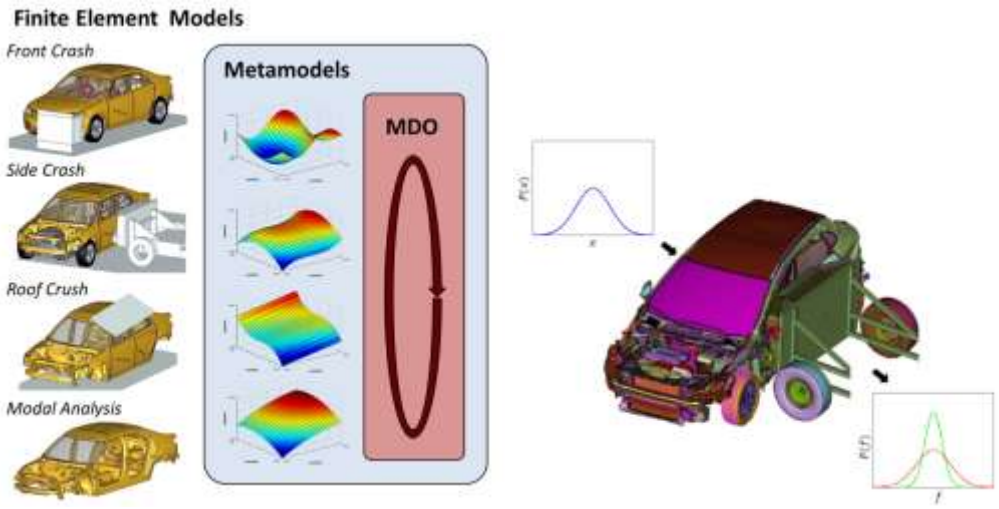
Robust and multi-disciplinary optimization of vehicle structures



Project within Fordons- och trafiksäkerhet

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Content

FFI in short

FFI is a partnership between the Swedish government and automotive industry for joint funding of research, innovation and development concentrating on Climate & Environment and Safety. FFI has R&D activities worth approx. €100 million per year, of which half is governmental funding. The background to the investment is that development within road transportation and Swedish automotive industry has big impact for growth. FFI will contribute to the following main goals: Reducing the environmental impact of transport, reducing the number killed and injured in traffic and Strengthening international competitiveness. Currently there are five collaboration programs: **Vehicle Development, Transport Efficiency, Vehicle and Traffic Safety, Energy & Environment and Sustainable Production Technology.**

For more information: www.vinnova.se/ffi

1. Executive summary

The development of efficient vehicle structures has been one of the main focuses of the automotive industry to handle the global demand on emission targets, increased safety requirements and competition in the global market. Consequently, it is necessary to develop tools and efficient methodologies to optimize the vehicle structures. The main aim of this project is to develop efficient simulation-based robust design optimization and multidisciplinary design optimization (MDO) methodologies which are applicable to automotive product development.

In this work, efficient methodologies and process to implement robust design optimization and multidisciplinary design optimization in the existing product development process have been developed. These methods were found to be suitable for automotive product development. In the first part of the project, a description of the differences between MDO in the aerospace and automotive industries has been outlined and a process suitable for MDO of automotive structures that fits the development process and company organization has been presented. This process is demonstrated using a simple example but also tested on large-scale industrial applications. In the second part, potential methods and tools to perform robust and reliability-based design optimization have been identified and efficient methodologies were developed. These methodologies were verified and demonstrated using large-scale vehicle engineering applications.

2. Background

The development of vehicle structures comprises many different phases from early concept development to the final detailed phase where the complete product is analyzed. In recent years, simulation-based design process has become an integral part of the automotive product development process to achieve the cost and time efficiency. Optimization methods will have a vital part in these development phases. CAE-based optimization will become an important part of the virtual design process, to create optimized designs. Robust design optimization of structures, which includes uncertainties in input parameters in the optimization process, is important to create a robust and reliable design. Furthermore, it is also necessary to consider all relevant disciplines simultaneously during optimization to create a balanced optimum design.

The development of optimization methods and tools has increased significantly and many industrial applications can be seen in the literature. However, vehicle structure development is a complex process and involves many disciplines. Some of the responses are highly non-linear and the computational effort is also very high. Consequently Meta-models are used to handle time consuming simulations during optimization.

3. Objective

The main aim of the project is to identify efficient methodologies and process for performing robust design optimization and multidisciplinary design optimization of vehicle structures, which can be implemented into the existing product development process.

The FFI goals, which are relevant for this project, are given below

Industrial goals:

Implementation of MDO and robust design optimization which :

• Reduces the product development time.
• Increases the ability to find lightweight solutions.
• Increases the ability to generate a system with robust features.
• Increases the system understanding.

Commercial goals:

Robust lightweight solutions which will increase the ability of the company to be competitive in the global market and to offer products that meet customer and market requirements on environmental and safety features.

Academic goals:

- Investigate existing and develop new theories and methodologies in multiobjective structural optimization.
- Investigate existing and develop new methods in robustness and reliability-based structural optimization.
- National research environment around optimization driven design, interaction with parallel research projects, such as the former ProViking research program.

Transportation goals:

- Systems with low weight to meet the CO2 requirements and fuel efficiency.
- Robust performance (crash, dynamics, etc.) for “real life performance”.

4. Project realization

The project was carried out at Volvo Car Corporation and Combitech AB in close cooperation with Linköping University, Dynamore Nordic AB, Altair AB and Enginsoft AB. Two PhD students, Ann-Britt Ryberg and Sandeep Shetty, were responsible for the project execution. Professor Larsgunnar Nilsson at the Division of Solid Mechanics at Linköping University, Dr. Harald Hasselblad and Dr. Mikael Fermér from Volvo Car Corporation and Thomas Sjödin from Combitech has been supervising the project work. Regular meetings were held between the partners to steer the project.

5. Results and deliverables

In this work, efficient methodologies and processes to implement robust design optimization and multidisciplinary design optimization in the existing product development process have been developed. The academic results from the project are presented in two licentiate thesis, in addition to onsite presentations at the industrial parties.

A description of the differences between MDO in the aerospace and automotive industries has been outlined and a process suitable for MDO of automotive structures that fits the automotive development process and company organization has been presented. Further details are given in Ann-Britt Ryberg's licentiate thesis no. 1565, Linköping University.

Potential methods and tools to perform robust and reliability-based optimization have been identified and efficient methodologies were developed. A description of how these can be integrated in the development process has been formulated and demonstrated using vehicle engineering applications. Further details are given in Sandeep Shetty's licentiate thesis no. 1643, Linköping University.

5.1 Delivery to FFI-goals

The project results contribute to the fulfilment of the FFI goals. Most of the FFI goals have been met. The main results from the project are listed below

- A multidisciplinary design optimization process for large-scale automotive structural applications has been presented and tested on a demonstration example.

- The developed process is simple, efficient, flexible, and suitable for common structural MDO applications in the automotive industry, such as weight optimization with respect to NVH and crashworthiness.

- The process can easily fit into an existing organization and product development process.

- Approaches to perform metamodel-based multiobjective reliability-based optimization and robust design optimization are presented and verified using complex vehicle engineering applications.

- The results show that metamodels can be used as a substitute for expensive FE models in the optimization of vehicle structures. The results of the study also show the importance of considering uncertainties in the optimisation in order to obtain a robust and reliable design.

- The approaches to perform robustness evaluation and non-deterministic optimization presented in this work were found to be suitable for vehicle engineering applications

6. Dissemination and publications

6.1 Knowledge and results dissemination

Potential methods and tools have been identified, and challenges that exist to implement optimization driven development in the vehicle industry have been formulated. Weight minimization, improved crash safety and robustness can be achieved using the developed methodologies. Presented methodologies can also be used in the early phases of design process to gain system knowledge.

The study results show that the presented methodologies and process are suitable for vehicle engineering applications. Part of these methodologies is directly implementable in the existing design process and remaining part need slight improvement.

6.2 Publications

A.-B. Ryberg, R. D. Bäckryd, L. Nilsson (2012) , '*Metamodel-based multi-disciplinary design optimization for automotive applications*', Technical report LIU-IEI-R-12/003, Linköping University.

R. D. Bäckryd, A.-B. Ryberg, L. Nilsson (2013), '*Multidisciplinary design optimization methods for automotive structures*', Submitted for publication.

A.-B. Ryberg (2013), '*Metamodel-based design optimization – A multidisciplinary approach for automotive structures*', Licentiate thesis LIU-TEK-LIC-2013:1, Linköping University.

A.-B. Ryberg, R. D. Bäckryd, L. Nilsson (2014), '*A metamodel-based multi-disciplinary design optimization process for automotive structures*', Accepted for publication in Engineering with Computers.

S. Shetty and L. Nilsson (2013): '*Robustness study of a hat profile beam made of boron steel subjected to three point bending'*. Submitted for publication.

S. Shetty and L. Nilsson (2014) '*Multiobjective reliability-based and robust design optimisation for crashworthiness of a vehicle side impact*'. Accepted for publication in the International Journal of Vehicle Design.

S. Shetty (2014) '*Optimization of Vehicle Structures under Uncertainties'*, Licentiate thesis LIU-TEK-LIC-2014:1, Linköping University.

S. Shetty (2014) '*Efficient reliability-based optimization using a combined metamodel and FE-based strategy*'. Proceedings of the 4th International Conference on Engineering Optimization (EngOpt), Lisbon, Portugal.

7. Conclusions and future research

The approaches to perform robustness evaluation and non-deterministic optimization presented in this work were found to be suitable for vehicle engineering applications. The presented MDO process is simple, efficient, flexible, and suitable for common structural MDO applications in the automotive industry, such as weight optimization with respect to NVH and crashworthiness.

The future research will focus on proceeding with implementation of the tools and methods and, where appropriate, develop and improve methods to handle the complexity

faced. The two research students will cooperate on selected topics to reach the PhD exam. Sandeep Shetty is located at Volvo Cars with the main focus on robust optimization and Ann-Britt Ryberg at Combitech with the focus on multidisciplinary design optimization.

8. Participating parties and contact person

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