New climatisation Manikin improves interior design

Stronger than ever before, today's newly developed products are expected to meet a wide range of customer needs. This applies especially for developments in the area of air conditioning and heat management of exhaust systems. The new thermal simulation software THESEUS-FE, developed by P+Z Engineering, provides design engineers with an efficient tool not only to shorten development times considerably, but also to improve development results and thus creating the basis for customer-oriented products.

Whether car, truck, train, ship, aeroplane or in architecture quality, functionality and the success of the advisable solution depends severely on its respective thermal behaviour. Particularly with regard to the design of air condition, passenger comfort or thermal management, computer-assisted analyses are part of the imperative development process components. It also becomes more and more crucial to recognize and analyse functional or qualitative defects of components, which are exposed to permanent thermal stress, already in the concept phase.

P+ Z Engineering GmbH, a Munich based engineering services provider, has therefore developed a new thermal solver which simplifies calculations within these areas considerably. From the early 1990’s, a team of engineers has been dealing especially with these problem definitions. Based on the so acquired know-how, THESEUS-FE, an implicit finite element solver, which is especially designed for the interests of air conditioning (passive heating, active cool-down, De-Icing, Defogging etc.), passenger comfort (comfort analyses) as well as the thermal management (heat source optimization), arose.

In the concept phase only incomplete geometry information is typically available. By using parametric models, the solver is able to support and optimize the performance of new concepts in this phase. With increasingly precise geometry information in the following series development, the software delivers the result quality requested in this phase by using coupling routines to common CFD-Solver. Hence, the assessment of product development is supported along the complete process chain. The excellent performance of the solver for steady state and transient calculations is ensured by the use of modern iterative methods.

THESEUS-FE stands out due to his innovative, easy-to-learn and clear structured graphic user interface (GUI). Tabular input desks keep the operation anytime transparent so that it is possible for experts as well as beginners to configure and evaluate thermal systems easily.

In principle, the execution of a CAE analysis nowadays consists of three different areas: the Pre-Processing, where all available and necessary data will be processed, the calculation itself, where numeric approaches will be solved, and the Post-Processing, which contains different possibilities of data evaluation and visualisation. Most of the calculation tools available on the market integrate all three areas - so does THESEUS-FE - , to be able to guarantee a calculation sequence of operations as general as possible.

The user can directly read in surface geometries and adapt parameters like material properties, surface qualities or other environmental variables with few inputs in the Pre-Processor. The implemented solver determines the energy balance based on the calculation of thermal radiation (including solar irradiation), fully internal 3D heat conduction and finally convective values. The constitutions of heat transfer are used in terms of balance sheets and statements for the calculation and interpretation of the heat conditions. The general problem for calculating view factors consists in the interaction of the individual surfaces since every object with a temperature unequal 0 emits and reflects radiation, so is in the permanent change of the energy entries by radiation. A special feature of THESEUS-FE is its very efficient calculation of these view factors by considering Blackbody (complete absorptive) and grey-body radiation (shared absorptive). To be able to calculate radiation phenomena numerically, it is necessary to compute the radiation exchange between surfaces in a first step, the so-called “View Factor” calculation, and in a second step to solve the grey-body equation. For the calculation of the view factors the user can choose alternatively numeric, analytic or half-analytic methods with variable precision and speed-up. This high-sophisticated view factor calculation method was realized with a new specifically developed, so-called "Surface-to Surface" technology which is already available as a parallelized version. The graphic presentation of the results is carried out after the calculation (steady state or transient) in the own Post-Processor. This offers a huge variety of output variables, like temperature or heat flux over the time.

Models up to 250 000 elements can be computed on conventional desktop PC systems. For larger models, mainly in combination with fully coupled CFD calculations, a virtual reduction of the element number can be realized by using a new “Patching” algorithm (an exactly defined number of elements is assigned to a larger “Patch”). This feature takes view factor calculation and the thermal solver into account, which leads to improved calculation time. Another proceeding to minimize memory and computing time is the subdivision of the modelled system into cavities, whose radiation exchange is decoupled: a modelled system with several small cavities needs considerably less memory and computing time than a single one! The programme therefore provides convenient results considerably faster than comparable solver. The used method is element-based which means that the 3D models will be described by using surface grids only at the moment, preferably with triangles or quads. Volume elements aren't supported yet, but will be available in the near future.

Another outstanding feature is the new implemented virtual Manikin. The human body itself causes a variety of boundary conditions, changing continuously by different activities. We, for example, sweat if we feel too hot or shiver if we feel cold. On the other hand the humidity conditions are permanently influenced by our breathing within our immediate surroundings. It comes along, that any human being represents a "heat source" of it’s own, depending on it's activity and clothing. In average, the human body produces between 60 Watts (relaxed sitting) and 500 Watts (wood cutting) performance itself and this continues further into the environment e.g. as thermal radiation again. All these complex conditions influence a meaningful comfort assessment. In the past, only stationary global comfort indices have been used to predict thermal comfort (i.e. Fanger or Hsu). With THESEUS-FR and for the first time, full transient local comfort assessment of passengers will now be possible considering the complete metabolic heat balance including blood circulation, sweating, trembling, air humidity by breathing, heat performance of it's own as well as all the other complex environmental parameters described above. This will be realized by implementing the DTS model (Dynamic Thermal Sensation) based on Fiala (1). The number of used virtual Manikin within the model to be examined (for example 4 in a standard passenger car, 60 in an aeroplane prototype) is only limited by the complete element number and used resources.

Calculations of exhaust systems and heat shield design are preferential application areas of the CAE tool in the area of “underhood thermal management (UTM)". In combination with CFD calculations, radiation exchange, heat conduction and convective values for inner and outer airflow can be evaluated integrally, saving time and money. Also, for the component optimization, for example for choosing temperature constant materials for heat shields, instrument panels or interior trims, THESEUS-FE is applied.

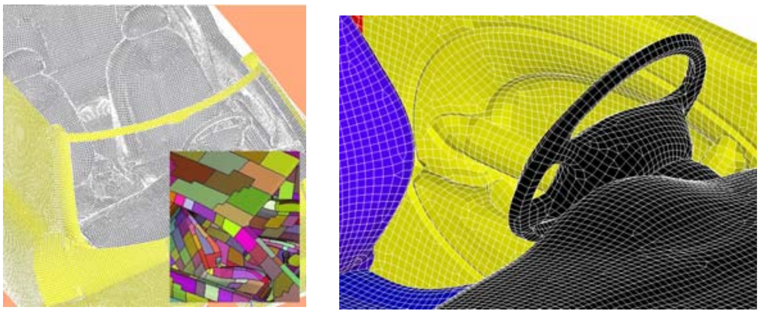
For the calculation, the user simply imports a Nastran file which contains the geometry information of the model and starts to setup the model by assigning material properties and other boundary conditions. THESEUS-FE contains a database with the most important materials from the automotive industry which can be enlarged arbitrarily. If the model is completely defined in the Pre-Processor, the calculation can be started, but not before the programme has subjected the model successfully to an entrance test. If wrong or not suitable parameters were set, a warning appears displaying an error message. Only if all errors in the system are removed, the calculation starts. This ensures that no unnecessary and time intensive calculations are done, whose results will be faulty.

The view factor calculations necessary for the thermal analysis can immediately be started after reading in the geometry, if no cavities are being used. So the view factor matrix can be build parallel to the further preparation of the model for the thermal simulation in the Pre-Processor. The essential needed view factor results are therefore available fundamentally earlier, too. After starting the thermal solver, the complete system will move into an energetic balance by using the previous computed view factors. For a steady state calculation this runs quite rapidly. For a complete, time-dependent air conditioning calculation the thermal balance must be charged for every time step anew, what leads to enlarge calculation times inevitably/compelled. The calculation is ended if either the predefined iteration steps are reached or the system is balanced out completely.

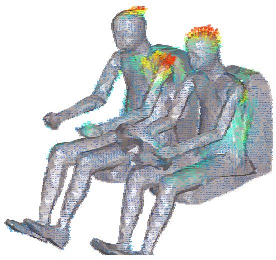
The user has different options to view and evaluate calculation results in the integrated post processor. With the help of coloured scales the user is able to represent the respectively desired variables graphically. Of course, the user can also print the requested results as representing (representative?) 2D plots or 3D screenshots or can export result data to be used for other commercial Post-Processors. Next to the new implemented DTS model for local comfort studies the long-standing standard global comfort indices like PMV (2) (Fanger, ISO7730), PPD, ET and HSU (3), can be evaluated in the Post-Processor, too.

Conclusion

For several years now, a clear trend towards a more intensive use of numeric simulation can be seen. Not only OEM's but also subcontractors have recognized the advantages of such applications and use them visibly/noticeably. The meaning of the numeric simulation increases continuously with reference to air conditioning and passenger comfort. The experts of P+Z Engineering therefore develop permanently improvements for the new solver, for example the compatibility to common software tools from the FE and CFD area.

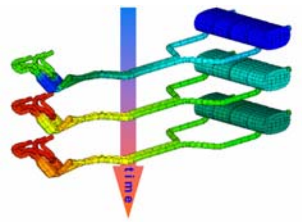


Geometry with about 195k elements



Airflow velocity impacting the passenger.

By use of special thermal bridges the contact of the virtual Manikin to the seat is closed so that the heat transport between passenger and interior can be considered completely.



The picture shows an exhaust system calculated with time-dependent temperature variation.

References

(1) Fiala, D., "Dynamic simulation of human heat transfer and thermal comfort", Ph.D. thesis, DeMontfort University, Leicester (UK), 1998

(2) Fanger P.O., "Thermal Comfort – Analysis and Applications in Environmental Engineering", 1973

(3) Hsu, S., "A thermoregulatory for heat acclimatisation and some of its applications" Ph.D. thesis, Kansas State University (USA), 1977

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