TOPOLOGY OPTIMIZATION AND 3-D PRINT ACCORDING TO AEROELASTIC BEHAVIOR OF HIGH ASPECT RATIO WING

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Abstract: In this paper, CFD/CSD method was applied to achieve the deformation and loads of high aspect ratio elastic wing under aerodynamic loads. According to the results, topology optimization (TO) method was applied for the purpose of reducing the total weight of high aspect elastic wing. TO method involves iteratively reducing individual elemental density until the desired mass or volume constraint is met. Two different TO styles were approached: a global three-dimensional configuration and a traditional two-dimensional rib and spar optimization which is according to the baseline design. The configuration of TO was exported to FEM software and the von-mises stress, displacement, and buckling were compared to the baseline wing. The weight saving was verified to prove the effect of TO method. Different to traditional manufacturing, 3-D print was adopted to realize the complex structure manufacture of TO. The results show that a total wing mass reduction of 10 percent can be realized.

1 INTRODUCTION

Current aircraft wing design structure is limited primarily by traditional manufacturing techniques so there are more troubles for the application of complex configuration. TO method which is focus on providing an improved distribution of loads throughout the structure provide an efficient way to eliminate unnecessary material to realize the purpose of saving weight. In other words, only material vital to the support structure is used. The process carries out iteratively determining load bearing elements in a domain in the structure of wing and eliminating nonessential material. While TO method is applied, the objective is to reduce weight meanwhile retaining structural stiffness and stress levels must be satisfied.

TO is not a new theory and is frequently used within the Aerospace Industry. Airbus Aeronautical Company applied both Altair Inc. and in-house developed software in order to optimize the design of individual spars and wing-box structures for large commercial aircraft. Currently, examples of TO used in the aerospace industry are generally limited to two-dimensional designs and the results are used as guidance towards a more reasonable design through interpretation. Three-dimensional designs created by TO are often very complex and historically not feasible to manufacture through traditional means. However, advances in Additive Manufacturing (AM) have made this concept a seemingly more viable approach. 3-D print is a kind of AM and widely used in commercial field. 3-D print consists of building a product by applying thin layers of material to generate a shape so optimized design produced is less limited in shape compared to traditional manufacturing constraints.

2 WORK DESCRIPTION

The purpose of this paper is to discuss the feasibility of using TO method to reduce the weight of high aspect ratio of UAV and manufacturing the structure. Firstly, CFD/CSD analysis was used to calculate realistic dynamic pressure values for the surface of the wing. Secondly, computational analysis on the baseline aircraft wing is carried out to determine localized stress and displacement values. Thirdly, TO method is used under constraint condition meanwhile retaining structural stiffness and stress levels for all applied loads. Fourthly, FEM is applied to test the stress level and the weight saving condition is examined. Finally, the three-dimensional structure is printed using 3-D print.

3 RESULTS

CFD/CSD simulation was finished and pressure distribution of the wing of UAV is obtained. In the simulation, the loose-coupling mode is adopted. The flow field and solid field are solved separately and the data of interaction surface are exchanged in each time step. The meshes of CFD and FEM simulation are shown in Figure 1.

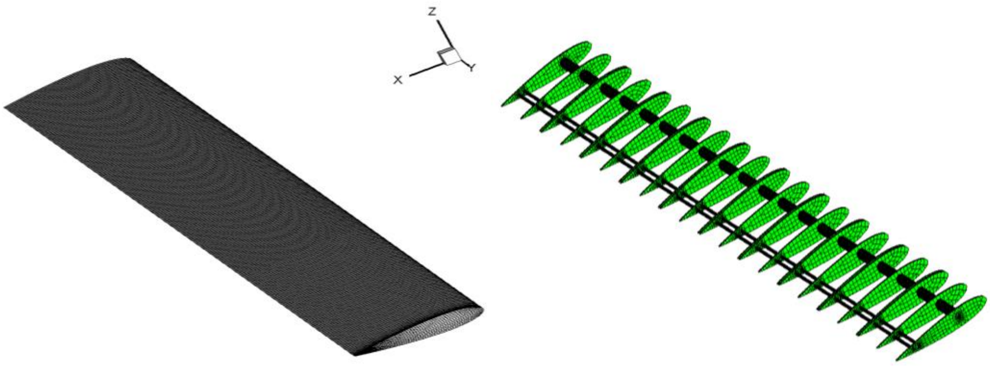


Figure 1: CFD and FEM meshes in CFD/CSD simulation

The iteration was between CFD and FEM codes and finally the loop was terminated until the static aeroelastic deformation was not increased any more. The pressure distribution and static equilibrium deformation was shown in Figure 2.

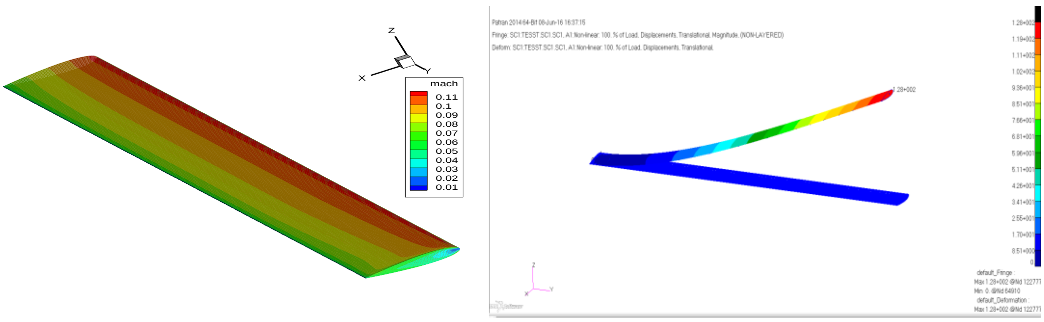


Figure 2: Pressure distribution and static aeroelsatic deformation

The process of static aeroelsatic iteration simulation was shown in Figure 3. The results show that after eight iteration loop, the static aeroelsatic equilibrium achieved. The structural stress condition is shown in Figure 4.

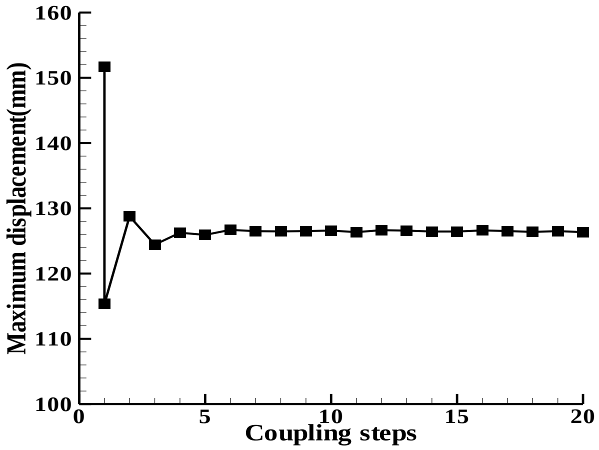


Figure 3: Iteration step in static aeroelastic simulation

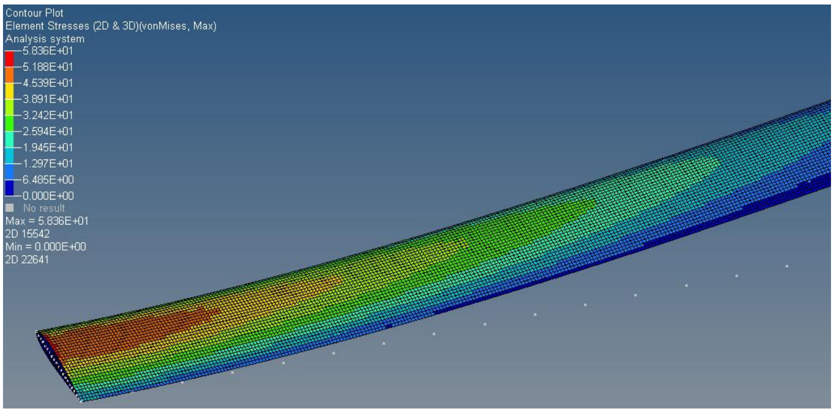


Figure 4: Static aeroelsatic deformation and stress simulation

According to the loads of CFD/CSD simulation result, TO method is applied on the root section of a high aspect ratio wing under some constrain condition. The preliminary results are shown in Figure 5.

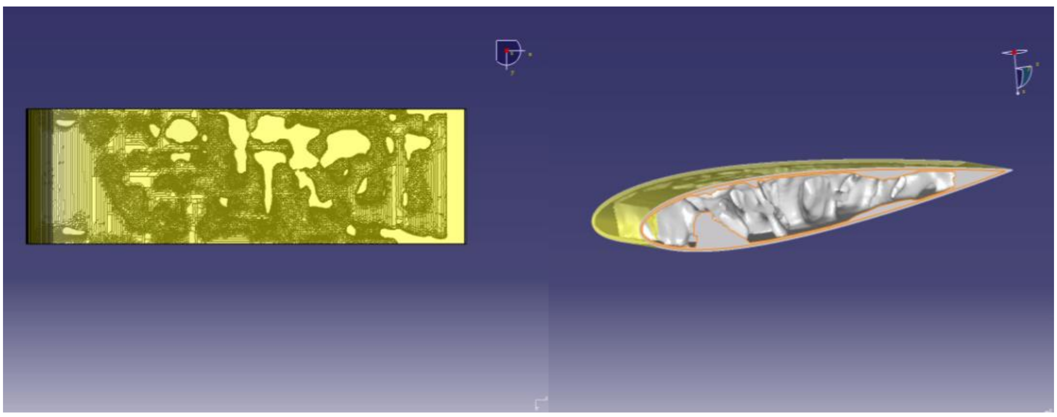
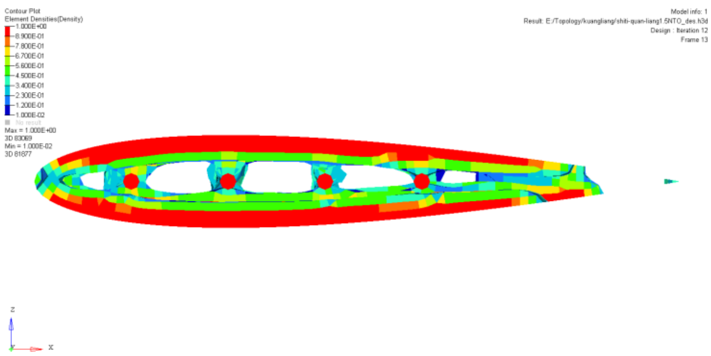


Figure 5: 3-D TO result of a wing section

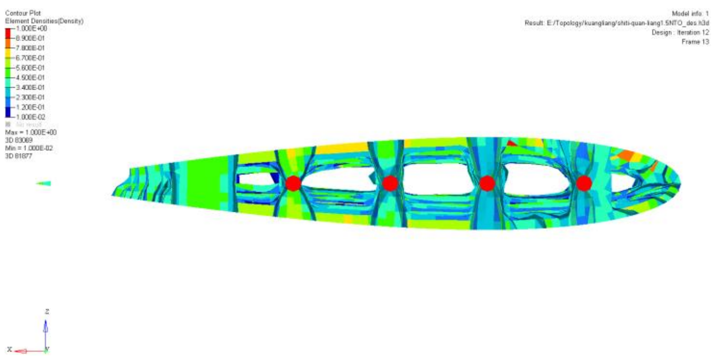
The optimization results are compared to results of David Walker[5]. The validity of the method and software is approved. The resulted TO structure of a wing section is manufactured by 3-D print technology shown in figure 6. Selective Laser Sintering (SLS) was used to print the sample, and the result shown that the complex inner structures from TO are fully reproduced with satisfying accuracy.

Figure 6: TO results manufactured by 3-D print.

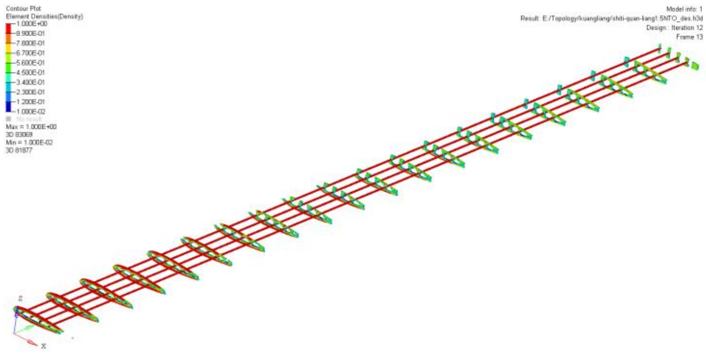
The structure of a high aspect ratio wing is optimized using TO method according to the aerodynamic loads provided by CFD/CSD simulation shown in figure 2. The structure has 4 struts stretching from root of the wing to the tip, which are preserved, and the structures between the struts and shell of the wing are subjected to TO process, the results of which are shown in figure 7.



(a) Section of TO results at wing root.



(b) Section of TO results at wing tip.



(c) Global view of the TO results.

Figure 7: TO results of the high aspect ratio wing according to the aerodynamic loads.

Most parts of the optimized structures are connected to each other with only a few hanging part that does not connect to any other structures. The hanging parts could be removed in post process, which has little influences on the global performances of the structures. The weight of the optimized results are reduced and the mechanical performances of the structure are preserved. Due to limited funds, the structure is not manufactured but the feasibility of the TO combining with 3-D printing process is proved by the wing section parts. We hope in our future works the structure will come into reality from the numerical model via 3-D printing technology.

4 ACKNOWLEDGMENTS:

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5 REFERENCES

[1] Sigmund, O., "A 99 line topology optimization code written in Matlab," Structural and Multidisciplinary Optimization, Vol. 21, Springer-Verlag, 2001, pp. 120-127.

[2] David Walker, David Liu, and Alan Jennings, Wing Design Utilizing Topology Optimization and Additive Manufacturing, AIAA 2016-1246.

[3] Sydney Australia, A.Rinku, G K Ananthasuresh, Topology and Size Optimization of Modular Ribs in Aircraft Wings, 11th World Congress on Structural and Multidisciplinary Optimization, 07th -12th, June 2015.

[4] Haris HameedMian,GangWang, Zheng-YinYe, Numerical investigation of structural geometric nonlinearity effect in high-aspect-ratio wing using CFD/CSD coupled approach, Journal of Fluids and Structures 49(2014)186–201.

[5] David Walker, David Liu, and Alan Jennings, Topology Optimization of an Aircraft Wing, AIAA 2015-0976.

[6] Walker, D., Liu, D., Jennings, A., Topology optimization of an aircraft wing, 56th AIAA/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, 2015.

[7] Sigmund, O., Design Of Multipysics Actuators Using Topology Optimization; One Material Structures, Computer methods in Applied Mechanics and Engineering, Vol. 190, No. 49, pp. 6577, 2001.

[8] Altair Engineering Inc., "Optistruct 12.0 User's Guide," 2013.

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