ARTICLE IN PRESS

Chinese Journal of Aeronautics, (2016), xxx(xx): xxx–xxx

Chinese Society of Aeronautics and Astronautics
& Beihang University

Chinese Journal of Aeronautics

cja@buaa.edu.cn
www.sciencedirect.com

Structural optimization for multiple structure cases and multiple payload cases with a two-level multipoint approximation method

An Haichao, Chen Shenyan *, Huang Hai

School of Astronautics, Beihang University, Beijing 100083, China

Received 19 September 2015; revised 5 February 2016; accepted 5 April 2016

KEYWORDS

Multipoint approximation;
Multiple payload cases;
Multiple structure cases;
Sensitivity analysis;
Structural optimization

Abstract This paper is to address structural optimization problems where multiple structure cases or multiple payload cases can be considered simultaneously. Both types of optimization problems involve multiple finite element models at each iteration step, which draws high demands in optimization methods. Considering the common characteristic for these two types of problems, which is that the design domain keeps the same no matter what the structure cases or payload cases are, both problems can be formulated into the unified expressions. A two-level multipoint approximation (TMA) method is firstly improved with the use of analytical sensitivity analysis for structural mass, and then this improved method is utilized to tackle these two types of problems. Based on the commercial finite element software MSC.Patran/Nastran, an optimization system for multiple structure cases and multiple payload cases is developed. Numerical examples are conducted to verify its feasibility and efficiency, and the necessity for the simultaneous optimizations of multiple structure cases and multiple payload cases are illustrated as well.

© 2016 Production and hosting by Elsevier Ltd. on behalf of Chinese Society of Aeronautics and Astronautics. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

1. Introduction

Since the concept was proposed in the 1960s, structural optimization has experienced its significant progress and now it is a practical design tool in the field of structural engineering like aircraft and aerospace systems.[1] Three main optimization problems are considered and investigated which include sizing, shape and topology optimization,[2,3] and each kind of optimization problem owns its characteristics and difficulties. Whichever type the optimization problem belongs to, it always consists of three parts, i.e. design variables, objectives and constraints. When taking practical conditions into consideration, the complexities have been increased in structural optimization problems by involving multiple variables, objectives, constraints, etc.[4–6] For these problems, when finite element (FE) methods are used for structural analysis, it can be found that there is only a single FE model involved in general cases.

* Corresponding author. Tel.: +86 10 82338404.
E-mail addresses: anhaichao@buaa.edu.cn (H. An), chenshenyan@buaa.edu.cn (S. Chen), hhuang@buaa.edu.cn (H. Huang).

Peer review under responsibility of Editorial Committee of CJA.

ELSEVIER Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.cja.2016.08.012
1000-9361 © 2016 Production and hosting by Elsevier Ltd. on behalf of Chinese Society of Aeronautics and Astronautics.
This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Please cite this article in press as: An H et al. Structural optimization for multiple structure cases and multiple payload cases with a two-level multipoint approximation method, *Chin J Aeronaut* (2016), http://dx.doi.org/10.1016/j.cja.2016.08.012

In reality, it is also required to conduct structural optimizations in multiple structure cases,[7] in which more than one FE model should be considered during the optimization process. Here, the so-called multiple structure cases refer to a structural system with different working modes or states. For instance, when a variable-sweep aircraft takes off or flies at high speed, it corresponds to two working modes, i.e. low and high sweep angles, for the wings; for another, the flexible attachments in a spacecraft, like the solar array panels and antenna, have compacted and deployed states, which correspond to launch stage and orbital status. The mechanical requirements such as deformations and strengths under the involved structure cases are different, indicating different design constraints, while the structure system is still composed of the same components, implying the same design variables. Accordingly, structural optimization under multiple structure cases is to design the shared structure components and to minimize the structural mass meanwhile simultaneously considering all constraints under each structure case. Therefore, at each iteration step, structural analysis should be carried out for all the FE models when conducting optimizations for multiple structure cases. So it can be seen that optimization in multiple structure cases is quite different from the usual optimization considering multiple load cases and it has drawn high demands in optimization schemes.

In terms of multiple payload cases, it refers to a structure acting as a platform to be equipped with multiple payload systems. For instance, in spacecraft designs, to decrease the design period and costs, a same satellite platform[8,9] could be adopted with different payloads. Under this condition, it is required that the optimal design to this platform should be carried out by simultaneously considering various known payload cases. Similar to the multiple structure cases, the structural response demands for different payload cases are various, while the structure systems have the same platform. In addition, it also involves different FE models and each model is related to one payload case. Correspondingly, more than one structural analysis is needed at each iteration step. From this view point, structural optimizations for multiple structure cases and multiple payload cases can be classified into the same category of optimization problems. However, the related publications on multiple structure cases are limited and more research work is needed to be developed and explored.

Based on a two-level multipoint approximation (TMA) method, Huang et al.[7,8,10] developed an optimization system which considers single structure case with high efficiency even for large-scale engineering problems; afterwards, this method was improved and utilized[11,12] in an optimization design of a satellite platform by taking multiple structure cases into account. However, as a backward difference method was used for the sensitivity calculation in this method, extra function evaluations are introduced and more CPU time is cost consequently. On the other hand, when considering multiple structure cases, some structural mass will be lost due to the changes between different structure cases. For example, for the solar array panels, the total mass in the deployed-panel case is slightly smaller than that under the compacted-panel case, which is due to the mass loss of the initiating explosive devices. When the total structural mass is treated as an objective in the optimization design, it will be different in multiple structure cases even with the same design variables. However, even though the optimization system has the preliminary capability by handling multiple structural cases, it could only deal with problems with mass being unchanged in different structural cases. Thus, the efficiency as well as the capability of this optimization method needs to be enhanced.

With the use of this TMA method, Chen and Huang[8] conducted the optimization design to the main frame of a satellite platform, while Peng et al.[9] developed an efficient truss structure optimization framework and optimized the similar main frame structure. The main difference of these two satellite structures lies in the different payloads, which results in different requirements in the designs. If the optimization results obtained in one payload case were used for another case with a different payload, this optimization design could be infeasible to satisfy all constraints. Therefore, an efficient optimization strategy should also be proposed by considering multiple payload cases.

Thus, the main objective of the present study is to present an optimization scheme for solving the structural optimization problem considering multiple structure cases and payload cases. Since the previous optimization scheme developed in Ref.[8] exhibits good performance in engineering optimization designs and it has the preliminary capability to address multiple structure case problems, this method is employed and then improved in this work. By using analytical method for sensitivity calculation in this study, the computational efficiency and result accuracy are increased to some extent. Considering the common characteristic for multiple structure and payload case problems, which is that the design domain keeps the same no matter what the structure cases or payload cases are, these two kinds of optimization problems are formulated into the unified expressions. Based on the unified problem formulations, an efficient optimization system is then established by involving both types of optimization problems. Numerical examples are then conducted to demonstrate its feasibility and efficiency.

The outline of this paper is organized as follows. Section 2 formulates the problem expressions with a unified form by involving both multiple structure cases and multiple payload cases. Section 3 introduces the optimization strategy followed by the establishment of optimization system presented in Section 4. Numerical examples, including an optimization of solar array panels with two structure cases and a design for a satellite platform with three payload cases, are shown in Section 5 and a brief conclusion is drawn in Section 6.

2. Problem formulation

Structure mass is often treated as an objective in structural optimization problems and it is also the objective in the present work. For structures with multiple structure cases or states, the total mass will be different in different structure cases, which is due to the mass loss of some devices used for the changing the structure case. Similarly, for a structure platform with varied payloads, the total structural mass also varies along with different payload masses. For these two types of problems, what they have in common is that the design domain is unchanged. For multiple structure cases, the devices used for changing structure case always do not need to be optimized and they are not involved in the design domain; while for multiple payload cases, only the platform needs optimization design for reducing its design period and costs as well as being suitable for each payload case. By sharing the same design domain, it

Download English Version:

https://daneshyari.com/en/article/7154326

Download Persian Version:

https://daneshyari.com/article/7154326

Daneshyari.com