New Materials and Processes
for Passenger Car Diesel Engine Pistons
Introduction

The development targets for today’s diesel engines cater to high performance and high torque while curbing fuel consumption. Additionally, exacting demands are made on noise reduction and ride comfort.

The European exhaust gas standards EURO 5 and EURO 6, which are coming into force in 2009 and 2014, respectively, are bound to accelerate the development of high-performing injection and exhaust gas post-treatment systems.

In order to meet the future requirements coming from the mentioned standards, KS Kolbenschmidt GmbH has developed a new generation of aluminum materials for pistons and a novel laser technology for local improvement of the thermal fatiguing characteristics of the material in the combustion chamber bowl zone. The optimization of the dimensioning and computation methods applied, along with improved piston cooling and the reduction of piston friction are features to be considered for every new piston development.

Thermal and mechanical piston loads

The aforementioned customer requirements prompt higher mechanical and thermal stresses acting on the piston. The demand for low weight coupled with geometric constraints (low compression height, small pin diameter) for peak pressures of 200 bar and beyond are the drivers for consistent further development of our aluminum materials and the search for new design solutions.

The pin boss design, refined pin bore geometry and pin geometry are the geometric measures at hand to boost the boss load capacity – however, an improvement in the allowable load exerted on the boss invariably leads to a higher bowl edge load. Hence in each case a trade-off must be made between boss and bowl loads. To achieve a maximum contact surface between the piston pin and the boss, the piston-boss spacing is reduced by using a tapered conrod. High contact pressures between pin and conrod as well as the shape stability of the small-end conrod bore are setting limits. When all geometric possibilities are exhausted – such as the curved inner boss surface – the use of boss bushings is reasonable.

Fig. 1: Passenger car diesel pistons designed for high thermal and mechanical loads
to achieve a further increase in boss load capacity. This solution has been proven in mass production for many years. The changeover to lead-free bushing materials as prescribed by the EU End-of-life Vehicle Ordinance has been largely completed.

The second, especially critical, area of high-loaded state-of-the-art diesel pistons is the combustion chamber bowl. Future specific engine performance outputs of 70 kW/l and more will result in bowl edge temperatures exceeding 400°C (cf. Fig. 2.).

The combination of thermal-mechanical fatiguing (TMF) and the high frequency fatiguing (HCF) resulting from the gas force may lead to cracking at the bowl edge or other areas of the bowl subject to high load. This requires improvement of the material characteristics.

**New material generation – V4**

Diesel pistons made of the new KS Kolbenschmidt alloy V4 are specifically suited to comply with the aforementioned requirements. The aluminum-based alloy will appreciably extend the product life in temperature ranges above 300°C. This is made possible by a selectively developed alloy composition and a process-controlled microstructure adapted to the specific thermal and mechanical piston loads (cf. Fig. 3). Fig. 4 illustrates the improvements achieved with it in the bowl edge thermal shock test.

**New laser technology – local bowl edge remelting**

For especially high local thermal and mechanical loads at the bowl edge of diesel pistons, KS Kolbenschmidt has developed a hybrid remelting process where a zone subject to high load is remelted under controlled conditions by applying laser technology (Fig. 5).

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**Fig. 2**: Temperatures in a passenger car diesel piston as a function of engine power output
This will produce an optimized, fine and homogeneous microstructure. This structure improves the thermal fatiguing properties of the critical zone by up to 60%. Further advantages are higher process stability compared to casting and improved surface quality for finishing. The laser remelting method is a tailored solution that allows a distinct increase in reliability and quality of diesel pistons to be achieved.

**Piston cooling – DynamiKS® – new piston cooling concepts**

For effective temperature control, pistons have a hollow annular cooling channel filled with oil through a nozzle installed on the crankcase. The oil will absorb heat and dissipate it upon leaving the channel. The position, and mainly the shape, of the cooling gallery significantly influence the temperature distribution of the piston.

This is the reason why KS Kolbenschmidt is continuously optimizing its cooling gallery designs. Today’s KS Kolbenschmidt standard is the ContureKS® cooling gallery with variable cross section that has already provided satisfactory service in millions of passenger car and utility vehicle diesel pistons.

The latest development, the DynamiKS® pump cooling gallery (Fig. 6), takes advantage of the piston movement dynamics to attain an increased oil throughput. The special, staged geometry, patent pending design imposes a velocity component on the oil in a circumferential sense during oscillation. The higher flow velocity substantially enhances the oil transport. Compared to ContureKS®, a temperature reduction of up to 20 °C is achieved at the bowl edge.

Both ContureKS® and DynamiKS® cooling galleries are produced cost-effectively using saltcore technology, a method tried and tested for more than 40 years. The DynamiKS® pump cooling gallery is already service proven in mass production, being applied for maximum specific engine performance outputs.

Further solution approaches geared to improving piston cooling have been analyzed at KS Kolbenschmidt in the advanced development phase. To this end, piston temperatures for a typical passenger car diesel engine with different cooling gallery geometries, in combination with one and two cooling oil nozzles, were measured and compared. The twin-nozzle concepts especially yielded a further distinct boost in cooling efficiency /1/.

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**Fig. 3:** Macrostructure V4 in bowl edge zone

**Fig. 4:** TMF results V4

**Fig. 5:** Passenger car diesel piston with remelted bowl edge
Outlook

The ring carriers in a piston can be used for supporting a specific cooling gallery which consists of a specific-shaped plate welded tight to the ring carrier. This design is particularly appropriate for pistons where high loads require that they have a ceramic fiber reinforcement – FibreKS® – in the piston relief zone. The Squeeze-Cast process needed for this piston type requires fewer cast-in parts but the gallery geometry must be appropriate for the high pressures inherent in this process. Pistons of this design have already demonstrated their functionality in many engine runs.

A subject which has again and again been in the focus of discussion is the use of steel pistons in passenger car diesel engines.

For this market, it should be considered that the assets of steel pistons such as reduced installation clearances, low consumption figures, long service life have to be harmonized with the customer demands for low emission levels, light-weight, efficient cooling and a competitive price.

The latest results of various advance development projects demonstrate that this is viable, and the foundations are laid for the application of this technology in mass production. Fig. 7 shows a cross section through a KS Kolbenschmidt developed passenger car steel piston for diesel engines of low compression height.

As one of the leading international piston manufacturers, Kolbenschmidt Pierburg is in a position to deploy the synergies between the areas of large pistons, utility vehicle and passenger car pistons for the benefit of each and every one of these product ranges. In doing so it can draw on the wealth of experience gathered from local development projects worldwide at the development centers and plants in Europe, North and South America as well as Asia.

Bibliography
