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Simulation Driven Development – an enabler for future energy efficient vehicles

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Executive Summary

Energy efficient, light weight and well-balanced design is becoming increasingly important. To support this challenge, simulation and optimization need to be efficiently used during the development process. This presentation will give you an overview of how Volvo Cars strategically work with simulation driven development to support light weight and energy efficiency designs. Benefits and challenges with simulation driven development will be presented along with several inspirational cases across the organization. You will also hear about how Volvo Cars coordinates an internal competence network on simulation driven development.

1 Simulation Driven Development

Low weight is crucial for energy efficiency in electric vehicles (EVs). A lighter vehicle uses less energy to move, which directly extends the battery range and reduces overall energy consumption. This is particularly important as advancements in battery technology struggle to meet the increasing demands for longer ranges and better performance.

By optimizing the weight of an EV, manufacturers can achieve significant efficiency gains. For instance, a lighter chassis can allow for a smaller battery pack while still maintaining the desired range. This not only conserves energy but also reduces material and production costs, making EVs more affordable and sustainable.

Furthermore, the benefits of a lightweight design extend to the overall performance of the vehicle. Enhanced handling, faster acceleration, and improved braking efficiency contribute to superior driving experience and increased safety. These attributes collectively enhance the appeal of EVs to consumers.

In summary, the pursuit of low weight is essential for maximizing energy efficiency in electric vehicles. It influences not only the vehicle's performance and range but also its sustainability and market viability. Innovations in materials and optimization techniques will be key to achieving these goals in the future.

Simulation Driven Development (SDD) is an advanced engineering approach where simulation tools and techniques are employed throughout the product development process to optimize design and performance. Unlike traditional methods, which often rely on physical prototyping and testing, SDD uses virtual simulations to predict and enhance the behavior, efficiency, and durability of a product before it is manufactured.

Figure 1: Building early knowledge by simulation driven development

The transition from virtual verification to Simulation Driven Development marks a significant shift in how design and optimization are approached. This methodology not only accelerates the development timeline but also expands the design space, allowing for more innovative and effective solutions, especially in the era of Battery Electric Vehicles (BEVs). By integrating simulations early and continuously in the design process, engineers can explore a broader range of possibilities and make informed decisions that improve the overall quality and performance of the final product. See Figure *1*: Building early knowledge by simulation driven developmentFigure *1*.

1.1 The role of optimization within simulation driven development

Structural optimization is vital in simulation-driven development (SDD), enhancing design efficiency and innovation. It allows engineers to explore a broader design space and find efficient structural configurations that meet performance criteria. This involves adjusting parameters for optimal weight, stiffness, and strength.

In SDD, structural optimization helps create lightweight structures without compromising safety or functionality. It balances trade-offs between material usage and structural integrity, especially important for Battery Electric Vehicles (BEVs) to improve energy efficiency and range.

Moreover, structural optimization enables iterative testing and refinement, ensuring each design iteration improves. This process uses computational power to evaluate numerous designs rapidly, speeding up development and fostering innovation by uncovering unique solutions.

2 Organization

Implementing simulation-driven development (SDD) within an organization involves several key challenges:

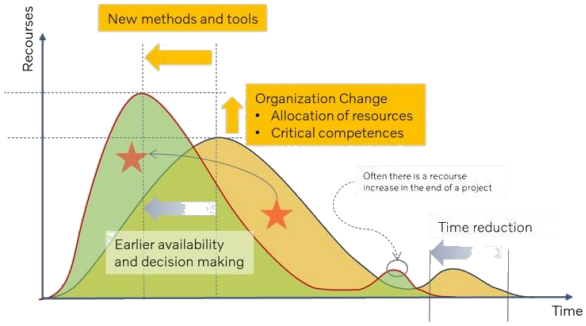

Figure 2: Challenges with SDD

Firstly, we have organizational challenges and resource allocation. Traditional engineering practices often resist the shift towards simulation driven development. Clear request for SDD related activities is essential to overcome this resistance and build confidence across the organization.

Secondly, integrating SDD tools with existing systems and processes requires investment in development of new workflows. Ensuring data and model consistency across attributes and platforms is crucial for efficient implementation of SDD.

Thirdly, organizational structures may need to be re-evaluated to support collaborative work, and roles, competences and responsibilities may need to be redefined to align with SDD processes. Traditional roles like CAE and Design Engineers float together into more Concept Engineers roles enabling efficient SDD.

Finally, continuous education and skill development are vital to keep up with evolving simulation technologies.

By addressing these challenges, companies can fully leverage the benefits of SDD, leading to innovative and efficient design solutions.

3 Optimization Competence Arena

"*Experience shows that, about 80 % of the final product weight is determined by the designers' first concept*." [1]

This statement perfectly indicates the need for SDD in the early phases of design, where we set the foundation for an efficient design. It is important to be able to handle cross attribute challenges when defining your optimization problems in the early phases. This approach goes, not only for weight reduction but for all project development guiding towards efficient and balanced solutions. An SDD approach also builds knowledge about the system and component when it comes to dimensioning requirements and load cases.

Within Volvo Cars we coordinate activities and share experiences across all development areas and attributes within an Optimization Competence Arena. This arena servs as a cross technical knowledge network for common optimization competence development.

When we perform activities, the arena helps securing the right competences to manage the tasks. The arena also serves as a base for defining and handle challenging method development projects as well as coordinating training and competence development.

4 Case studies

In this chapter some optimization approached within a SDD process will be presented.

4.1 Structural optimization

Structural optimization is like using a Swiss Army knife. You need deep knowledge about the different tools and how to use them efficiently in sequence and how to combine them from early to late project phases. One of the tools suitable for early conceptual phases is Topology Optimization. Topology optimization is widely used for cast components and plastic molded parts to identify an efficient material distribution based on single of multiple load cases and a given packaging space. However, topology optimization can also be used to identify weaknesses in a larger structure such as a BIW (Body in White), Figure *3*, or finding locations for possible holes in sheet metal components. This can be efficiently combined with thickness optimization.

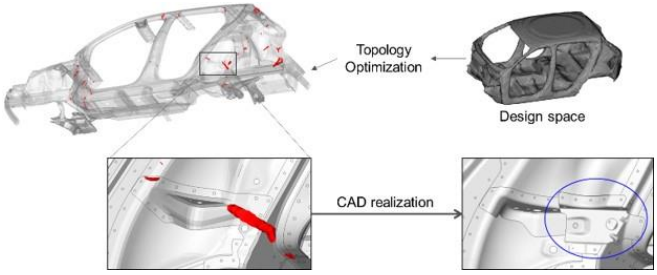

Figure 3: Structure screening of a BIW using topology optimization

The use of topology optimization can give up to 30% weight reduction to a reference design using more experience driven development. However, to get the full potential, implementing topology optimization requires knowledge about design interpretation and needs to be combined with e.g., shape optimization and cast simulation.

4.2 Improving energy efficiency by CFD optimization

As mentioned, energy efficiency is especially important for BEV´s. One study [2] using SDD and optimization to reduce energy consumption is on a cooling system design where pipeline design, supervised by genetic algorithm is deployed. Figure *5*, This project resulted in a higher heat transfer coefficient (40.90 W/m2K) than

a manually designed cooling system, with 0.55 kPa lower pressure drop. This was done by capturing diverged flow field supervised by topology optimization. Figure *4*.

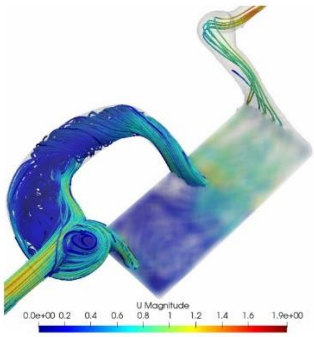

Figure 4: Illustration of the streamlines in a gradient-descent based multi-objective topology optimization

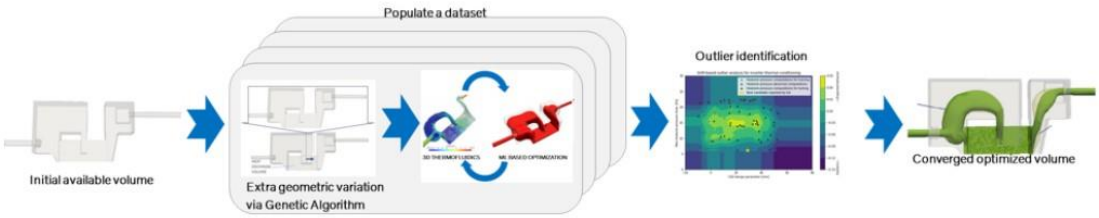

Figure 5: Prescribed process for GA to run topology optimization schematics.

5 Conclusions

At Volvo Cars, the journey towards simulation driven development started some 25 years ago. For more than 10 years an optimization competence arena has been active in setting the culture for SDD and support in method and tool development.

At Volvo Cars we see clear weight reduction in many areas supporting future challenges towards EV´s. Experience from vehicle development at Volvo Cars has proven that SDD can unlock weight savings of typically 10-30 %, compared with a more traditional ways of designing systems and components.

References

[1] Altair, *Design the Inspire way*, https://blog.altair.co.kr/wp-content/uploads/2012/12/Inspire_eBook_2017.pdf, 2017

[2] Raik Orbay et.al, *An artificial intelligence pipeline for critical equipment thermal conditioning system*, EPE'22 ECCE Europe, ISBN 978-9-0758-1539-9, Conference Paper, 2022.

Presenter Biography

Harald Hasselblad works as a Technical Expert within weight management and optimization at Volvo Cars. He is responsible for corporate weight strategies and driving an Optimization Competence Arena, supporting Simulation Driven Development within Volvo Cars. The arena supports the development and implementation of methods and tools for efficient engineering and optimization in early and late project phases. Harald started his carrier as a PhD student at Volvo Cars. His research area was focusing on topology optimization and methods for the early concept phases. Harald's expertise lies within conceptual analysis and optimization and working with development methods and tools for structural optimization. He received his PhD in Mechanical Engineering from the Linköping University, Sweden. He has now worked at Volvo Cars for 25 years.