SAND2018-xxxx R

FY18 ASC P&EM L2 Milestone 6356: Improve Replication of In-service Mechanical Environments

Executive Summary

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Introduction

The overall goal of this work was to improve the modeling of laboratory shock and vibration testing.

Laboratory shock and vibration testing is used to qualify Nuclear Weapon components for the environment they will experience in the field. Standard practice is to use rigid test fixtures so that no spurious modes are introduced during laboratory testing. Rigid test fixtures may however in some cases change the dynamics of the component being tested, resulting in laboratory testing being more severe than what would occur in the field.

This milestone investigated the use of topology optimization to create laboratory test fixtures that would better replicate the dynamics that components experience in field environments.

Milestone Description

As written in the ASC Implementation Plan, the milestone description is as follows:

> NW components are typically integrated into a subsystem assembly and exposed to external STS environments from flight, transportation, and handling. Modeling is used to produce shock and vibration test specifications for NW components for design, qualification and production. It has been recognized that there are a number of limitations in current modeling techniques. One of these is that the dynamics of the next level of assembly are rarely considered in deriving design and qualification test specifications and assessing performance and safety margins. This milestone will leverage and advance evolving topology optimization tools in PLATO, incorporating assembly dynamic metrics that enhance environments replication by enabling optimized test fixture design. This will be a joint L2 milestone with IC/topology optimization.

Impact Statement

A success of this milestone was the enhanced capabilities added to the Sandia PLATO topology software. A capability was developed to optimize a design based on matching the frequency response functions between two structures. The PLATO software also developed level set optimization capability, multiple element definitions, and a restart capability. The current capabilities of PLATO to optimize shock and vibration test fixtures greatly exceeds anything that is available commercially.

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In addition, this milestone demonstrated that the use of modeling can result in significant improvements in laboratory shock and vibration testing. However, it also demonstrated the difficulties that remain, and that a significant amount of research and development is required before this approach can be used routinely for laboratory testing.

Summary of Work Done

To meet the milestone objective, the PLATO software team developed the capability to optimize a design based upon matching the frequency response functions between two structures, developed level set optimization capability, developed multiple element definitions, and added a restart capability.

Through use of the PLATO software it was discovered that the optimization space is non-convex and many local minima exist in the domain. The extent and difficulty of the number of local minima in the error domain was explored by altering several optimization parameters to determine the differences in results. These studies discovered that it is extremely difficult to converge to the global minimum.

Even though there were difficulties of optimizing based on the objective function of matching frequency response functions, a test fixture was developed for a test bed example. This test fixture used the restart capability within PLATO's topology optimization algorithm along with the frequency response function matching objective function. The topology-optimized test fixture was integrated into the test bed. Analytical comparisons were made between the field environment, the rigid test fixture attached to the component, and the optimized test fixture attached to the component. Through quantitative comparison to the field configuration, the optimized test fixture provided an improvement over the rigid test fixture. Though the optimized fixture was an improvement, it did not identically replicate the stress field in the field configuration because the mode shape that was excited was not the same as the field configuration. The main conclusion from these results were that using topology optimization in the same way as proposed here does not result in ideal fixtures, but it can result in an improvement over todays fixtures and processes

In conducting this work, an error metric was developed that provides a metric on the effectiveness of the test fixture. Not only can the error metric be used for test fixture effectiveness, but it can be used in other projection analyses such as structural dynamic substructuring.

Path Forward

The successful completion of this effort has given Sandia a unique advanced topology tool for use on optimizing test fixturing. It also demonstrated that improved modeling of fixturing can improve laboratory shock and vibration testing. The results are encouraging enough that future work is planned to improve modeling of test fixtures.

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