsion systems and the strong political push for extended and wide-spread electrification, the new research activity aimed towards an increased electrification grade, utilizing more powerful electrical traction systems on higher voltage levels. As part of efforts to reduce transport-related CO_2 emissions, improvement measures to increase the engine brake thermal efficiency of a HD diesel engine within a hybrid drive concept were analyzed. A maximum thermal efficiency potential of 56% at the best BTE point was determined, as shown in the bar chart in Fig. 1.

The combustion system layout realizes rapid mixing and conversion of the fuel injected at a high rate by optimizing the free jet length using a star-shaped piston bowl and an expanded spray angle. The necessary charge motion, adapted to this, is realized with only minor flow restrictions, and the gas exchange work is further reduced through flow-optimized intake and exhaust ports. High peak pressure capability enables early combustion phasing, thereby reducing efficiency losses caused by deviations from the ideal process. The increase in permissible NOx raw emissions allows the elimination of EGR, which alleviates the trade-off for faster mixture preparation by providing a higher oxygen supply, enables further reduction of gas exchange work, and simultaneously improves the efficiency of the charging system. The illustrated turbo-compound technology enables an additional increase in useful work with only a slight increase in gas exchange losses. In combination with electrification of auxiliary drives, an overall efficiency of 54 % can be achieved for a conventional engine concept. Introducing geometrically extended expansion (Atkinson cycle) and further increasing the engine's peak pressure capability to 300 bar, makes it possible to reach an effective engine efficiency of 56 %.

Investigating the potential of High Power Density Engines with 43 bar IMEP 'GenSet applications' a significant reduction in compression ratio is necessary as peak firing pressure is reached immediately. So best thermal efficiency of 45.6 % for high power density engine is reached with a CR of only 14. (Fig. 2)

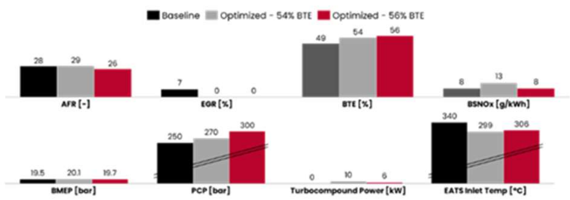

Fig.1 Comparative Depiction of main engine parameters at the main operational mode @1200rpm

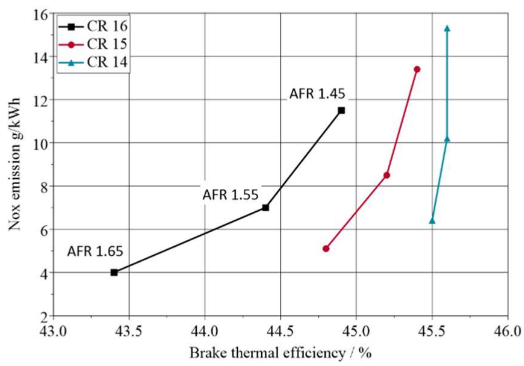

Fig.2 NOx / BTE tradeoff for CR and A/F Ratio Variation for High Power Densitiy Engine (IMEP 43 bar)

2026 JSAE Annual Congress (Spring) - Summarized Paper
Issued on May 22, 2026