

New MAHLE Steel Piston and Pin Coating System for Reduced TCO of CV Engines

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ABSTRACT

Total cost of ownership is requiring further improvements to piston friction reduction as well as additional gains in thermal efficiency. A piston compression height reduction in combination with carbon based piston pin coatings is enabling advancements in both demands. MAHLE implemented a new innovative metal joining technology by using laser welding to generate a cooling gallery. The MonoLite concept offers design flexibility which cannot be matched by any other welding process. Especially an optimum design and position of the cooling gallery as well as durability for very high peak cylinder pressures can be matched. This is particularly advantageous for complex combustion bowl geometries that are needed in modern diesel engines to meet fuel economy and emission requirements. The MonoLite steel piston technology offers a superior compression height reduction potential compared to typical friction welded designs. Using this benefit to reduce side forces by a longer connecting rod, the full friction reduction potential is achieved by a combination with a new low friction carbon based coating on the piston pin. The new coating shows best-in-class performance in terms of friction and high temperature resistance compared to currently available pin coatings.

The shorter compression height also results in reduced oscillating masses. This can be used for further weight reduction in the whole drivetrain, which allows the implementation of further systems for better fuel efficiency, e.g. waste heat recovery, without reducing payload.

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INTRODUCTION

The reduction in fuel consumption and thus CO₂ emissions is always the focus of the development of all heavy duty vehicles and buses. This development target is also pursued with highest priority for the future drive concepts in the commercial vehicle sector, because today about 35% of the average logistics costs are determined in the long-distance transport by fuel consumption [1].

Therefore for the carrier, fuel consumption is an essential purchase criterion to optimize operating costs and to remain competitive by having low total cost of ownership (TCO).

In recent years substantial progress in the increase of the thermal and mechanical efficiencies was achieved for the motors. It is expected in the future that more optimization measures including better exhaust gas heat recovery (Waste Heat Recovery) will improve in conventional diesel engines the thermal efficiency (BTE) up to 55% [2] [3].

A relevant contribution to this optimization will come from the reduction of the internal engine friction. The piston assembly represents up to 25% of the energy loss [4] [5]. At the same time, the increasing performance requirements regarding power response, in combination with a probably, slightly increased gross load weight,

will raise the maximum torque targets. This can be achieved among others by increasing the peak firing pressure and modifying accordingly the piston assembly.

The balance between those different requirements for a modern heavy duty diesel engine drives MAHLE product development by focusing on a system approach. In this case due the development of the new MonoLite® piston in combination with the new carbon based piston pin coating was possible to contribute significantly to the fuel consumption reduction by minimizing the friction losses and contributing to a relevant reduction of the oscillating masses. This new Heavy Duty PCU system helps to achieve the future emissions requirements and to accomplish successfully a competitive TCO. Additionally the application of low viscosity oils is a typical friction reduction measure. The presented technologies also cover the connected potential increase of scuffing and wear sensitivity.

NEW MAHLE STEEL PISTON CONCEPT

So far, MAHLE has already since 2000 successfully introduced the one piece Monotherm® steel piston into the market which is still in production today. It offers a very good ratio between weight/compression height and durability for applications in the range of up to 23MPa peak cylinder pressures [7].





Figure 1. Monotherm® one piece steel piston

However, engine trends and regulations such as EU VI or GHG14 and beyond are targeting for higher maximum PCPs, which makes a full skirt piston a preferred solution. MAHLE developed for this purpose the MonoWeld® friction welded piston, which offers not just a higher durability, but as well an improved cooling efficiency. In a direct comparison between the two concepts, a temperature reduction at the bowl rim by up to 70K could be achieved (see [figure 2](#)). This improvement is based on two aspects. One being the reduction of the wall thickness towards the bowl and the other aspect being the improvement of the hydraulic parameters in the cooling system of the piston by the closed cooling gallery.

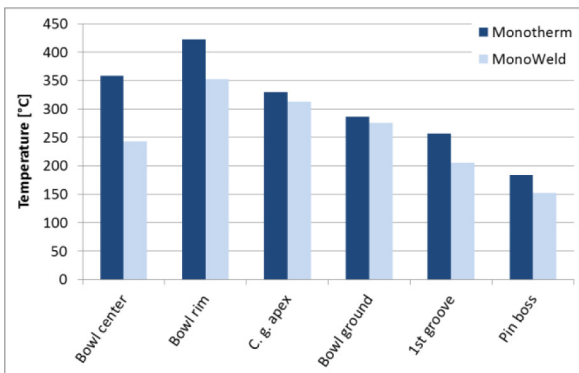


Figure 2. Temperature measurement results Monotherm® vs. MonoWeld® at rated power and 20 MPa

A drawback of the friction welded piston is the necessary space to accommodate the weld seams and flesh with the according heat affected zone. This leads to an increase of the minimum achievable compression height of the piston compared to the Monotherm® design (57% vs. 45% CH/D). In order to combine the two aspects of the aforementioned design concepts - the high cooling efficiency on the one hand and the low compression height and weight on the other hand - MAHLE introduces a completely new piston concept, based on a laser welding process.

The new MonoLite® piston offers a high durability for PCPs beyond 23MPa while being able to provide also a very progressive approach in terms of compression height down to approx. 45%. Key motivation of the piston development was a high degree of freedom for the design of the general compression height with regard to the load requirements and also to provide cooling gallery shapes and cross sections that give the best benefit in terms of bowl rim temperatures. Investigations have shown that a reduced cross section as part of a cooling optimization can have positive effects on the cooling performance by increasing the catching efficiency and reducing the

dwelt time of oil in the gallery. Additionally, shapes such as a kidney like design or other geometries are possible to be manufactured with the laser welding process. E.g., smaller cross sections compared to a typical friction welded design and specific shapes that can be implemented improve the overall cooling situation. This is accompanied by an optimized positioning of the gallery which can be maintained by the laser welding concept to provide the best solution for each application. In back to back measurements of a friction welded and a laser welded piston, the results show a similar result in bowl rim temperatures even though the cooling gallery of the laser welded piston is about 38% smaller in this case. The main difference can be seen in the pin boss temperature ([Figure 3](#)).

Furthermore, the laser weld seams do not imply a high amount of material being displaced during the joining process and therefore offering clean and smooth gallery surfaces over the whole circumference (see [figure 3](#)).

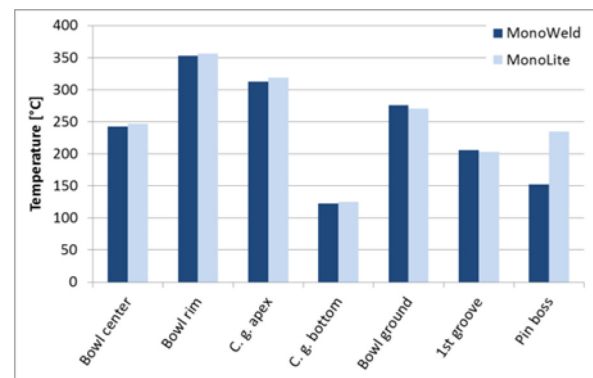


Figure 3. Temperature measurement results MonoWeld® vs. MonoLite®

Especially the aspect of a potential blockage of either the cooling gallery cross section in the upper part or the oil inlet can be completely avoided with this technology.



Figure 4. MonoLite® laser welded steel piston with low compression height

Comparing directly a friction welded piston with a laser welded solution for the same application and PCP requirement, the weight of the laser welded version can be reduced by approximately 1.1 kg (see also [figure 5](#)) for a typical 130 mm diameter class piston. A parametric study regarding higher PCPs and the anticipated increase in compression height for durability reasons show that even for up to 30MPa the laser welded piston would still offer a slight weight benefit of 80g compared to the 24MPa friction welded solution. The following [Figure 5](#) illustrates the scalability and benefits for weight and design flexibility for higher PCPs.