Developing lightweight automotive engines

By Colin Pawsey

One of the biggest drivers of innovation in the automotive sector today is the requirement to reduce carbon emissions, and this has a direct effect on the need to reduce vehicle weight. With passenger cars currently responsible for 12% of overall EU emissions of CO2, the EU regulations for passenger cars include stringent targets that manufacturers must adhere to. By 2015 passenger cars should have maximum emissions of 130g CO2/km, with a further target of 95g CO2/km to be achieved by 2020. Limits for the emissions of light commercial vehicles were added to the legislation in 2011, stating that the maximum should be no more than 175g CO2/km by 2017 and 147g CO2/km by 2020.

Car manufacturers will be assessed on the emissions of their overall fleet, with every new car given indicative emission levels based on the car's mass. Heavier cars are afforded greater emissions than lighter cars, and manufacturers are required to ensure that the average mass of all of its vehicles is in line with the average emission allowances. Thus the reduction in weight across the entire fleet will help manufacturers to comply with the regulations.

Heat resistant composites

The use of fibre-reinforced plastics in manufacturing has grown steadily in recent years as they offer excellent weight saving potential, better recyclability, and can often match steel for strength. Plastics are also being used much more commonly in engine parts and components, as newer materials are being produced which can withstand greater heat, and therefore can be used for a variety of new applications.

One example is a heat resistant polyamide, produced by the chemical company BASF, specifically for automotive applications in the high temperature range. The Ultramid Endure polyamide is glass-fibre reinforced, and combines excellent heat ageing resistance with the processing properties of PA 66. The new material can withstand continuous exposure over 3,000 hours to temperatures of 220°C, with peaks of up to 240°C; extending the range of applications which polyamide can be used for into the high temperature range.

The higher stiffness and resistance to heat ageing of the material means that more metal engine parts can be replaced with this type of polyamide. Testing by BASF showed that the new grade of Ultramid Endure D3G10 with 50% glass fibres offers a considerably increased stiffness at higher temperatures. Over a period of three months and 2,200 hours of heat ageing, the stiffness of the material remains stable at approximately 17,000 MPa, measured as tensile modulus in accordance with ISO 527-2 (1993) at 23°C. Before the ageing test, the material had shown a modulus of elasticity of more than 4,000 MPa at 220°C; around 30% more than the less stiff D3G7 polyamide.

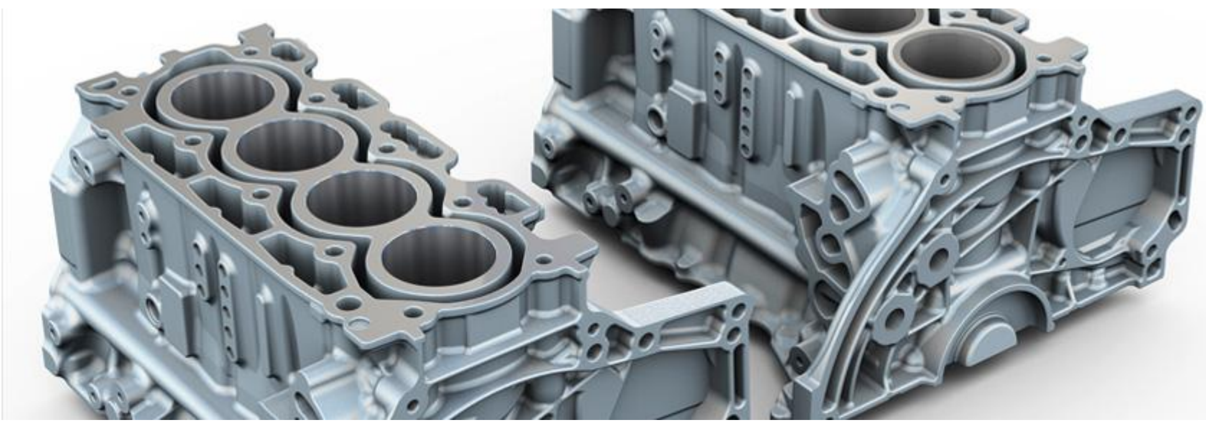
The excellent heat resistant properties of this polyamide make it suitable for many of the components that previously could only be constructed from metal, particularly those components in the charge air system of turbocharged engines. As automakers strive to improve energy efficiency, turbocharged engines are becoming more common, and operating temperatures can reach up to 200°C or more in areas between the turbocharger and intercooler. High temperature polyamides could replace metal parts and save weight in components such as intercooler end caps, resonators, intake manifolds and throttle valves.

Further innovations in weight saving have been showcased this year by plastics solutions provider Borealis and Borouge, as they have exhibited some of the components and under-the-bonnet applications used by BMW and Fiat/GM. Many of the applications use their Xmod short glass fibre-reinforced polypropylene. The weight reduction potential of these polypropylenes offers OEM's the opportunity to use PP for several applications such as fan shrouds, air intake manifolds and battery cases.

Fans and shrouds for the main engine cooling system are almost exclusively constructed from glass fibre-reinforced polyamide as dimensional stability at high speed and reduced warpage are extremely important. As an alternative Borealis Xmod high performance glass-fibre (HPGF) reinforced polypropylene offers easier and cheaper processing, and the lower density of Xmod GD301HP offers a weight reduction of 1.15g/CM^3.

Borealis has also developed a high performance polypropylene for use with air intake manifolds. Plastic air intake manifolds have steadily replaced metal parts over the last 20 years to the point where around 80% of cars in Europe have a plastic AIM. The benefits of using plastic include better technical functionality, greater design freedom, lower costs, and of course reduction in weight. One of the challenges facing OEM's is the increased operating and peak temperatures in cars today, resulting in performance limitations offered by standard polyamides. The high performance glass-fibre reinforced polypropylene (36% glass) which Borealis manufacture for air intake manifolds is cheaper to produce due to lower density and material prices, and offers a 15% weight reduction compared to standard polyamide.

Aluminium



Over the last few decades aluminium has increased in usage in auto manufacturing and now accounts for approximately 140kg per car. One of the main drivers for the increase in use of aluminium is the improved fuel efficiency and reduced vehicle mass. A variety of under-the-bonnet components are made from aluminium, generally in the form of aluminium casting alloys. The most common applications are housings for different aggregates, while there are also aluminium components in individual parts of the aggregates. Aluminium has replaced cast iron and zinc for these types of application, but the use of aluminium may be overtaken by more advanced lightweight solutions such as high performance plastics.

Aluminium will still have an important role in lightweight engines of the future as parts integration and the integration of additional functions into a single component is a key strength of aluminium high pressure die casting technology.

Components such as: cylinder head covers, oil pans, oil pumps, water circulation and coolant pumps, vacuum pumps, manifolds, turbochargers, and engine bearings can all be manufactured from aluminium, which serves to reduce engine weight.

The key to meeting carbon reduction targets is to make engines smaller, but at the same time increasingly powerful and light. The downsizing of engines includes designing engines with fewer cylinders. Less engine displacement however, means less engine power, so downsized engines are being supercharged and that places more demand on the engine materials.

Lightweight piston design

A new lightweight piston design from Federal Mogul is one innovation which will enable the downsizing of engines. The High-strength Advanced Elastoval II piston has been designed to equip the next generation of gasoline and natural gas engines. The design will help to achieve higher power, improved emissions and fuel economy. The High-strength aluminium piston will enter production later in 2012, and will be used in a European passenger car, contributing to gains in fuel economy.

The Advanced Elastoval II piston is lighter by up to 20% compared with previous generation pistons. It will deliver increased power outputs and will be constructed to withstand the higher pressures that occur late in the combustion cycle of highly charged downsized engines. Over the next few years Federal Mogul will increase the power output from current levels of 95 kW/L to 130 kW/L. The peak combustion pressures will rise from 110 Bar to 130 Bar, and even up to 160 Bar for engines using alternative fuels such as E100 or compressed natural gas.

To achieve the reduction in weight the entire structure of the piston has been re-designed. Wall sections in previous generation pistons measured 4mm, but the wall sections in the new piston measure as little as 2.5mm. The complex curved side panel forms of the new piston are inclined in two planes and are closer together at the top to support the piston crown, using multiple weight reducing pockets and crown reinforcing ribs. The piston pin bosses are curved towards the side panels and boss distance is reduced to the minimum possible. This design and better stress distribution allows for the maximum weight reduction.

Summary

To achieve the EU targets for reduced carbon emissions it is vital for OEM's to reduce the weight of vehicles across their fleets. Each and every component of the vehicle, whether large or small, is under scrutiny as manufacturers strive to save weight wherever possible.

The development of reinforced plastics in recent years has led to a significant growth in their use for automotive applications, and the recent development of heat resistant plastics has led to the design of under-the-bonnet components which are able to withstand the higher temperatures of modern engines.

Automakers are beginning to design and manufacture smaller engines, but are also trying to design them to be more powerful and at the same time reduce weight wherever possible. The challenge for tier one suppliers and component manufacturers is to produce lighter parts that have the strength and the heat resistant properties to withstand the demands of modern supercharged engines.

Colin Pawsey's background and experience is in the water heating industry, with a focus on technical data analysis and energy efficient products for both commercial and residential sectors. He also works as a freelance journalist focusing on renewable and sustainable resources, energy efficiency, and consumer information.

Sources:

http://ec.europa.eu/clima/policies/transport/vehicles/cars/faq_en.htm

http://www.plasticsportal.net/wa/plasticsEU/portal/show/content/products/engineering_plastics/ultramid_endure

http://www.borealisgroup.com/industry-solutions/mobility/lightweight-vehicles/lightweight-under-the-bonnet

http://www.alueurope.eu/applications/automotive/

http://www2.honsel.com/en/products/automotive/engine/

http://www.federalmogul.com/NR/rdonlyres/2CB78B9A-BDDE-4F8D-86F8-F4151F3186F0/0/pressreleaseAdvancedElastovalII.pdf