Overview of LS-TaSC™ and New Feature Highlights

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1 Introduction

The general capabilities of LS-TaSC were designed to solve topology and shape optimization of large nonlinear problems involving dynamic loads and contact conditions applied to solid and shell structures.

LS-TaSC can deal with huge models with up to 10 million elements, multiple load cases, and multiple disciplines. Three main categories of structural optimization problems can be addressed by LS-TaSC, including topology optimization, topometry optimization, and shape optimization. Topology optimization uses the relative densities of elements as design variables, minimizes the structural mass or a response, or maintain a target mass fraction at the global level, and maximizes the structural stiffness or the fundamental frequency at the local level. Topometry optimization uses the shell element thicknesses as the design variables, and it has similar setting options in terms of the definition of the objective function. Shape optimization chooses a free shape of the outer surface contour to design and finds the best surface shape that yields a uniform stress on the surface. The von Mises stress field is designed, and the uniform surface stress reduces the occurrences of stress concentration.

Regardless of the optimization categories, different geometry and manufacturing constraints are available, including symmetry, extrusion, casting, forging, pattern repetition, and feature size control. LS-TaSC was initially applied to the design optimization of highly nonlinear mechanics problems but has over time been expanded to be relevant to a comprehensive range of practical applications such as found in automotive design [1-3].

LS-TaSC is integrated seamlessly with LS-DYNA for structural analysis and results validation, with LS-PrePost for results visualization and model editing, and with LS-OPT for multi-level and complex design optimization problems. Recent developments on supporting user analysis provide the users with the flexibility to conduct design optimization of multiple load cases analyzed by different analysis software that are conveniently accessible to them. Furthermore, importing LS-TaSC as an ACT extension to work with LS-DYNA on the ANSYS Workbench extends the user experience beyond the LS-TaSC GUI.

2 Constrained Multi-disciplinary Topology Optimization

Due to the complexity of automotive design, design requirements such as structural strength, stiffness, frequency characteristics, as well as impact energy absorption and pedestrian safety, are of great importance. These requirements demand advanced methodologies to address optimization problems with multiple constraints and multiple disciplines. To fulfil these demands, LS-TaSC incorporates multiple innovations such as a special theory for the *maximization of energy absorption* for impact problems [4], the *multi-point method* for computing design sensitivities for the constrained topology optimization of impact problems [5], and the *spatial kernel method* for multi-disciplinary topology optimization involving impact, static, and NVH load cases [6].

Designing for impact is fundamentally different from designing for other disciplines, in part because the maximization of the energy absorption requires special handling to have a stable structure. Our implementation therefore solves for the saddle point problem instead of the normal energy minimization, which can be described as

$$max_{\xi} min_{x}\, E(\boldsymbol{\xi}, \boldsymbol{x}) \quad (1)$$

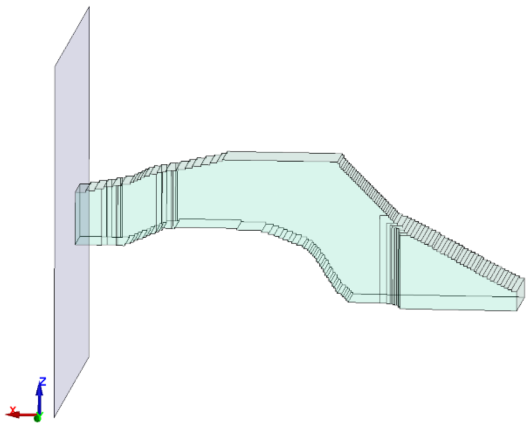
Where E is the energy, $\boldsymbol{\xi}$ is the spatial kernel variable vector that relates to the global properties of the design, and $\boldsymbol{x}$ is the topology design variable vector. The optimization scheme therefore solves a dual problem [7]: the upper level problem solving for the properties of a feasible structure and the lower level problem solving for the topology of a stable structure with these properties. The lower level problem is solved by using the projected subgradient method [8] considering the Lagrangian, while the upper level problem is solved by using finite differences or surrogate models.

For design sensitivity analysis, the numerical gradients provided by the multi-point method and the metamodels, specifically for the crash discipline design problems, and the analytical gradients, i.e., the frequency gradients, are used in LS-TaSC. The user-provided gradients that are computed by other structural analysis platforms can also be used in LS-TaSC.

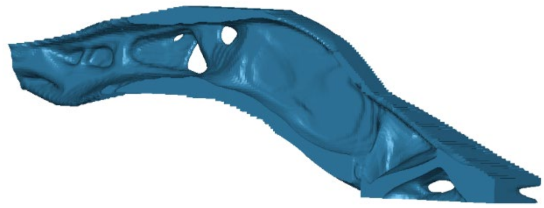
3 Highlights of New Features

Highlights of the major new features of the latest versions are summarized below.

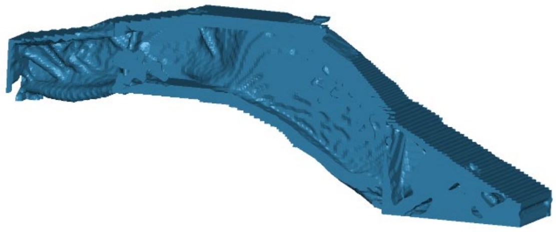
- *Multidisciplinary Design Optimization for Shell Thickness*: Multidisciplinary design optimization of shell structures involving impact, static, and NVH load cases can be resolved similarly to the optimization of solid parts. The importance of each design discipline is defined by using one or more constraints applied to the structural responses under the specific load case.
- *Support for User Analysis and DSA*: A new capability in LS-TaSC allows users to export the results (i.e., structural response values and design sensitivities of interest) of an entire load case analyzed by other platforms such as MSC Nastran or ANSYS Mechanical, improving communication and hand-offs between LS-DYNA and other software to facilitate individual design requirement integration. The new release can read results of any analysis types from another platform for design optimization computation.
- *Minimum or Maximum Feature Size Controlling*: Following the capability of controlling minimum member size in the previous release, the new release provides better control of maximum member size for parts. Fig. 1 shows an example of the topology optimization of a structural part for three load cases, i.e., a bending load case, a torsion load case, and an impact load case. The voids can be prevented by applying a minimum and maximum thickness definition together with the casting.



(a) Base structure (bending, torsion, and impact)



(b) Design result with a casting definition



(c) Design result with a casting definition together with a thickness definition

Fig.1: Design of a cast part without and with a minimum and maximum thickness constraint.

- *As an ACT extension on Workbench*: Because of the seamless integration with LS-DYNA, LS-TaSC can be imported as an ACT extension to work with LS-DYNA to form a completed workflow on Workbench. Fig. 2 shows an example of adding LS-TaSC as an ACT extension and reading the design optimization result on Workbench.

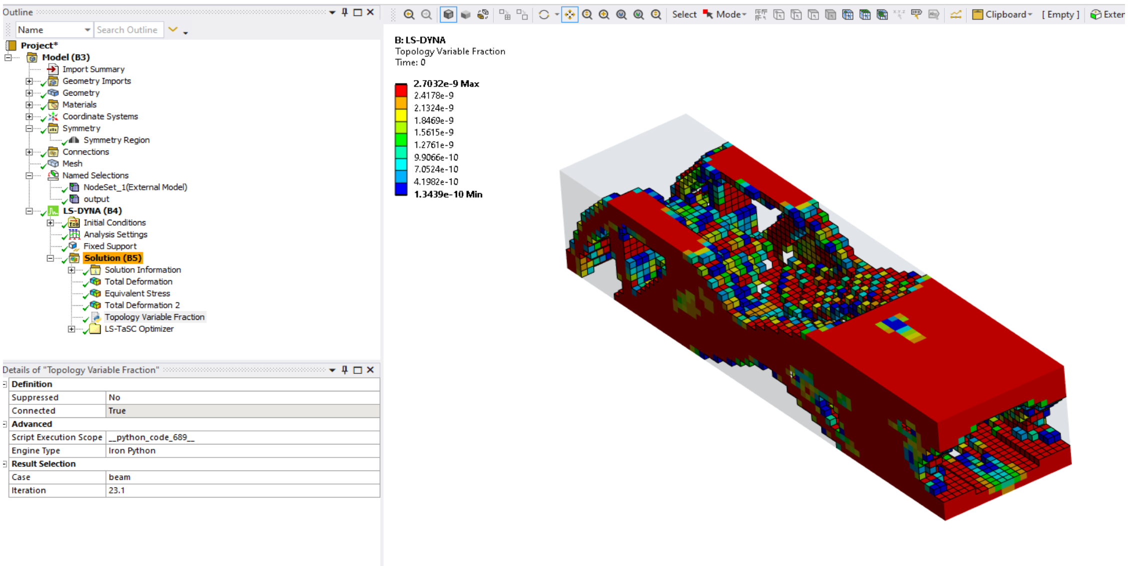


Fig.2: LS-TaSC as an ACT extension to work with LS-DYNA on Workbench. (Figure courtesy of Rajesh Meena, Imtiaz Gandikota, and Ram Gopisetti.)

4 Summary

The paper provides an overview of LS-TaSC, specifically on its ability to solve constrained multidisciplinary topology optimization problems. Highlights of new features incorporated in the latest versions are summarized. This demonstrates the successful expansion of the usability of LS-TaSC in terms of structural type, manufacturability, and user experience.

5 Literature

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