Improved aerelastic design through structural optimization

Michał Nowak
Poznan University of Technology, Division of Machine Design Method
ul. Piotrowo 3, 60-965 Poznań, Poland
e-mail: Michal.Nowak@put.poznan.pl

Abstract

The paper presents results of coupled multiphysics computations. The presented procedure shows the concept and presents some preliminary results of static coupling of structural and fluid flow codes as well as biomimetic structural optimization. The biological phenomenon of trabecular bone functional adaptation was here a model for the biomimetic optimization formula. The structural bio-inspired optimization system is based on the principle of constant strain energy density on the surface of the structure. When the aerelastic reactions are considered, such approach allows fulfilling mechanical theorem for the stiffest design, comprising the optimizations of size, shape and topology of the internal layout of the wing structure.

Keywords: fluid-structure interaction, biomimetics, structural optimization

1. Introduction

Nowadays, to design an aircraft structure the coupled fluid-structure interactions (FSI) simulations are crucial. On the other hand, for the structural design optimization techniques have to be used [2,10]. There are many examples of using optimization techniques to design the structural elements of an aircraft [2,9,10,11,19]. In the resent years, especially the topology optimization method has been introduced to the designing processes. A good industrial example is the structure of the Airbus A380 wing. The structural elements of the wing were designed in two design steps. First, the optimal material distribution was defined using the topology optimization - the SIMP method. Then, after the extraction of the geometry from the topology optimization results, the model for size and shape optimizations was derived. The size and shape optimizations were the next step in the wing designing process. Splitting the topology and then size and shape optimizations is necessary, due to completely different optimization methods used in each case.

2. The bio-inspired optimization method

While examining biological structures, we often realise that they are optimal from both mechanical and mathematical optimality perspectives. The trabecular bone is here a good example. Wolff’s law [21], formulated in 19th century assumes that bone is capable of adapting to mechanical stimulation and optimizing energy expenditure to keep tissue in good condition. This aspect could be useful when studying issues of structural optimization. Healthy tissue of trabecular bone has very sophisticated shape. The tissue forms a network of beams called trabeculae. This structure is able to handle a wide range of loads being continually rebuilt. The phenomenon of trabecular bone adaptation has two important attributes. First, mechanical stimulation is necessary to conserve rebuilding balance. Second, the process of resorption and formation occurs only on the bone surface. In this way the bone reacts to external forces and the process of healing leads to mechanical adaptation [1,6,7,8,13,14]. It is interesting, that SED, as energy measure, is also emphasized in optimization research, distant from biomechanical studies [4,12,17,20]. To design an aircraft structure, coupled fluid-structure interactions (FSI) simulations are crucial. On the other hand, for the structural design the optimization techniques must be used. Combining both fluid-structure interactions simulations and structural optimization it is possible to obtain an improved solution. In the paper the practical aspects of the biomimetic structural optimization implementation into the FSI computational environment is discussed. For the structural optimization purposes the biomimetic system based on the principle of constant strain energy density on the surface of the structure was prepared [16]. The simulation system consists of Finite Element Mesh generator, decision block setting criteria for structural adaptation and the Finite Element Analysis in a parallel environment. The presented in the paper design problem can be defined as a determination of the internal structural layout of the wing. The outer profile of the wing must remain its form because this form satisfies aerodynamic constrains. In the presented method the optimization of the internal wing structure was coupled with the FSI environment [17]. The performed algorithm contains coupled fluid code TAU (Deutches Zentrum fuer Luft und Raumfahrt)[5, 18], structural code Abaqus and specialized procedures like mesh deformation tool AE_Tools. Pressure distribution resulted from the FSI a calculation of the static coupling was applied on the wing surface and this was the base for the load definition for the optimization procedure.

The presented here approach allows to comprise the optimization of size, shape and topology [3, 15]. The developed numerical environment is able to be used in practical problems. Presented method is especially useful in case of multiple load cases problems as well as when during the process of optimization, when a functional structural configurations are needed.
The biomimetic optimization system was implemented into the FSI environment. Figure 1 depicts the algorithm for coupling aeroelastic analysis with structural optimization. The approach presented here is based on the assumption that different codes will be used separately for each part of simulation field. But the main coupling process still concerns two blocks – CFD for the fluid flow computations and the CSM for the structural deflections computations. The structural biomimetic optimization is performed inside the CSM block.

Figure 1: The algorithm for aeroelastic analysis coupled with the biomimetic structural optimization

4. Conclusions

The above presented approach allows to comprise the optimizations of size, shape and topology without the need of parameters definition. The considered here aeroelastic design problem seems to be similar to the bone mechanical adaptation phenomenon. The presented biomimetic approach allows the mechanical structure to adapt to mechanical loads, like the bone adapts to mechanical signals.

References


3. The computational environment