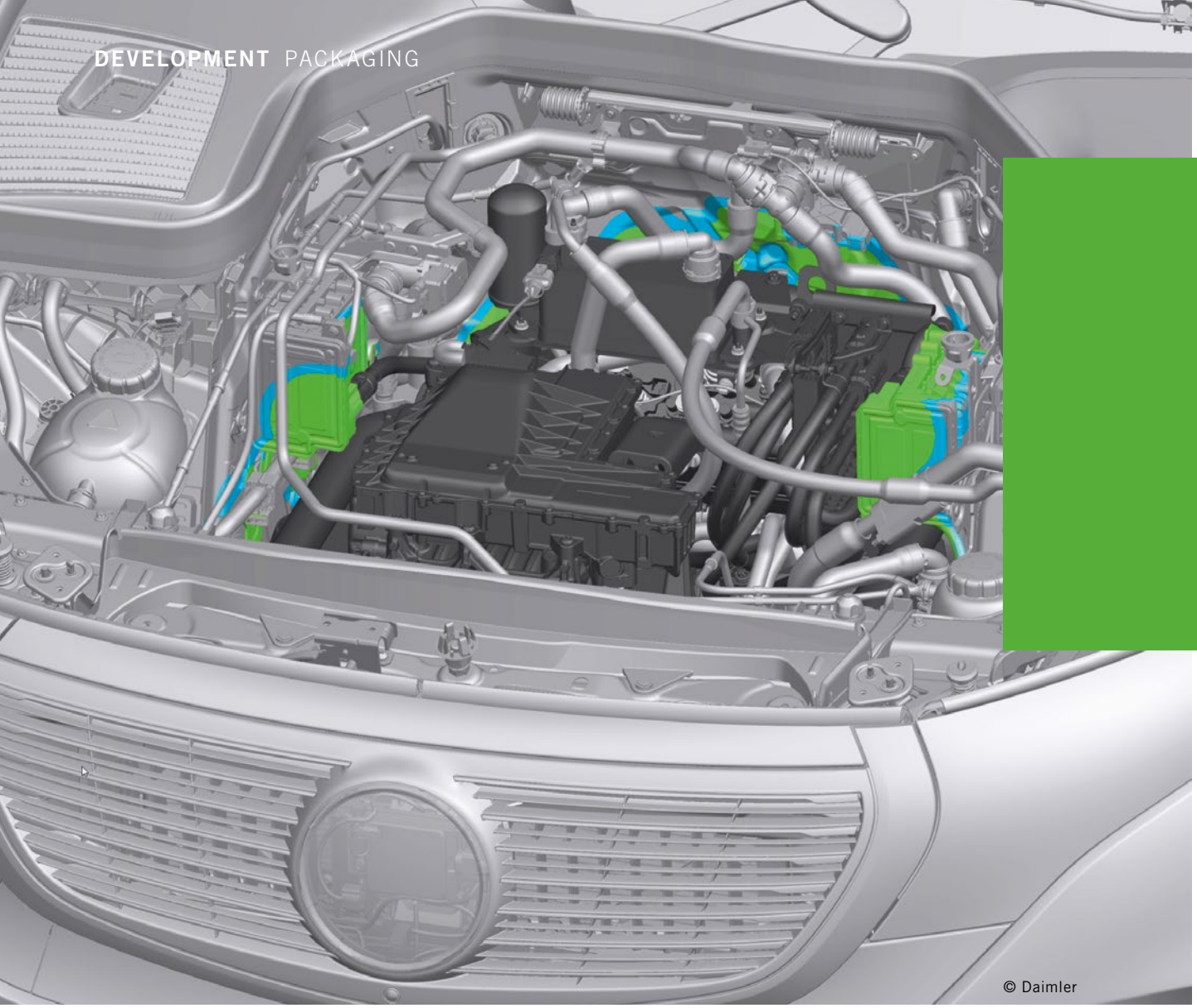

HIGH-PRECISION MOTION ENVELOPES AND DISTANCE BANDS

During the development of new vehicles, extensive measurements of engine and wheel movements are carried out under real driving conditions. With the digital mock-up software Melvis of the company Rmags, such measured movements can be transferred to a digital vehicle model and analyzed. The user is supported in virtual safeguarding and optimizing the installation space.

The use of the software is even possible in the early phase of the product development process, when no prototype vehicles have yet been built. In this case, movements that were measured on predecessor vehicles can be transferred to the new model, or alternatively movement data from simulations can be used.

The software has been developed by the company Rmags GmbH in cooperation with Mercedes-Benz since 2013. It is mainly used in the field of complete vehicle design – just as the TrunkPacker software, an Rmags software for the virtual and fully automatic determination [1] of the trunk volume according to ISO 3832.

For analyzing installation spaces reliably, the software offers high-precision motion envelopes, distance bands as well as systematic distance investigations. During the development of Melvis, special emphasis has been placed upon high performance and low main memory consumption. This means that even complex installation spaces, such as an engine compartment, can be safeguarded efficiently. Melvis has shown to be particularly useful to help with the packaging process at Mercedes-Benz, as demonstrated in the following two application cases.

FIRST APPLICATION CASE: POWERTRAIN

Mercedes-Benz uses the Melvis software to safeguard engine movements in the engine compartment. Challenges in this application are high packing density, an enormous amount of geometric data and very high accuracy requirements.

Before the software existed, distances between the engine and the surrounding components had to be safeguarded using a static distance catalog. In this catalog, minimum distances were recorded, that had to be respected when the vehicle was stationary. These were chosen sufficiently large so that no contacts would occur during real driving conditions. Thus, sometimes a larger clearance distance than necessary was reserved.

With the software, detailed engine movements can already be viewed in the digital development phase. This

Safeguarding of Complex Installation Spaces for Engine and Wheel Movements

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With the help of a digital vehicle prototype, the movements of components in small installation spaces can be safeguarded with more efficiency. In this way, expensive and time-consuming adjustments to the hardware prototypes can be avoided. Rmags in conjunction with Mercedes-Benz has developed its digital mock-up software Melvis in order to analyze the clearance of engine and wheel movements at an early stage of development.

makes it possible to estimate the required minimum distances more accurately and specifically. In this way, it is possible to identify where there is still available installation space that can be used effectively.

Since no prototype vehicles have yet been built in the digital development phase, the engine movements of comparable predecessor vehicles are used. For this purpose, motion data is recorded with optical measuring systems for various standardized driving maneuvers that cause extreme engine movements. The resulting motion tracks of all engine-vehicle combinations can then be transferred to the digital model of the new vehicle and then analyzed with the software. The software offers three functions, namely computation of intelligent motion envelopes, band analysis using interactive distance bands and a quantification of minimum distances.

Melvis can compute highly precise and intelligent motion envelopes efficiently, **FIGURE 1**. In the engine movement scenario, a motion envelope encloses the space occupied by the engine during its motion. This makes it possible to quickly check whether the engine is maintaining the required

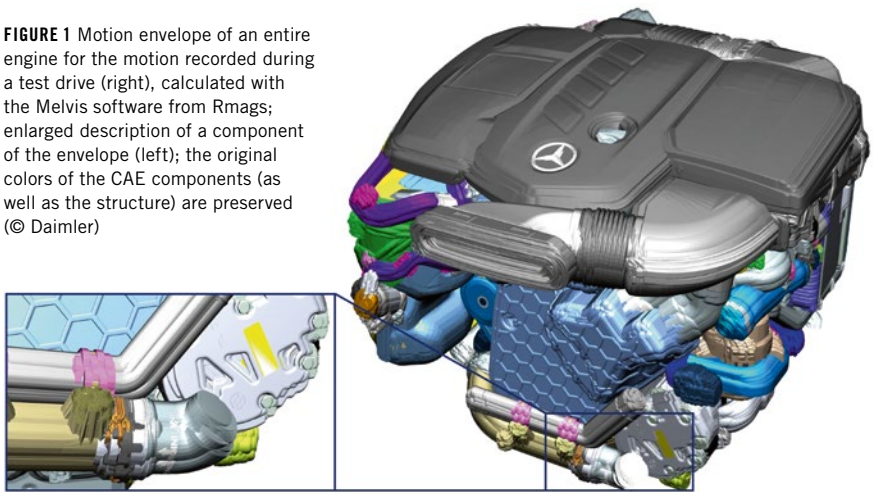

FIGURE 1 Motion envelope of an entire engine for the motion recorded during a test drive (right), calculated with the Melvis software from Rmags; enlarged description of a component of the envelope (left); the original colors of the CAE components (as well as the structure) are preserved (© Daimler)

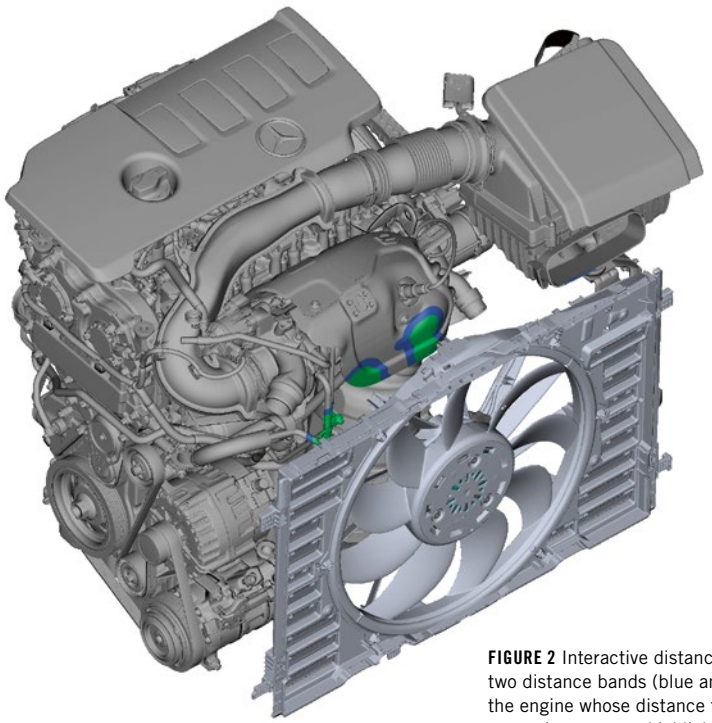

FIGURE 2 Interactive distance band analysis with two distance bands (blue and green): areas of the engine whose distance to the fan lies within a certain range are highlighted; the width of the bands and the motor position can be changed interactively (© Daimler)

clearance distances to all surrounding components during the entire movement.

A motion envelope, computed with the software, has a precision in the sub-millimeter range. Nevertheless, the calculation is efficient: For example, to compute a motion envelope of an engine over all driving maneuvers, the engine, which typically consists of several million triangles, must be moved over approximately 200,000 measured motion positions. The computation can be carried out within 1 to 2 h on a powerful off-the-shelf desktop PC.

The generated motion envelopes are "intelligent": The color information as well as the structure of the moving component are preserved. The user can thus determine for each point on the motion envelope which component touched this point in which position.

With the Melvis software, the user can do band analyses using interactive distance bands, **FIGURE 2** and Title Figure. In the engine scenario, for example, a distance band consists of all points of the engine, whose distance to surrounding components is within a certain range. These points typically form a band-like area when highlighted with a specific color.

Before the distance band is shown, a short pre-calculation is done. Then, the actual calculation of a distance band takes place by using the graphics card in a few milliseconds. This makes it possible to interactively modify the position and the geometry of the components as well as the distance intervals. Here, the actual distance band is always shown to the user in real-time.

Melvis can play back the recorded movement of the engine and immediately show the correct distance band for every time frame. In this way, the user can visually identify regions of the engine that fall below a predefined clearance in the course of the movement. It is possible to interactively change the width of the distance band. In doing so, for every change the distance band is instantaneously updated in real-time. It is even possible to simultaneously display several distance bands with different distance intervals in different colors, **FIGURE 2**. Thus, different tolerance ranges can be specified.

The application of distance bands is particularly useful in combination with motion envelopes. The user can then see at a glance where vehicle components would fall below an adjustable distance value at any time of the movement.

With the Melvis software, the user can also systematically identify and examine interesting regions, this means that minimum distances can be quantifiably determined. For this purpose, all areas on the engine are automatically determined and marked that fall below an adjustable clearance to the surrounding components in the course of the motion. The user can examine these regions systematically with exact distance computations, **FIGURE 3**. In this way, narrow spaces can be efficiently and quantifiably investigated and documented. The systematic approach also ensures that no areas of constriction are missed.

The software has become an integral tool in the overall vehicle design in the area of engine integration at Mercedes-Benz. It makes validating the engines in the vehicle more efficient, because development proposals can be digitally checked and optimized more quickly and with less effort.

SECOND APPLICATION CASE: WHEEL CLEARANCE

In addition to the analysis of engine movements, the Melvis software is also used in other areas of Mercedes-Benz development. An interesting example is the analysis of wheel clearances. One method of determining the wheel clearance is coating the wheel arches with foam. When performing certain driving maneuvers on a test site, the foam is pressed in or scraped off by the tire according to its clearance.

With the help of a digital vehicle prototype, the wheel clearance can be analyzed at an early stage of development for various wheel/tire combinations. In this way, expensive and time-consuming adjustments to the hardware model can possibly be avoided. The digital packaging heavily uses motion envelopes in order to conveniently describe the exact installation space required. The motion data for determining the envelopes comes either from a measurement on the test vehicle or from a simulation environment. Based on this motion data and 3-D models of the associated wheel/tire combinations, digital motion envelopes can then be generated, **FIGURE 4**.

In contrast to foaming the wheel arches, the individual driving maneuvers can be evaluated independently. Also, there is

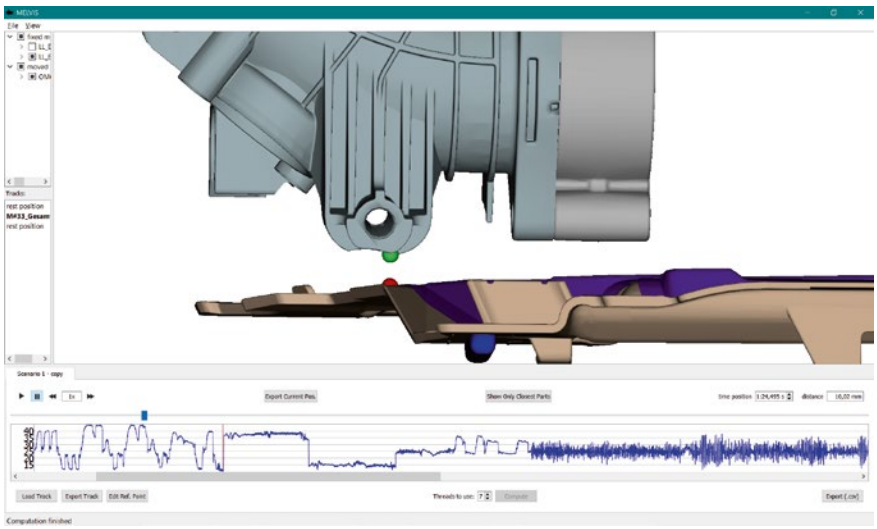

FIGURE 3 Screenshot from the Melvis software: focussed calculation of the minimum distance between two components during a movement; the red and green dots indicate the spatial positions on the components that realize the distance for the current point in time (top); the blue graph shows the temporal evolution of the minimum distance during the movement (bottom) (© Daimler)

no need to perform a separate driving test for each wheel/tire combination, since the required motion data can be recorded once and then be transferred to different scenarios.

As every millimeter of packaging space is precious nowadays, the motion envelopes should be as exact as possible. Therefore, the engineers at Mercedes-Benz now use the Melvis software to generate motion envelopes of tires and wheels. Thanks to a special functional extension, it is possible to import the same file format for the wheel motion that was previously used together with the existing CAD system. This allows the software to fit seamlessly into the present process chain.

With Melvis there is no undesired underestimation of the motion envelope. This means that an accurate and digital image of the measurement can now be generated. Due to the efficiency, the computation of an envelope with up to one million wheel positions is possible without any problems.

The Melvis software enables the users to calculate and visualize the data of motion envelopes quickly, easily and with a high degree of accuracy in 3-D. Mercedes-Benz would like to intensify the further co-work with Rmags in order to create the tire motion envelopes already in the basic design stage of a vehicle with Melvis. This would result in a productive use across all series.

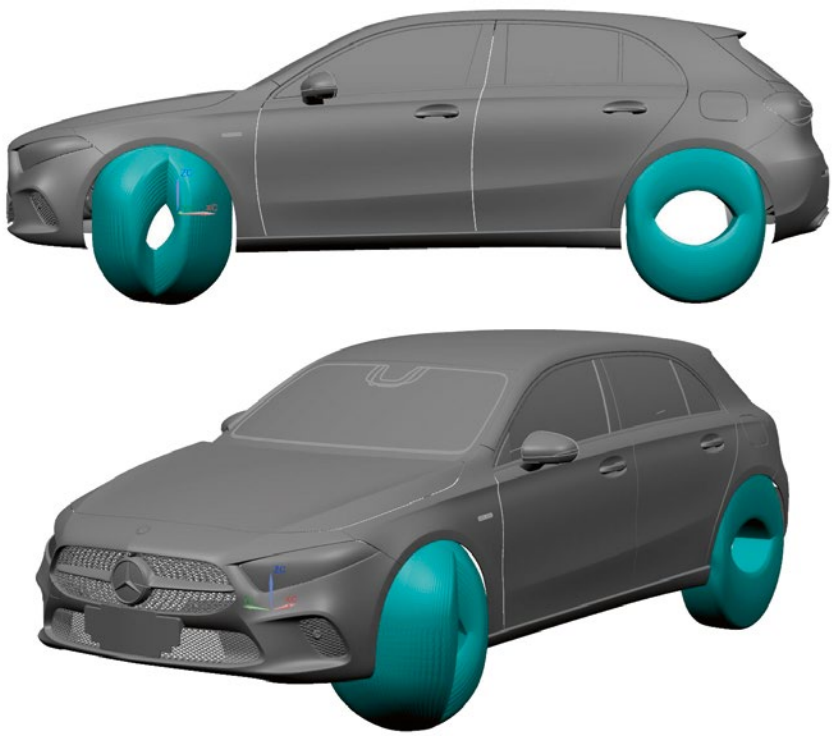

FIGURE 4 Motion envelopes of front and rear tires: the space occupied by a tire is represented by a motion envelope (© Daimler)

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[1] Dziegielewski, A. von; Erbes, R.: Fully Automatic Determination of the Trunk Volume. In: ATZworldwide, 2/2016, No. 2, pp. 56-60

THANKS

The authors express their gratitude to the following contributors: Prof. Dr. rer. nat. Elmar Schömer (University of Mainz), Kathrin Gärtner, Nico Siebert, Daniel Renz, Michael Müller (all Mercedes-Benz), Dr. Kai Werth and Dominik Will (both Rmags).