Modular high-pressure diecasting for al cylinder blocks (18 June 2009 at 09:36)

Modular high-pressure diecasting concept for high performance aluminium cylinder blocks

To meet future demands on CO₂ emissions and fuel consumption, lightweight design is one of the challenges of the automotive industry, say Dr Stephan Beer and Dr Eduard Koehler from KS Aluminium-Technologie GmbH.

The cylinder block is the heaviest single component in the vehicle and provides a variety of solutions to achieve a significant mass reduction. KS Aluminium-Technologie GmbH is introducing several concept modules to satisfy the demand for downsized lightweight, high performance engines.

It will hardly be viable to achieve the 2012 EU fleet target for CO₂ emissions without comprehensive lightweight design and downsizing of the engines. The first-mentioned approach generates new impulses for using aluminium as a substitute for grey cast iron in cylinder blocks, with a focus on solutions favouring low component weight in particular.

Downsizing means the trend to reduce the swept volume and, at least for premium-car engines, also to reduce the number of cylinders. This implies a distinct boost in specific power output in order to compensate the loss of performance and consequently also leads to higher ignition pressures.

This development will prompt a ‘skyrocketing’ further increase in mechanical and thermal component stress, which will primarily affect the cylinder block as the central component. In future these changing general conditions will determine the selection of the component concept. At the International Automobile Exhibition 2005 (IAA), KS Aluminium-Technologie GmbH presented an innovative cylinder block concept based on high-pressure diecasting incorporating the implementation of various technologies. This concept was specifically geared to meet future demands.

By means of prototypes, the technical feasibility of the concept was demonstrated in principle. This basic idea has meanwhile been developed to a highly flexible, mass-production compatible ‘modular high-pressure casting concept’ for aluminium cylinder blocks.

Engines downsized on the basis of the new concept excel by high specific power output and benefit particularly from the development approach of the initial concept for implementing the cost-effective production of a light-weight but nonetheless rigid, highly stress-resistant and absolutely function-optimised cylinder block for diesel and petrol application with ignition pressures up to 200 bar.

The smaller the cylinder block, the higher the cost pressure that prevails, even for downsizing, despite ever growing demands. Thanks to its extremely high productivity, high-pressure diecasting is the method of choice to achieve the most favourable production costs.

Casting technologies for lightweight aluminium cylinder blocks

With the ‘modular high-pressure die casting concept’ individual concept modules compensate the process-specific disadvantages of conventional high-pressure diecasting. These modules may be applied selectively without being interdependent, resulting in high flexibility of the concept. By suitable module combinations, a high-pressure diecast aluminium cylinder block can be produced that is nothing short of high-grade, low-pressure die or sand castings and which offers a decisive cost benefit in mass production.

High-pressure diecasting allows the realisation of extremely thin walls, the nominal average wall thickness being 3.2mm. Hence it meets especially favourable pre-requisites for lightweight design.

In combination with its near net shape benefits compared to low-pressure diecasting (when disregarding the light-weight benefit of technologies that do without liners) which does not require a core or only applies a water-jacketed sand core, the component weight can be reduced once over by between 8 and 15% if the specific application permits. Although in comparison to sand casting, high-pressure casting generally constrains the design freedom appreciably, similarly low component weights can be achieved provided that the component design is tuned to the casting method applied.

The concept modules of the ‘modular high-pressure casting concept’ for aluminium cylinder blocks are in detail:
Module 1: High strength through high-pressure diecasting which permits unrestricted heat treatment
Process-specific porosity (gas inclusions under high pressure) and the re-feeding problems involved only enable a relatively low strength level to be achieved with conventional high-pressure diecasting, especially in the thick-walled bearing bulkhead area.
In addition, the former problem prevents strength-promoting heat treatment as it may lead to component destruction through blister formation during solution annealing. A multitude of process optimisation steps ranging from optimised die filling through to the application of vacuum in the high-pressure die allows production of unrestrictedly heat-treatable castings, even in high-pressure casting machines.
Also, with a view to the dynamic characteristics, the attainable strength values are up to the standards of low-pressure die and sand castings (where in the latter case elaborate local mould chilling is required!).

Module 2: LOKASIL® or coated cylinder bore surfaces as a substitute for heavy grey cast liners
High-pressure diecasting features the general advantage of producing, during the casting process, local aluminium matrix composites (MMC) with adapted material properties by infiltrating highly porous pre-forms made from application-specific particles and/or fibres under high pressure. As a result, LOKASIL cylinder bore surfaces optimally fit in with the ‘modular high-pressure die casting concept’.
These surfaces are able to replace the usually cast-in massive grey cast liners and additionally contribute to weight reduction. With the LOKASIL Ib variant, for some time a further low-cost pre-form, based on silicon particles and specific ceramic fibres, has been available that is absolutely competitive with grey cast liners.
LOKASIL contributes to the achievement of a very compact component design with minimum bore distances of 4.5mm; it reduces cylinder distortion and causes thermal relief.
A further positive feature is that the cylinder bore surfaces are suitable for coating thanks to the excellent quality of the material in combination with the already mentioned optimised casting technology (cf. concept module 1).
On the other hand, the presented modular concept supports all current liner solutions.

Module 3: High component rigidity through closed-deck design with sand core suitable for high-pressure diecasting
Open-deck design is required as a standard in conventional high-pressure diecasting to allow steel moulding. However, this design is a constraint to the rigidity of a component, especially in the top cylinder area. For small high-performance engines, especially diesel engines, the closed-deck option may therefore be a mandatory necessity.
That is why for many years KS Aluminium-Technologie GmbH has made endeavours to develop suitable technologies for producing lost sand cores for water jackets that can be used for closed-deck designs in a reliable high-pressure diecasting process.
Based on a warm-box core with specific coating, it has now become possible to offer the closed-deck option as high-pressure diecasting at acceptable cost for specific mass-production applications.

Module 4: MMC bearing bulkhead reinforcement
The MMC bearing bulkhead reinforcement option was already presented in detail in connection with the Prototype 2005. In this case, too, the material’s characteristics were specifically tailored to the application.
The main focus is on light-weight design in combination with the compensation of the temperature-related clearance fluctuations in the crankshaft main bearing which are inevitable in the case of aluminium (minimisation of bearing clearance losses/dissipation loss of oil pump and noise stimulation).
The composite material which is applied locally, is able to replace heavy cast-in parts, mostly made of nodular cast iron, in the main bearing area of bedplates (bottom parts in the case of bipartite design of the engine block) with the beneficial effect of saving weight (fig. 5).
The gap-less integration with the adjacent aluminium has the additional advantage of preventing leaks in the lubricant oil supply line to the main bearings (fig. 6).

Conclusions
With the ‘modular high-pressure die casting concept’, KS Aluminium-Technologie GmbH offers a proper solution to the demand for downsizing, especially for current and future high-performance engines. Subject to suitable design of the components, the concept can also be
applied to diesel engines for passenger cars. High-pressure diecasting as a highly productive casting method combined with an array of independently applicable technologies accounts for the great flexibility and economics of the concept. In contrast to casting methods implying product quantity restriction, the Casting Concept is generally appropriate for unrestricted mass production of high-grade aluminium engine blocks. The local application of aluminium matrix composites in the cylinder bore and main bearing areas (in the case of bipartite design) is suitable for achieving additional light-weight construction potential, apart from the functional benefit.

References, trademarks and contacts
Illustrations are from KS Aluminium-Technologie GmbH, Neckarsulm, Germany, and LOKASIL® is a registered trade name of KS Aluminium-Technologie GmbH, Germany.
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