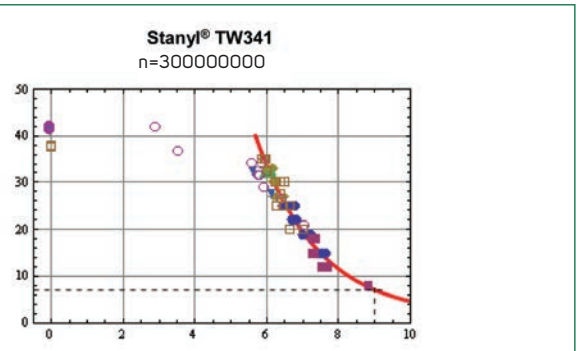
Material matters for engines

High performance and high-tech plastic gears are helping to create more sustainable cars that boast better fuel economy and far less CO_2 emissions

The current climate in the automotive industry is heavily influenced by more stringent emission regulations, leading to new, innovative approaches to engine design. Enhanced fuel consumption and lower CO_2 emissions will dominate future platform programs, emphasizing downsizing and down-speeding to improve the efficiency of diesel and gasoline engines. As a result, weight reduction is now more than ever seen as one of the key drivers to reaching upcoming emission performance standards such as the new Euro 6 legislation in Europe.

One method to achieve weight reduction is the replacement of metal parts with parts made from plastics, engineered to withstand the higher temperatures caused by smaller engine compartments, downsized engines, and the increased use of forced induction systems. With close to 30,000 parts in a single vehicle, every piece that can be converted successfully from metal to plastic contributes to the goals set for weight reduction.

Metal to plastic conversion with engine parts allows not only for a weight saving to be realized, but also fewer emissions, better fuel economy and lower production costs



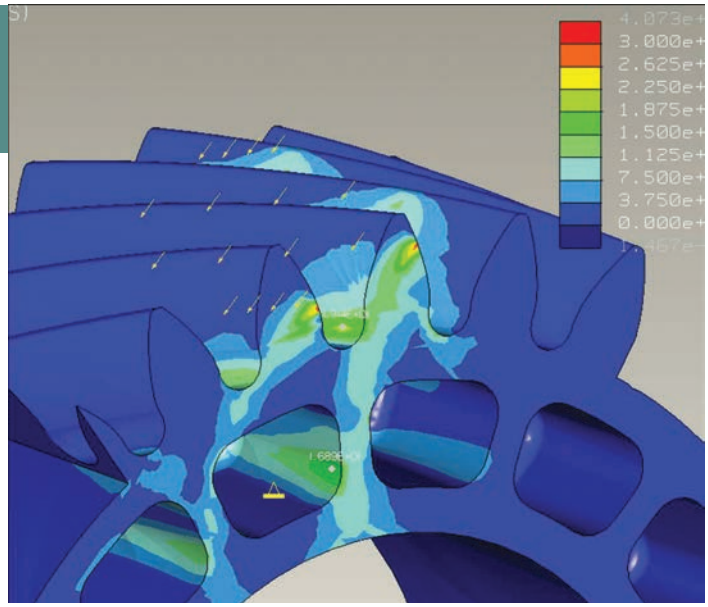
The stress level S_{max} at which the average number of load cycles-to-failure is 1 billion (or more) is about 6,4 MPa (extrapolated).

The fatigue results obtained for unfilled Stanyl TW341 in 140°C engine oil

Metal-to-plastic conversion is not unusual. It has already been demonstrated in many applications such as air inlet manifolds, air ducts, and charge air cooler end caps to name just a few examples.

Moving into the architecture of the engine, it becomes clear that with respect to the current high pressure on efficiency improvement, there is a major opportunity for metal-to-plastic conversion in engine and transmission applications. This is especially the case when one also considers that cost and NVH aspects can be improved by replacing machined metal gears with injection-molded plastic ones. However, what is important is that the right material is selected to ensure that the lighter gear can improve efficiency without compromising strength or safety.

Gears are components that have proved to be a perfect fit for the high-performance Stanyl PA46 polyamide of DSM. Stanyl PA46 has been used in gear production for more than 10 years and in hundreds of applications, including electronic throttle controls, starter motors and water or oil pumps. With a melting point of 295°C, this high-performance material has been engineered to retain its



FEA results: Von Mises stress distribution gear web is 43% lower after optimization

The advanced DSM testing facility investigated in 2008 the feasibility of replacing metal balance shaft gears with Stanyl PA46 gears

mechanical properties at temperatures ranging from 100° to 170°C. It offers best-in-class endurance and fatigue resistance at temperatures above 100°C, and works equally well in dry or lubricated conditions due to its extremely low wear rates.

Parts within the engine are subjected to extremely high temperature levels, as well as aging, which is caused by heat and oil attacking the materials used. PA46 is a material with excellent potential in this area, as its superior fatigue performance, low wear rate, and very good oil and heat-aging properties fulfill the challenging requirements in these applications.

Engine experiments demonstrate that Stanyl PA46 has very good wear resistance in engine oil lubricated systems. Stanyl PA46 answers the automotive needs for a reduction in costs, fuel consumption, and emission rates, by lowering production costs and part weight.

In 2008, DSM started a joint development program together with industry partners VCST, Werner Bauser, and the Institute of Automotive Engineering (ika) at RWTH Aachen University, to investigate the feasibility of replacing metal balance shaft gears with Stanyl PA46 gears.

For the three-year program, two meshing metal gears of a twin-shaft mass-balance system were taken as reference. The two helical gears drive the weighted balance shafts that counteract high-speed second-order engine vibrations and are rated for a maximum drive torque of 10Nm static and dynamic at engine speeds up to 6,000rpm. The mass-balance system of the bolt-on type is used in a range of 2-liter and 2.4-liter four-cylinder gasoline engines with power ratings up to 136bhp per liter in turbocharged gasoline direct injection form. The helical gear tooth geometry of the metal gears was redesigned in order to increase contact ratio (≥2), lower root stress (≤30MPa), and limit specific sliding (≤-3.5) for unfilled Stanyl PA46 during maximum loads and high temperatures. Local stresses and stress distribution were further optimized by FEA, and close attention was paid to the mold design and injection molding process that included extensive molding trails and subsequent gear quality measurements to ensure reproducible DIN 9 gear quality according DIN 3920.

Durability testing with the two meshing Stanyl PA46 gears (TW341) was carried out at DSM's gear testing facility in Geleen, The Netherlands. To date, test results have surpassed the durability needs for the maximum torque as the gears still run after 111 million load cycles at 12Nm and 12,000rpm in 110°C engine oil. As Stanyl PA46 has a specific mass that is five to eight times less than that of steel for the given gears, this has resulted in a 43% lower weight or 160g per gear set for the mass-balance module. This reduction, together with the resulting lower mass moment of inertia of both gears, gives a potential of 0.06g/km of CO_2 reduction when considering the NEDC cycle for a mid-size vehicle.

In addition to the CO_2 regulation penalty savings, PA46 gears offer considerable benefits over steel with respect to the manufacturing process by injection molding Stanyl PA46, reducing the overall cost of the gear by 50%. Other key benefits include noise reduction due to the material's lower weight. Working with leading players in the industry, DSM's high-performance plastic materials help to create vehicles that are lighter, more fuel efficient, and therefore more sustainable.

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