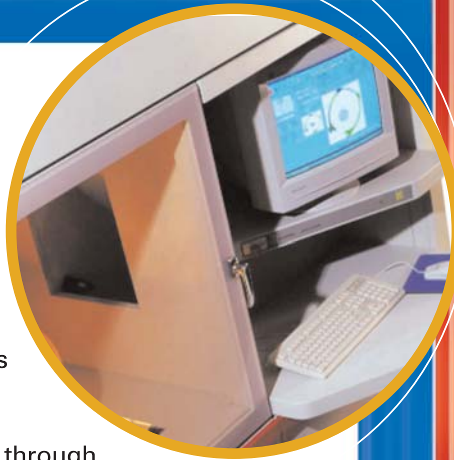
Cooler engines - from computer to reality

Sector:	Automotive
Technology:	SLA® system



Modern engines have an enormous ratio of power to engine capacity. As designers are obliged to come closer and closer to the limits of material stress load, even small discrepancies in cooling systems can have severe consequences. Theoretical calculations need to be verified via practical tests using a flow pattern test model created using stereolithography (SL).

Stereolithography is a process that translates CAD designs into solid objects through a combination of laser, photochemistry and software technologies. With 3D Systems® ' stereolithography apparatus, a three dimensional part is built within a matter of hours without tooling, machining or cutting.

"While it's no longer possible to work without computers we still can't wholly rely on them" says Peter Look, executive secretary at rapid prototyping and tool manufacturer SLM Modelltechnik. SLM has vast technical expertise in using stereolithography to produce transparent models of cooling circulation systems in cylinder heads and crankcases. Using three SL models, the engine designers can verify the dependability of their calculations.

Cooling tests in action: VW Group

According to Mr Look, during the past years the VW group has checked the efficiency of cooling systems for every newly developed engine using SLM flow pattern test models. The tests are performed by attaching the SL model to an engine block on a test bench and fitting it with auxiliary units such as a water pump and a thermostat.

The system is then filled with a cooling agent and driven in a cold state - "without ignition" - through a variety of operating conditions. The flow is made visible with fine air bubbles or other tracers in the water. The series of tests and evaluations take from 4 to 6 weeks, and may be continued in conjunction with further development activities.

According to Mr Look, the most important criteria are that there should be no "dead water zones", that sufficient volumes of cooling agent should be circulating, especially in the cylinder heads, and that serviceability requirements should be met, such as short draining and refilling cycles. If weak points are found, the relevant segment of the SL model can be disassembled and modified.

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>
> *- Olaf Wilde*
> *Development, Flow Pattern Test Models*

Engines under pressure

The continued refinement of car engines has resulted in the development of enormous loads on materials. "The first turbulence-chamber diesel from VW in 1975 produced only approx 25W of power per litre of engine capacity. Today's high pressure direct injection engines, on the other hand, attain up to 58kW/l," explained SLM's Olaf Wilde, responsible for the development of flow pattern test models. Engine development is leaning more towards aluminium instead of cast iron despite its substantially lower thermostability.

When developing the cylinder heads for the Audi V6/V8 diesel drive trains with common-rail direct injection, it was found that the central area in close proximity to the combustion chamber as well as the islands formed by the exhaust channels were subjected to thermal loads of 180-220°C or even higher. In this temperature range, aluminium materials reach their limits so designers are forced to feel their way ahead at every step. The reliability of the cooling effect at every point in the system becomes a factor of prime importance.

The need for practical testing

"Today, the design of engines is carried out with the assistance of CAD systems, while the flow behaviour is simulated with the help of CFD (computer fluid dynamics) software", revealed Peter Look. He stated that in spite of all the benefits of CFD, these programs are not yet able to simulate reality 100%. Therefore, the accuracy of these predictions has to be checked by using physical flow pattern test models. Previously, the production of these was extremely expensive. First, a true-scale model of the water cavity was generated and used as a core in the moulding process using highly transparent casting material. The model itself was made of a special bismuth alloy with a very low melting point which could be melted out once the material had hardened.

This procedure, however, had several disadvantages. The production of the sacrificial model required the manufacture of very expensive tooling. In addition, these flow pattern test models were both insufficient in terms of dimensional accuracy as well as surface quality. The designers therefore faced a worrying level of residual risk regarding the validity of the results attained via the test model. Moreover, modifications could not be carried out on these encapsulated models. If necessary, the expensive and time-consuming production process had to be run again after adaptation of geometrics in a CAD system.

Transparent models at short notice

"In the past the production of a transparent flow pattern test model like this typically took up to four months. Today we need only 4-5 weeks using stereolithography and at only one third the cost of previous production processes," reports Olaf Wilde. Furthermore, one was able to guarantee that the model corresponded wholly with the CAD data and the model surface quality fully met customer requirements. Of most significance to the developers was the fact that the model was composed of several layers which can be dismantled and modified at will. The engine developers no longer needed to pause for long periods of time waiting for modifications, but could examine the effects of a variation in geometry in a short period of time.

"In principle such a model consists of a segmented thin "shell" around the water cavity, the individual segments of which are made by stereolithography and then backfilled with translucent material in a casting process", says Peter Look. "The starting point is the CAD data of the water cavity which is provided by the engine designers and subsequently processed by SLM. The "virtual" water cavity is sheathed with a thin "shell" only a few mm in thickness, from which it is then "extracted", leaving a hollow shell. Subsequently, the separate faces (or planes) are defined and the individual parts provided with the supporting structures and allowances for processing. Special process-specific adaptations are also carried out. The shells are then built using stereolithography on an SLA 7000 system from 3D Systems. After being embedded in translucent plastic, the parts are machined mechanically and provided with drillings, alignment pins and tapped bushings for attachment of auxiliary aggregates.

Mastering the model

"When we were asked for the first time four years ago whether we could produce such a model for a development department at Volkswagon, it sounded pretty simple", continues Olaf Wilde. "Through experience, however, we quickly found out that the devil was in almost every detail. For the first model we thought that four months for production would be sufficient. In the end, however, we actually needed over a year to to master the process for flow pattern models. This development was carried out in close co-operation with the engineers at VW, who had recognised the potential of the new process and provided their active support. Today, we supply models not only for cylinder heads but also for crankcases. Additional areas of application include airplace engines and the filling simulation of foundry moulds with special liquids, the flow behaviours of which correspond with molten metal.

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