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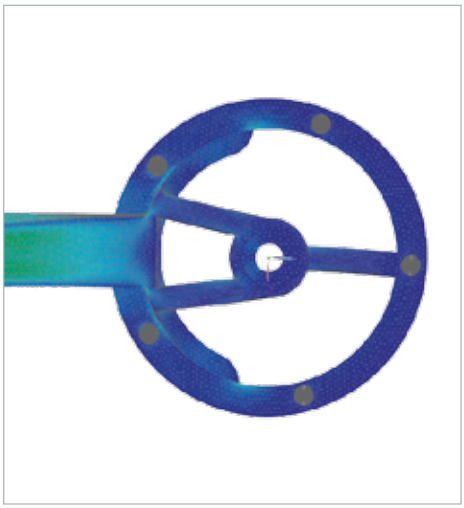
Using HyperWorks for Teaching Computational Optimization Methods in Engineering Design at Northwestern University



NORTHWESTERN UNIVERSITY

Key Highlights

Industry
Research

Challenge
Implement a series of engineering design courses

Altair Solution
OptiStruct® and HyperStudy®

Benefits
- Working with cutting-edge computer-aided design (CAE) tools helps undergraduate students develop the skills required to solve real-world engineering problems

Customer Profile

Northwestern University in Evanston, IL., USA is a premier research university that provides students and faculty with exceptional opportunities for intellectual, personal, and professional growth. The Integrated DEsign Automation Laboratory (IDEAL) of the Department of Mechanical Engineering, under the direction of Dr. Wei Chen, focuses on the development of rational design methods based on mathematical optimization techniques and statistical methods for use in complex engineering design and product realization problems. The complexity is considered from various aspects, such as the large number of physical interrelated elements, the complexity and computational cost of design simulations, the heterogeneity of information at different levels of abstraction, the various sources of uncertainties, the multidisciplinary organization with conflicting goals, and the difficulty in understanding the socio-technical interfaces. Methods include robust topology and shape optimization to comprehend variation in loading, material properties, or geometry resulting from imprecise manufacturing processes. IDEAL has been instrumental in developing engineering design courses in the areas of engineering optimization, computer analysis, advanced computational and statistical methods for product and process design, and senior capstone courses.

The Challenge: Implement a series of engineering design courses

Computational design methods like modeling, simulation, and optimization are playing an increasingly important role in engineering design decision making. Engineering design is characterized by creating and evaluating

Keywords: Northwestern University, IDEAL, HyperWorks, OptiStruct, HyperStudy

Northwestern University Success Story

"On behalf of my class, I would like to thank Altair for your generous support to university learning."

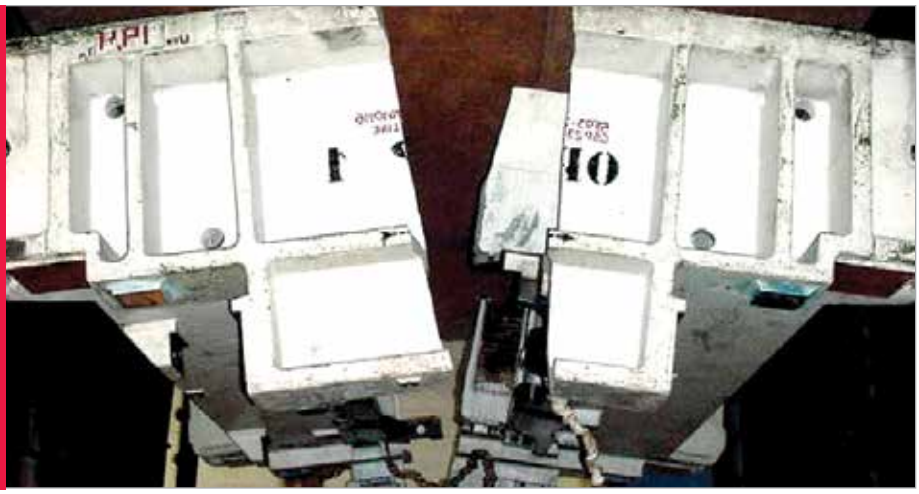
Dr. Wei Chen
Wilson-Cook Professor of Engineering Design,
Professor of Mechanical Engineering, and Director of the Integrated DEsign Automation Laboratory (IDEAL)

design alternatives, in which a preferred design must be selected from among many alternatives. Selecting a preferred design without the aid of computational methods can range from difficult to impossible. Therefore, it is extremely important that engineering design students be exposed to computational tools that will allow them to make sound design judgments when completing their design projects. It is extremely important for engineering design courses to incorporate the application of design decision methods to industrial problems. Working on industrial projects provides engineering students the experience needed to approach real-world design problems later in their careers. In addition, teaching these tools at the graduate-level allows students to apply advanced computational design techniques to problems in their thesis or dissertation field of research.

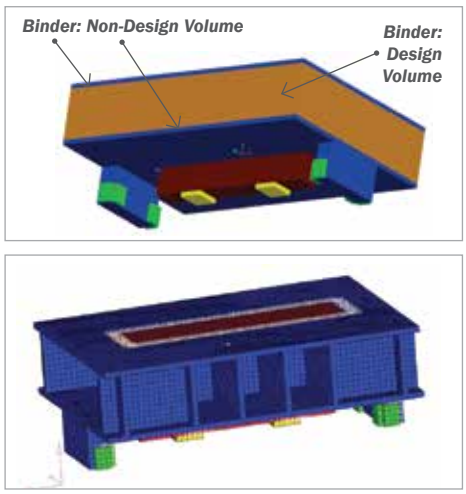
The Solution: Utilization of HyperWorks in engineering design courses

HyperWorks OptiStruct and HyperStudy optimization programs have been utilized in multiple engineering design courses at Northwestern University. Four courses in computational design have been developed as part of IDEAL in the Mechanical Engineering Department. Computational Methods for Engineering Design is a senior undergraduate and entry-level graduate course that is cross-listed under both Mechanical Engineering and the Segal Design Institute. Engineering Optimization for Product Design and Manufacturing, a second co-listed course, is directed at entry-level graduate students. A third course, Engineering Design, is a senior-level capstone design course. A fourth course, Advanced Computational & Statistical Methods for Engineering, is directed toward graduate students and builds upon the foundation provided to students in the undergraduate courses by focusing on computational optimization methods in research. Prior to the introduction of these courses, computational design was not included in

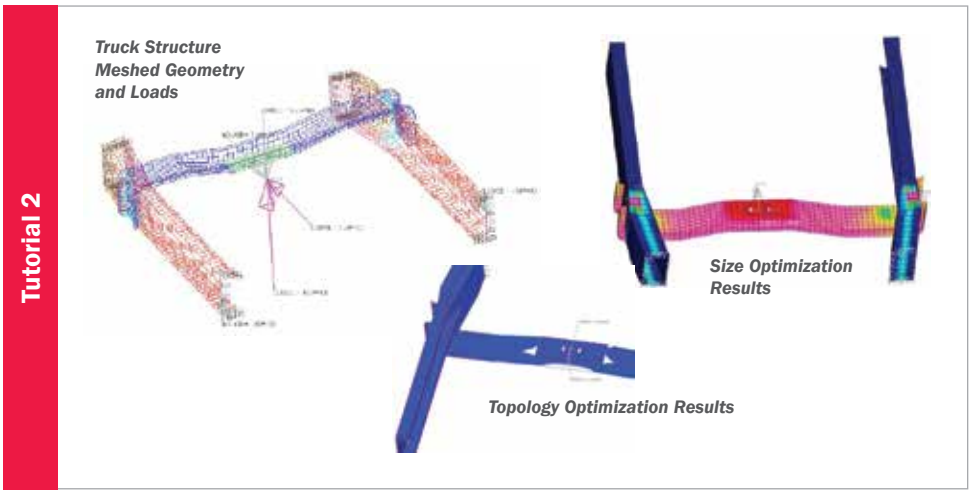
Tutorial 1



Stamping die failure



Die binder optimization result



Truck frame optimization

Top: Original bicycle crank design
Bottom: Topology optimization result

the Northwestern University Engineering curriculum. With the introduction of these courses, a repository of computational design tutorials using industry-sponsored design projects has been established. Two examples of these tutorials are presented below.

Tutorial 1: Stamping Die Design
For this design tutorial, the optimal design of a die-cast binder component of an automotive stamping tooling system was investigated. The original die-binder was experiencing failure, and traditional methods for creating a light-weight design were not adequate. To create an improved design, a two-phase sequential topology and size optimization analysis using OptiStruct was applied. The objective was to minimize the volume (and hence weight) while meeting allowable stress and manufacturing constraints. Phase I of the process applied topology optimization to minimize the binder compliance for a selected volume fraction of material. Phase 2 of the optimization was conducted to minimize binder weight subject to maximum stress load and minimum binder wall thickness constraints. The two-phase method produces an acceptable minimum-weight design with a uniform 30 mm wall thickness.

Tutorial 2: Truck Frame Optimization
For this design tutorial, a partial truck frame front structure consisting of fore-aft rails and cross-members was evaluated. The meshed geometry with loading and boundary conditions, derived from real vehicle operating conditions, was provided. Students proceeded to apply OptiStruct to compute the optimized geometry of the framed structure. The results for topology optimization show that frame material was removed near the cross-member center. The subsequent application of size optimization resulted in a cross-member thickness of 6 mm and an optimal rails thickness of 7 mm.

The Result: Student projects highlighted at twice yearly design competitions

Since 2008, Altair has conducted a university fellowship program to establish regional centers of expertise in HyperWorks CAE software instruction and research applications at select Altair client universities in the United States. The fellowship program supports the educational development of outstanding students and increases the integration of HyperWorks software in academic curricula. As part of the program, Altair co-sponsors a semi-annual symposium at each of the fellowship universities to highlight HyperWorks case studies completed by students, faculty, and regional industrial companies. At Northwestern, Altair's first fellowship university, the focus has been to support graduate students studying computational optimization at IDEAL. A design competition has been utilized to highlight the success of student projects. Each student must profile the design problem addressed, methods used, results, and visuals in a large poster-sized format.

For a recent symposium, student projects from the Computational Methods for Engineering Design class were premiered during this competition. A student project optimizing a bicycle crank set received top honors from a panel of judges representing Caterpillar Corp, Skidmore Owens & Merrill, Motorola Corp, Altair Inc., Illinois Institute of Technology, and Northwestern University. After the judging, Dr. Wei Chen, Director of IDEAL commented, "On behalf of my class, I would like to thank Altair for its generous support of university learning. I cannot over-emphasize the value of this event to our students. I'm sure students find presenting their work to a panel of judges who have significant depth of experience in design optimization to be extremely rewarding." Members of the panel of judges were similarly complimentary, claiming to enjoy the collaboration and rapport with students enabled by the competition.

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About Altair

Altair empowers client innovation and decision-making through technology that optimizes the analysis, management and visualization of business and engineering information. Privately held with more than 2,000 employees, Altair has offices throughout North America, South America, Europe and Asia/Pacific. With a 28-year-plus track record for high-end software and consulting services for engineering, computing and enterprise analytics, Altair consistently delivers a competitive advantage to customers in a broad range of industries. Altair has more than 3,000 corporate clients representing the automotive, aerospace, government and defense, and consumer products verticals. Altair also has a growing client presence in the electronics, architecture engineering and construction, and energy markets.

About HyperWorks®

Performance Simulation Technology

HyperWorks is an enterprise simulation solution for rapid design exploration and decision-making. As one of the most comprehensive, open-architecture CAE solutions in the industry, HyperWorks includes best-in-class modeling, analysis, visualization and data management solutions for linear, nonlinear, structural optimization, fluid-structure interaction, and multi-body dynamics applications.

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