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Simulation – Entwicklungszeiten verkürzen

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# Even Faster Development of Cylinder Head Covers

**Simulation.** These days, fully functional, low-cost engine components, such as cylinder head covers, frequently have to be developed in plastic. Increasingly often, designers try to avoid prototype moulds and move straight to the stage of building series-production moulds. This means that simulation is becoming even more important. At the same time calculation results must meet increasingly high standards of accuracy. Development time can be shortened by using informative material characteristics with interpretation by experienced development partners.

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The use of plastics in all areas of automotive construction is leading to enormous weight and cost savings. While plastics are a natural choice for exterior and interior parts (e. g. bumpers or dashboard panels), their use is made more difficult under the hood because engine components not only have to meet styling requirements but also fulfil other important functions. However, with correct plastics design by experienced experts, plastics can be used without any problem under the hood as well. Taking the example of a cylinder head cover (Fig. 1), these requirements and the necessary development steps are described. Other functional engine components can be developed in plastic in the same way.

Cylinder head covers made from thermoplastics are state of the art for many European automotive manufacturers and in some cases have been used in series production for more than ten years. In the USA, the market for thermoplastic cylinder head covers is developing only slowly. Instead, thermoset components are often used under the hood for fire safety reasons. The European experience and clear cost advantages will encourage the use of thermoplastic components in the USA in the medium term.

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Fig. 1. Different cylinder head covers available on the market

The Asian market for cylinder head covers is split: for Korean manufacturers, as in Europe, thermoplastic valve covers are state of the art, while in the Japanese market they are developing at the same slow rate as in the USA. Nevertheless, some thermoplastic cylinder head covers are already in series production in Japan.

## Component Requirements

In addition to its styling function, a valve cover has a number of other important functions (Fig. 2). The first is to ensure reliable, durable sealing of the valve gear. It is absolutely essential to prevent oil leaks, not just for environmental reasons, but to stop oil losses and the resulting need for more frequent oil checks. The plastics used, mainly glass-fibre-reinforced polyamide grades, must therefore be resistant to all engine oils and all chemical media used under the hood (e. g. cleaning agents). Components that come into direct contact with the engine/engine oil must be able to withstand a continuous service temperature of 130 °C and short-term peaks up to 150 °C. Component design must take into account the typical creep behaviour of the material in these temperature ranges.

For space-saving reasons, additional functions are increasingly being integrated into the valve cover, such as oil separators to separate the oil from the blow-by gases and pressure regulating valves to limit the blow-by gas flow. These additional elements must not only be incorporated structurally into the valve cover but must also be correctly designed in terms of function. Finally, it should be re- ▶

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membered that the cylinder head cover also serves as a mounting for ancillary components (e.g. ignition coils, sensors or even air filters). These ancillary components can exert a considerable dynamic stress, which must also be taken into account in development.

These days, comfort aspects are increasingly having an important influence on purchasing decisions, so that engine noise shielding is very important. As a large attached component, the cylinder head cover plays a critical role in determining the overall level of noise from the engine. For this reason, plastic cylinder head covers should not be any “louder” than their aluminium counterparts.

### Requirements

- **Function: sealing the valve gear**
  - Sufficient rigidity (to take the sealing stress)
  - Heat resistance
  - Resistance to under-the-hood media and cleaning agents
- **Cost reduction**
  - Possibility of integrating additional modules (oil separator, air filter, intake manifold, etc.)
  - Module carrier (ignition coils, sensors, styling cover)
- **Weight reduction**
- **Noise reduction**
- **Styling (surface quality)**
- **Simple final fitting (captive bolts and seals)**

**Fig. 2. In addition to their styling function, cylinder head covers have a number of other important functions**

## Development of Cylinder Head Covers

On the basis of the particular arrangement for fastening the cover to the cylinder head (seal contour and especially the arrangement of the bolts), experienced development engineers can decide immediately on the feasibility or otherwise of a plastic valve cover (Fig.3). Since, in most cases, the bolt hole pattern of the cylinder head cannot be altered, the decision for or against plastic as the material for the component is made at this point. If the use of plastics is feasible in principle, a concept study of different design variants can then follow.

However, for cost and time reasons, concept studies are rarely carried out in practice, which often results in a less than optimum design. To make a selection from different concepts, simulation techniques are used to assess the possible concepts and existing designs. The development of engine components today would be unimaginable without the use of simulation methods such as finite element analysis (FEA). Computer simulation makes it possible to predict deformation behaviour by the reaction force of the compressed seal (Fig. 4).

For attached parts such as ignition coils, in particular, a dynamic analysis must also be carried out by simulation. For this purpose, a modal analysis (Fig. 5) determines the resonance frequencies and modal eigenforms to permit calculation under harmonic excitation at the previously determined critical eigenfrequencies. This calculation results in stress and deformation patterns that indicate the vibrational stressing of the component. This makes it possible to decide, for example, whether fixing points for ignition coils will break off or not.

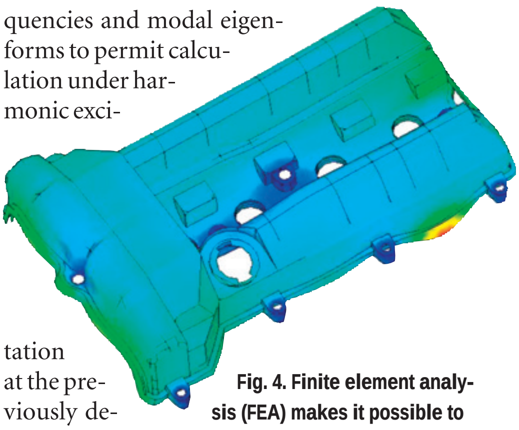

**Fig. 4. Finite element analysis (FEA) makes it possible to predict the static deformation behaviour of engine components**

These vibration calculations are also required as input values for estimating the acoustic behaviour of the component. Structure-borne and airborne noise calculations provide an indication of noise emission and local critical noise “hot spots” in the component.

The optimisation measures recommended as a result of these simulations are then incorporated into the design, e.g. in the form of additional ribs or modified geometry, to obtain a pre-optimised component. During mould construction, process analysis of the injection mould-

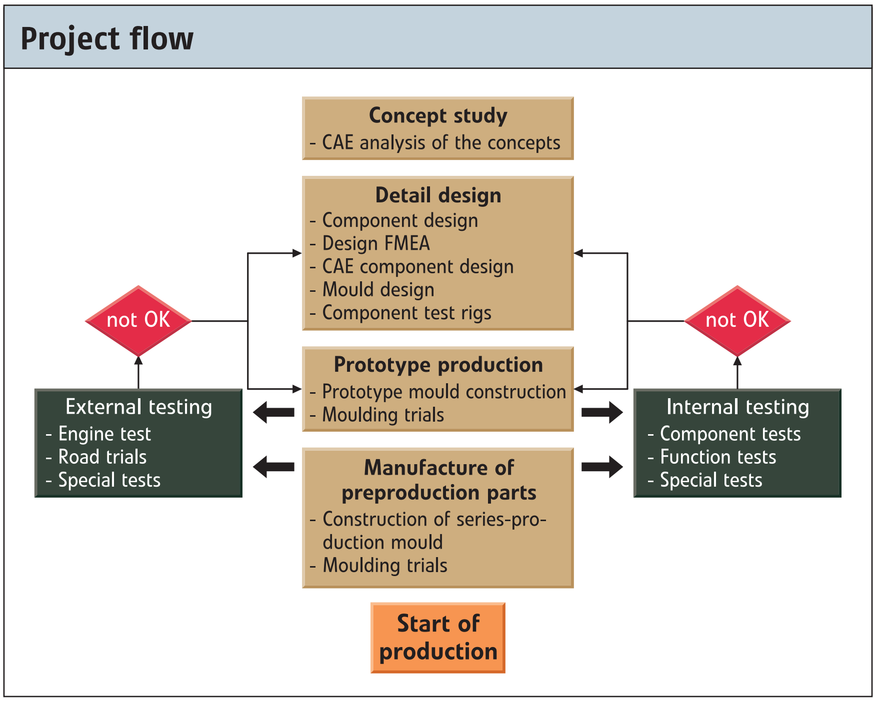


**Fig. 3. The decision to develop a cylinder head cover made from plastic is influenced by the experience of the developer**



 

## Modal analysis

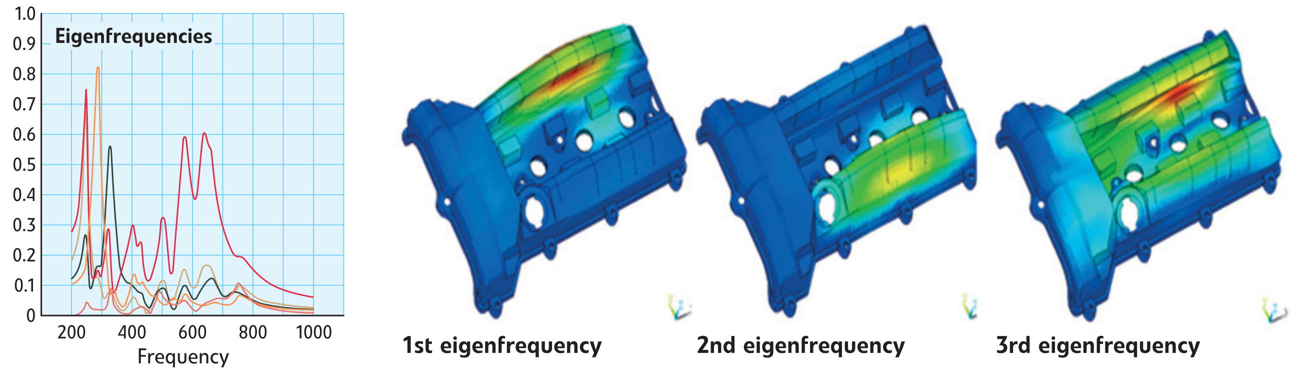


**Fig. 5. Dynamic analysis using FEA determines eigenfrequencies, eigenforms and vibration stressing of the component**

ing operation is carried out (Fig. 6) to establish the number of gates and gate positions required for complete filling of the component and to ascertain the filling pressure in order to determine the necessary machine size.

The fibre orientation also calculated during process analysis influences both the rigidity and warpage behaviour of the component after injection moulding. The aim here is to achieve a component that is as warpage-free as possible to ensure an optimum fit to the sealing faces. Each of these calculation steps can be undertaken by partners with sufficient experience in this area. Following this calculation phase, parts made in a mould like that to be used for the actual production process – generally a prototype mould – are tested to demonstrate they are fully functional.

As a result of increasing time pressure, designers today are trying to avoid prototype moulds and move straight to the stage of building series-production moulds. This means that simulation is becoming even more important and calculation results must meet increasingly high standards of accuracy. This approach can only be successful with "correct" choice of material characteristics for the calculation and "correct" interpretation of the results. Only engineers who are familiar with the complete system and have sufficient experience can decide whether the calculated value is critical. Experience and knowledge relating to comparison of theory and practice are essential for this.

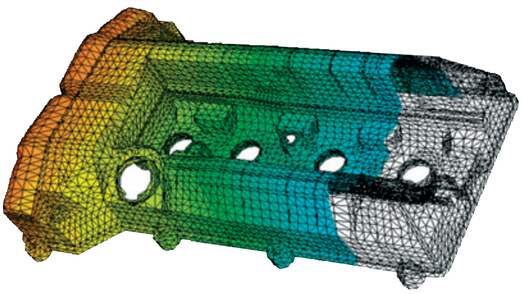

**Fig. 6. The moulding process in the mould is simulated by process analysis**

## Component Testing

Before cylinder head covers are required to demonstrate their functional capability on engine test beds or even in road trials, their "individual" functions are generally tested first. These tests are conducted on the basis of specifications by the automotive manufacturer or system supplier or the empirical values of a service provider.

The number of prototype components is generally limited. In addition, there is enormous time pressure so that the individual component tests have to be carried out quickly in a structured way. One of the most important tests, particularly as

## Failure criterion

**Leak testing (schematic)**

**Purpose:**
to prevent oil leaks

**Test conditions:**
temperature: – 40°C to 120°C

**Test criterion:**
leakage rate < 100 ml/min

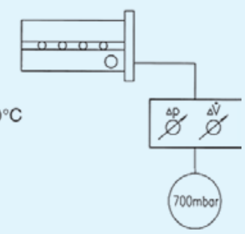


**Fig. 7A. Leak testing provides information about failure of the component**

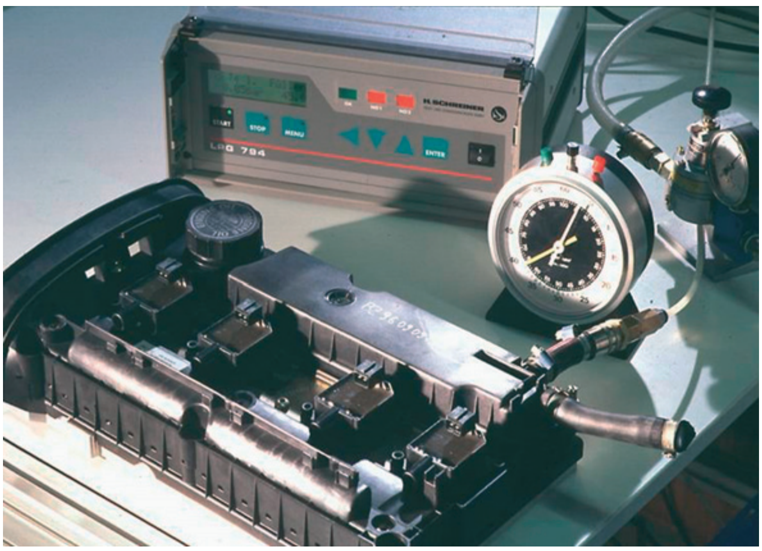

**Fig. 7B. Test set up for leak testing of cylinder head covers**

## Thermal change

**Thermal cycling test (schematic)**

**Purpose:**

simulation of cold start behaviour

**Test conditions:**

temperature:

-40°C/1h <->120°C/1h

100 cycles

**Criterion:**

no oil leakage,

no oil 'sweating'

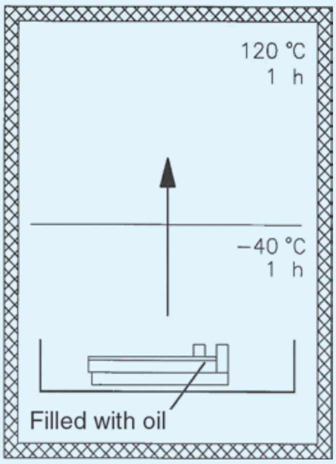


Fig. 8A. The thermal cycling test simulates the abrupt thermal change between hot and cold during a cold start in winter

Fig. 8B. Thermal cycling test arrangement for cylinder head covers

a failure criterion, is the leak test (Fig. 7). Weak points in the component (e. g. creep as a result of excessive stress) or failure of the seal (e. g. as a result of material embrittlement) are discovered immediately with this test.

A thermal cycling test simulates the abrupt thermal changes between hot and cold that occur during a cold start in winter (Fig. 8). Since leaktightness cannot be measured during the temperature change, this test is generally carried out with the cover filled with oil so that any oil leaks can be assessed visually on completion of the test. On the other hand, leaktightness can be measured at a constant temperature over the range –40 to +150 °C. It is particularly important to ensure that the sealing material has the necessary low-temperature flexibility. The dynamic behaviour estimated during the simulation must now be confirmed by vibration tests on a shaker.

Long-term tests over several hundred hours with thermal cycling are quite usual. In these tests, the resonance frequency is measured first of all, since stress at resonance frequency is the critical stress. This is followed by a resonance dwell test, in which the component has to withstand several million resonance vibrations undamaged. Another vibration test is the sine sweep test, in which the component must withstand varying sine vibrations within a frequency range. In this test, all the critical eigenfrequencies of a component are identified and tested.

Acoustic measurement of the system also takes place in stages. First an acoustic assessment is carried out without the engine (Fig. 9A). If an equivalent aluminium cover exists, a comparative measurement can be made. Careful consideration must be given as to how the noise is produced. Engines with timing chains create more structure-borne noise than engines with timing belts. For this reason, cylinder head covers for engines

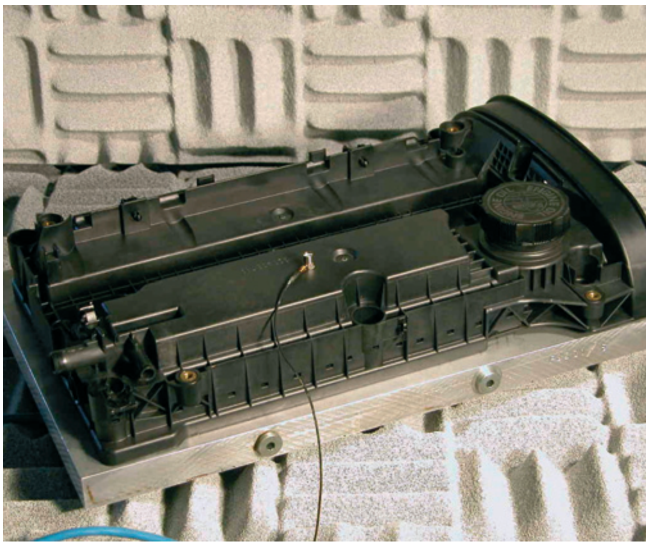

Fig. 9A. Structure-borne noise measurement of a thermoplastic cylinder head cover

## Noise measurement

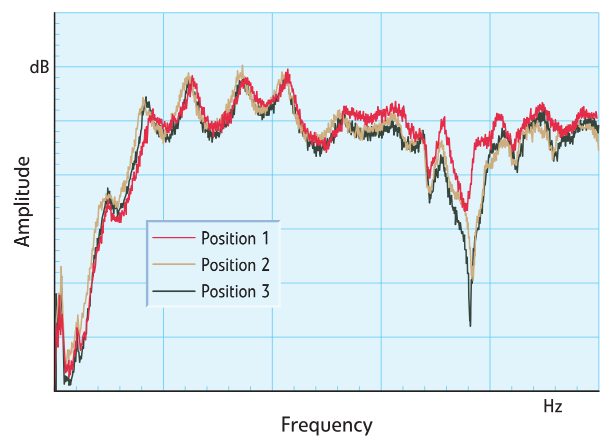


Fig. 9B. The characteristic tested is the structure-borne noise velocity on the component surface with timing chains are fastened to the cylinder head via decoupling elements such as additional rubber stoppers between the bolt heads and their bearing surfaces.

For both airborne and structure-borne noise excitation, it is advisable to use the excitation spectra of the relevant engine or very similar engines. In many cases, the measurement engineers carrying out the test can provide suitable signals for initial excitation.

The characteristics tested are the structure-borne noise velocities on the component surface, which essentially serve to localise the vibrating areas (Fig. 9B), and airborne sound data to provide information on global noise radiation. Comparative measurements of different design variants provide decisive criteria for component selection or modification here. Finally, the results are verified on an engine test bed and/or in road trials.

## Summary and Outlook

Engine components such as cylinder head covers require higher development costs than other automotive components. In collaboration with experienced development partners it is possible today to develop fully functional components at reasonable cost. The experience of the development partner in this area is crucially important to cut development times and costs to a minimum. Development aids such as FEA programs are only as effective as the experience of the user permits.

Engine components still offer very great growth potential today in terms of both the market situation and the technical opportunities for saving weight and allowing engines to run more efficiently. ■


**THE AUTHORS**

DIPL.-ING. MARCEL OP DE LAAK, born in 1970, studied plastics engineering at the RWTH Aachen University. After many years' as a project manager in the application development department of Rhodia Engineering Plastics, he founded the firm of consulting engineers, TiK-Technologie in Kunststoff GmbH, in Freiburg/Germany. He and his team have devoted themselves to the integrated, systematic development of plastics products and support their customers through consultation or by acting as project manager for component design, testing technology and process engineering throughout the development process from the initial concept to series production readiness.

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