ITEA 4

Project Results

COMPAS

Compact modelling for co-design and optimisation

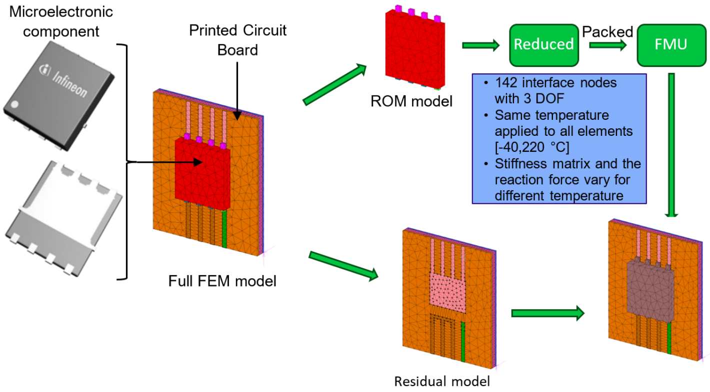
To make thermo-mechanical compact models a reality, the ITEA project COMPAS (Compact modelling of high-tech systems for health management and optimisation along the supply chain) developed software tools for co-design across the micro-electronics supply chain and investigated the development of ultra-compact digital twins.

In any supply chain, a partner may know much about the system but not the components (or vice-versa). However, every party has an interest in how forces affect components and their lifespans, such as how solder joints in a phone or car react to vibrations. This calls for co-design across the supply chain, but how can a company protect its intellectual property while sharing the necessary information? And how can failure progression be monitored? The answer lies in compact modelling.

Thermal compact models of component behaviour have long existed but options for thermo-mechanical applications have been lacking. COMPAS therefore aimed to develop software tools that (1) facilitate the efficient co-design of such high-tech systems across the supply chain using novel compact modelling techniques and (2) provide prognostics and health management for these systems using ultra-compact digital twins. This will accelerate computer-aided engineering (CAE) in the microelectronic supply chain by enabling the efficient exchange of simulation models between different disciplines and reducing the analysis time for non-linear simulations, allowing for a complete system perspective. The consortium also included world-leading automotive suppliers, positioning COMPAS for a strong impact on fail-safe operations in autonomous driving.

Technology applied

As mathematically simplified models, compact models are a standardised generic interchange format that protects proprietary information while enabling faster system-level simulations. For co-design across the supply chain, a reduction method for piecewise linearised thermo-mechanical models was developed that combines several linear models to accurately describe a non-linear model. These models did not previously exist and the method reduces full finite element models into compact models that serve as a 'black box' for sharing simulation data without the fine details. A major achievement was the successful promotion of a new XML element into the international JEDEC standard, which provides a template to fit the exchange format for thermo-mechanical simulations. COMPAS successfully demonstrated how a compact model can be embedded within the XML template as a functional mock-up unit (FMU) that can be used by customers to visualise and position the compact model in their finite element software.



< Temperature-dependent elastic materials evaluate the thermo-mechanical behaviour under different environments.

Additionally, the consortium performed a feasibility study on the development of ultra-compact digital twins that can be embedded directly into systems, avoiding the need to constantly send data to another location like the cloud. This reduces computational effort and boosts sustainability via lower energy usage. In the study, COMPAS created methods based on fatigue and creep strain to predict the level of delamination as a function of temperature cycles and developed a method using temperature sensors to characterise the state of a power switch regarding delamination.

The framework for the digital twin of the power switch's delamination has now been drafted and will serve as a springboard for future research.

Making the difference

As the first project to address standardised compact models for thermo-mechanical applications, COMPAS intended to increase the technology readiness level (TRL) of non-linear compact models from 3-4 to 6-7 and instead reached TRL 6-8. The consortium also verified the in-situ accuracy of thermo-mechanical non-linear models at 90% (versus a starting point of zero) and demonstrated a vendor-neutral interface for compact models via four software packages that are capable of handling the exchange format at TRL 7. Non-linear compact models and ultra-compact digital twins will enable design optimisation using a full system perspective, thereby reducing experimental development cycles, and provide advanced health management for fail-safe high-tech systems with less hardware redundancy. This will allow customers to save costs by avoiding unplanned shutdowns and for customers and suppliers to build better relations through co-design. Less physical testing and more simulation at system integrators also brings a strong competitive advantage through faster design cycles.

Regarding commercialisation, the need for fewer computational resources means that compact models and digital twins can be implemented locally and sold within products or as add-ons. MSC Software, for instance, has implemented FMU support for temperature-dependent compact models in the early 2024 release of their finite element software package Marc/Mentat, while Jade University of Applied Sciences is working with external partner CADFEM to introduce COMPAS' model order reduction as an add-on to ANYSYS. Smaller companies are also benefiting from the results: SME Reden created a framework through which knowledge gained in COMPAS can be applied to digital twin development for customers. Its generic nature allows them to use it for various customers and applications, helping them expand into new markets.

In the longer term, COMPAS can boost the reliability of automotive micro-electronics needed for autonomous driving as the application of thermo-mechanical compact models would represent a breakthrough in the reliability assessment of automotive-grade component assemblies during their design phase. In the meantime, NXP and Infineon will continue to pursue standardisation, possibly with further bodies, and the majority of the consortium intends to build on the feasibility study with a new project on ultra-compact digital twins. As a result, COMPAS is both a highly successful project in its own right and an important foundation for future innovation.

Major project outcomes

Dissemination

- More than 20 publications in scientific journal, conferences, and book chapters.
- Best poster presentation & outstanding paper award at the 2023 EurosimE conference.
- Organised a workshop 'Efficient Thermal-Mechanical Simulation Using Compact Models' and a symposium 'Model Order Reduction of Multi-physical Finite Element Models in Microelectronics'.

Exploitation (so far)

New products:

- Implementation of a Krylov based reduction algorithm into Simcenter.
- New Simcenter interface to evaluate parametric reduced order models.
- Software tool for reducing 3D FE models in ANSYS.
- FMU support of temperature dependent reduced order models in Marc/Mentat.

New services:

- Physical and real-time model-based system testing approaches using validated executable digital twins.
- AI models for device health status prediction, which can be used for new projects/ customers based on new datasets.
- Framework for digital twin development suited to gain insight in the performance of a digital twin that deals with uncertainties on the sensor and model side.

Standardisation

- Active presence in JEDEC JEP-30 committee; JEP-30 successfully extended to allow for electrical components the referencing of external models.
- Proposed a standardised exchange format for thermo-mechanical reduced-order models; using recent FMI 3.0 avoids new format & allows using existing FMU export/import capabilities.

COMPAS

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Partners

Belgium

- Katholieke Universiteit Leuven
- Siemens Industry Software NV

Germany

- eesy-innovation GmbH
- Fraunhofer ENAS
- Infineon Technologies AG
- Jade University of Applied Sciences
- MicroConsult Engineering GmbH
- Siemens AG

Netherlands

- Atlas Technologies B.V.
- Delft University of Technology
- Eindhoven University of Technology
- MSC Software Benelux
- NXP Semiconductors
- Reden BV

Project start

January 2021

Project end

December 2023

Project leader

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Project website

https://itea4.org/project/compas.html

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