Advances in Reliability, Safety and Security

ESREL 2024
Collection of Extended Abstracts

Nonlinear Dynamic Simulations Of Automotive Component Undergoing Vibration Loadings

Maciej Majerczak[a], Ewelina Czerlunczakiewicz[a], Marco Bonato[b]

[a]*Valeo THS, Skawina, Poland*
[b]*Valeo THS, La Verriere, France*

Keywords: nonlinear dynamic, accelerated tests, vibration, fatigue damage, FEA, fatigue simulation, automotive, heat exchangers

The modern development of products in the automotive industry requires a shift from traditional testing methods. With an increasing number of prototypes going digital to shorten the design validation phase and reduce physical testing, Finite Element Analysis (FEA) becomes essential for predicting product behavior. However, to fulfill the requirements of a shorter time to market and reduced design margins for the products, simulations must be not only accurate but also highly reliable.

Finite Element (FE) models need to accurately represent both geometry, with all the important details, and the physics being analyzed. This requirement leads to a significant increase in the size of FE models. Our case study addresses the challenges associated with relying on simulations, emphasizing the need to boost confidence levels in Finite Element Analysis results while minimizing the risk of red alerts, particularly in the dynamics domain (vibration stress loads).

Efficient methods widely used in the industrial dynamic calculations, such as frequency domain approaches like Steady State Dynamic (SSD), are chosen for their shorter computation times compared to time-domain counterparts. However, SDD methods bring a significant intrinsic limitation: they rely on a linear modelization approach.

One method that allows the consideration of nonlinear effects of Finite Element Analysis results in is based on the time-domain computational approach. To meet time and resource constraints, the implementation of a high-performance simulation solver is crucial. For this purpose two solvers were chosen for this task, and their performance was compared. Additionally, this study aims to identify bottlenecks within the entire computational process to improve the usability of this approach in daily tasks.

A real industrial application will be presented, featuring a Water Cooled Condenser - a multi-material heat exchanger operating within the car Heat Pump system subjected to vibration loads. This application involves a known failure mode, specifically leakage caused by cumulative fatigue damage.

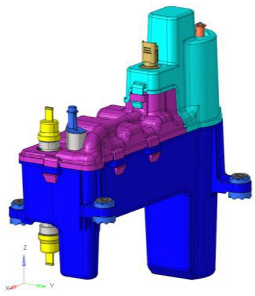

Fig. 1. Example of CAD of Water Cooled Condenser (a multi-material heat exchanger).

The primary objective of this thorough study is to compare and analyze the results derived from various approaches and solvers. This examination is conducted within the realm of durability design validation for an industrial product, which is actively subjected to vibration fatigue loadings. The overarching goal of employing diverse methodologies and solvers is to deepen our understanding of their respective strengths and weaknesses in addressing the challenges posed by vibration-induced fatigue. Through this comparative analysis, the study aims to provide valuable insights that can significantly impact the optimization and improvement of future design validation strategies for industrial products experiencing vibrational fatigue loads.

References

Czerlunczakiewicz, E., Majerczak, M., Bonato, M. 2023, Variability Of Fatigue Simulation Predictions For Automotive Components, 2023 Annual Reliability and Maintainability Symposium (RAMS), Orlando, FL, USA, 1-6, doi: 10.1109/RAMS51473.2023.10088243.

Lalanne, C. 2014. Mechanical Vibration and Shock Analysis, Volume 4, Fatigue Damage, 3rd Edition, Wiley-ISTE.

Wriggers, P. 2008. Nonlinear Finite Element Methods, Springer Berlin, Heidelberg.