The new W12 engine installed in the Audi A8 is the result of continuous development of the W12 engine concept. By optimising the intake and exhaust systems and by reducing friction within the moving parts, power and torque have been increased whilst at the same time reducing fuel consumption. Installed in the Audi A8, as in the new Bentley Continental GT [1], is the new 6 speed AL600 transmission, in which the front differential is located forward of the torque converter. In conjunction with the extremely short W12 engine, this allows permanent four-wheel drive to be realised whilst allowing a very short front overhang of the vehicle [2].

1 Introduction

Developed for the top luxury models of the Volkswagen Group, this W-engine series is derived from the V-type range of engines [3].

With a cylinder angle of 15°, the V engines have a good track proven history in many vehicle configurations with 5 and 6-cylinders [4]. They combine the advantages of a very good in-line engine with those of a conventional V engine. The 15° V engine is 25% shorter than similar sized in-line engines and about 80% narrower than comparable V engines. The result is a very compact engine, which is very similar to an ideal in-line six cylinder unit in terms of smooth running properties. If two of these compact V6 engines are joined to form a V engine with 72° cylinder angle and common crankshaft, the result is a V-V-12 engine or, simply, a W12 engine, see Figure 1 [3].

This engine was first installed in the A8 6.0 ltr [5] and as an 8-cylinder version in the Volkswagen Passat W8 [6], and later in the Volkswagen Phaeton W12 [7].

A version of the W12 with 2 turbochargers is now installed in the Bentley Continental GT [1], which has just started series production. The W16 engine in the top luxury Bugatti Veyron 16.4 [8] is also based on the W engine principle.

The new Audi A8 is now installed with
the revised W12 engine with increased performance and higher torque.

2 Further Development of W12 Engine

The following chapter concentrates on the most important changes to the main components, compared with the W12, installed in the VW Phaeton.

Figure 2 shows the lateral and longitudinal cross-section. The Table shows the technical data for the W12 engine in the new Audi A8.

2.1 Crankcase

The crankcase has been further developed from the previous model. The main external changes are the oil filter/cooler module, which is now directly mounted to the crankcase, and the modified gearbox flange for connection of a new 6-speed transmission.

One of the main goals in the further development of the W12 was the reduction of the friction losses of the moving parts. Part of these friction losses is attributable to the pump action losses of the air forced down by the pistons. These losses are relatively high on the W12 because the pulsating air mass beneath the pistons hits small crank chambers, which result from the engine’s compact design.

Until now, a means to compensate this pulsation was provided by 5 holes, of 24 mm in diameter, drilled into the cylinder block bearing pedestals. However, since with this solution the pillar of air must first pass into its own crank chamber and then via the pedestal bores into the adjacent crank chambers which are also covered by the crank webs, this results in pulsation losses.

In order to minimise these losses, pulsation cross-sections were engineered that are formed by two cores cast into the structure, Figure 3.

The geometry, developed from a series of FEM calculations, is distinguished by the fact that mechanical stress is focused in areas with high cross-sections and areas with low cross-sections have been placed away from the stress peaks, Figure 4.

This way, it was possible to reduce the maximum mechanical stress on the crankcase by about 5% in calculation, despite an increase in the pedestal hole sizes. In order to implement this calculated advantage in real terms on the cast part, a high level of quality has to be achieved in the surfaces of the pulsation cross-sections. At Kolbenschmidt, a combination of core sand and fine finishing was developed in a series of casting trials, which brings the desired high surface quality.

Since the cores are located in the supply cross-section of both cylinder banks, their influence on the form filling and hardening were checked and optimised using a computerised process.

Machining of the crankcase was simplified as the former pulsation drillings are no longer needed.

Particularly complicated in the manufacturing process were the vent drillings, which were necessary due to the collision of the lower cylinder bore edges. The core mounting is placed at the position where the vent drillings were previously made. The leak testing systems can therefore be taken over without change.

2.2 Crankshaft Drive

One of the most striking design features of the W engines is the narrow dimensions of the conrod bearings and main bearings. By virtue of the specified cylinder spacing of 65 mm in the VR engines, the main bearing widths were 15.8 mm and the conrod widths were just 11.6 mm at a bank offset of 13 mm.

The demand for a higher nominal output led to an increase in the nominal engine speed from 6000 rpm to 6200 rpm. In order to prevent a further rise in mechanical stress on the bearings, the crankshaft drive was completely reconfigured.

2.2.1 Pistons

The cast piston was given a fundamentally new design with drawn-in piston pin boss area beneath the piston ring pack (ECOFORM from the company Mahle), Figure 5. The compression height was reduced from 33 to 30 mm. The piston pin diameter was reduced by 1 mm to 19 mm.

Due to the special geometry of the W-engines, the following parameters have to be considered:
- asymmetrical force and weight distribution by angled piston crown
- installation positions with positive and negative cylinder angle offset
- axially low piston skirt.

A common machine grind pattern for all pistons was achieved through fine tuning the process. The achieved machine finish provides an even wear pattern, despite the tough requirements, and eliminates the use of pistons of different types.

2.2.2 Piston Ring Pack

In order to reduce oil consumption and friction losses of the moving parts in the crankshaft drive, a new piston ring pack was developed. The following ring sizes are installed:
- 1st ring: Square ring with 1.2 mm axial height (instead of 1.5 mm)
- 2nd ring: Taper faced compression ring with 1.0 mm axial height (instead of 1.75 mm)
- 3rd ring: Double-bevelled oil control ring with spiral-type expander with 2.0 mm axial height (instead of 3 mm).

This combination of measures results in a reduction in piston weight, inc. rings and piston pin, by 56 g to 391 g.

In particular, the tribology of the oil control ring was improved. By diagonally brushing the face of the rings, an optimal wear pattern was achieved, which, at the same time, brought with it outstanding oil scraping properties. Oil consumption was reduced even further, compared with the previous engine model, and at the same time an improvement in the blow-by characteristic was made.

2.2.3 Conrod

During optimisation of the forged conrod, there was to be no compromise in rigidity and safety against buckling to facilitate a reduction in weight. This was particularly important as the conrod length increased by 3 mm, compared with the series production conrod with 171.5 mm, as a measure to reduce the piston mass.

The safety against buckling of the conrod was maintained through a series of optimisation cycles with FEM calculations.

The bearing cap and rod are now fixed by means of two dowel pins. This design is characterised by a higher fitting accuracy compared to the previously used fitted bolt joint. In addition, it prevents the bearing cap from being fitted upside down, thereby improving process chain safety at the assembly facility, Figure 6.

The combination of measures resulted in a weight reduction of the conrod by 113 g. The conrod, inc. bearing shells and bushes, now weighs just 529 g.

2.2.4 Crankshaft

The hardening process for the forged crankshaft of the W12 engine had already been changed in series production from short time gas nitriding to plasma coating. With plasma coating, a greater hardening depth is achieved and the hardened surface is also more ductile. The fatigue limit was improved by about 10% thanks to this measure. The crankshaft balancing was adapted to the lighter crankshaft drive.

2.2.5 Main and Conrod Bearings

Particular attention was given to the conrod and main bearings. Due to the extremely compact design, the specific mechanical loads are considerably higher than those of