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Subscale Main Wing Design and Manufacturing of WIG Vehicle Using Carbon Fiber Composites

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Abstract

This work dealt with design and manufacturing of WIG vehicle wing using carbon/epoxy composite materials. In this study, structural design and analysis of carbon composite structure for WIG craft were performed. Firstly, structural design requirement of wing for WIG vehicle was investigated. After structural design, the structural analysis of the wing was performed by the finite element analysis method. It was performed that the stress, displacement and buckling analysis at the applied load condition. And also, manufacturing of subscale wing using carbon/epoxy composite materials was carried out. After structural test of target structure, structural test results were compared with analysis results. Through the structural analysis and test, it was confirmed that the designed wing structure is safety.

Key Words : WIG vehicle , Carbon composite, Subscale, Structural design

1. Introduction

Recently, various research and developments of the WIG craft have been actively performed as a new generation maritime transportation system. When a wing is closely flying on the ground or on the water surface within a couple of meters height, the lift force is greatly increased due to the ground-effect. The upper section of the WIG vehicle has an airplane configuration and its lower section looks like a high speed ship hull configuration[1-2].

In this study, a preliminary structural design and analysis on main wing and joint parts of the 20 seats small scale WIG craft. The structural configuration adopted the skin-spar type structure with foam sandwich, and main material took up the carbon/epoxy composite. Initial design was performed using the netting rule and the rule of mixture. Structural safety and stability evaluation on the design features was done by a finite element analysis method[3-4].

After main wing design, subscale wing structure was designed. And also, before manufacturing the full scale main wing of WIG craft, the manufacturing and test was performed by a subscale main wing for evaluation of the proposed structural design and analysis process. Through this comparison, even though there were some differences between them, it was confirm that the proposed design method is appropriate for the composite wing structure of WIG craft.

2. Structural Design and Analysis of Main Wing

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In the previous study, structural design of main wing of WIG craft was performed[5]. The structural design and analysis was performed after investigation on design requirement. The structural design proof load of main wing was defined through the small scaled WIG vehicle's design requirements and load case analysis, and also the carbon/epoxy composite material was selected by reviewing how mechanical property of the selected composite material will be reacted on the adopted structure.

Through investigating the aerodynamic and structural design requirements of the wing, design structural loads are calculated, and then the wing structure can be preliminarily sized using the netting rule and the rule of mixture and finalized by stress analysis using Finite Element Method until satisfaction of the desired target weight. Figure 1 shows the 3-D CATIA models of the whole vehicle structure and Fig. 2 shows the wing structure.

Preliminary Structural design results designed using the netting rule and the rule of mixture. Structural design load of the main wing was firstly estimated from aerodynamic design results using the simplified load estimation method.

Fig. 1 3-D Model of Small Scale WIG Craft

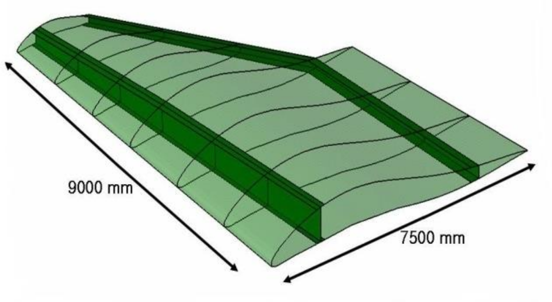

Fig. 2 3Wing Structural Configuration

In order to investigate structural safety and stability on the initially designed main wing, structural analysis was performed using commercial finite element code. For both weight reduction and structural stability the skin-spar type feature with foam sandwich was finally adopted. According to structural analysis results for the final design feature, it was found that weight of the finally designed wing was a bit less than the target weight, and the structural safety was confirmed by safety factor evaluation using Tsai-Wu failure criterion.

3. Structural Design and Analysis of Subscale Wing

In this work, subscale wing design and analysis was performed for verification of real scale wing design method and manufacturing process. The scaling ratio is 1/17. Structural design load of main wing was defined from relationship between main wing's lift, horizontal tail's lift and inertia load at maximum cruising speed. The main wing load distribution was applied using the chordwise and spanwise distributed load equations in considering the load factor of 2 which was given by the system design requirement. In this study, the main wing load was calculated with 20 segments divided into spanwise in consideration of inertia load due to dead weight. The design proof load was defined as 1.5 times as the calculated structural load. Because two engines are installed on main wing by the engine mounting frame, the load due to propeller thrust was calculated using relationship between break horsepower and propeller efficiency.

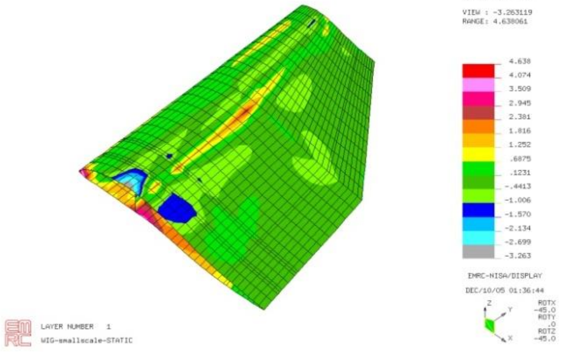

Fig. 3 Stress Analysis of Subscale Main Wing

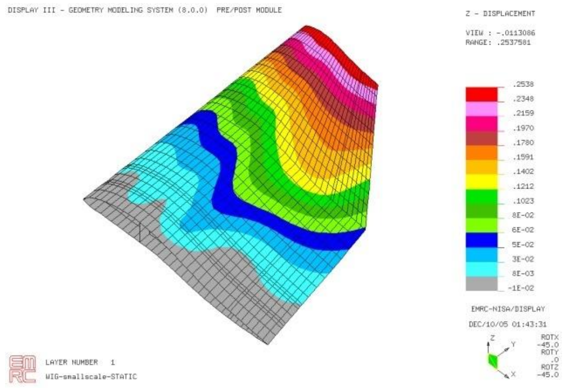

Fig. 4 Displacement Analysis of Subscale Main Wing

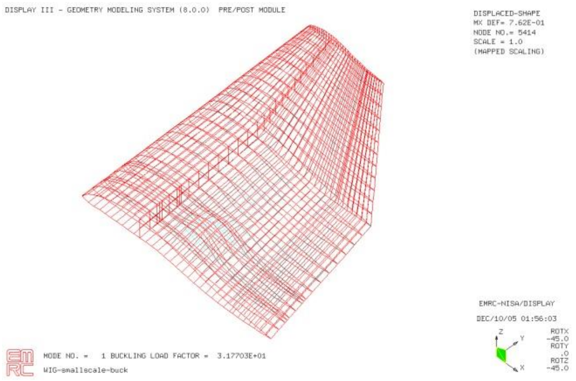

Fig. 5 Buckling Analysis of Subscale Main Wing

The structural feature was composed of 'I' type front spar and channel type rear spar to accommodate easily the control surface. According to structural analysis results for the final design feature, it was found that weight of the finally designed wing was a bit less than the target weight, and the structural safety was confirmed. As shown in the figure 3, maximum compressive stress on the upper skin is 3.26MPa, maximum tensile stress on the lower skin is 4.64MPa. Figure 4-5 shows maximum displacement and buckling load factor. The maximum displacement is 0.254mm and the first buckling load factor is 31.77.

4. Manufacturing and Structural Test of Subscale Wing

Before manufacturing the full scale WIG prototype, in order to evaluate structural design and analysis procedure the structural test was performed by a designed subscale main wing with the scaling ratio of 1/17. The subscale wing configuration is slightly different form the full scale one due to the manufacturing difficulty and the laboratory autoclave size. The subscale static structural test was performed under the simulated aerodynamic loads at three positions. The manufactured carbon/epoxy composite wing was set on the test rig and loaded by three point weights. Figure 6-7 shows mould design results for subscale main wing manufacturing. Fig. 8-10 shows manufactured prototype subscale wing. Figure 11 shows the strain measurement system. Table 1 shows comparison results between the measured value and the predicted value on the stresses.

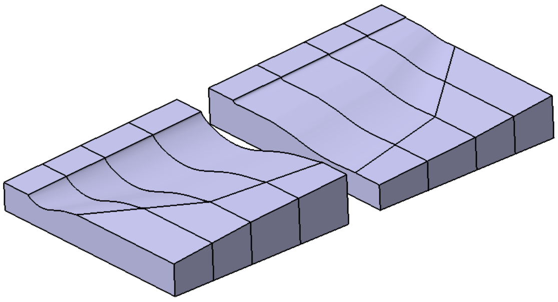

Fig. 6 Mould Design for Subscale Main Wing Manufacturing

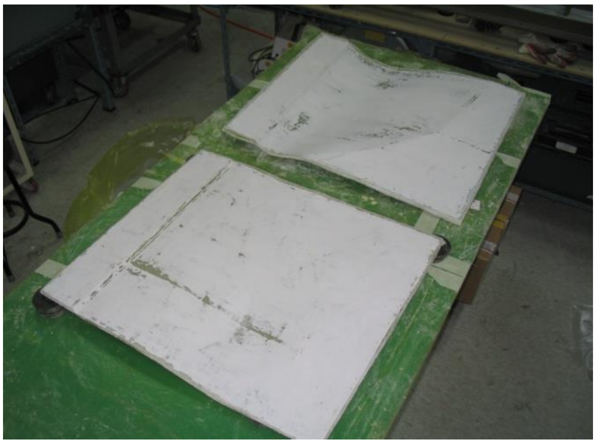

Fig. 7 Manufactured Mould

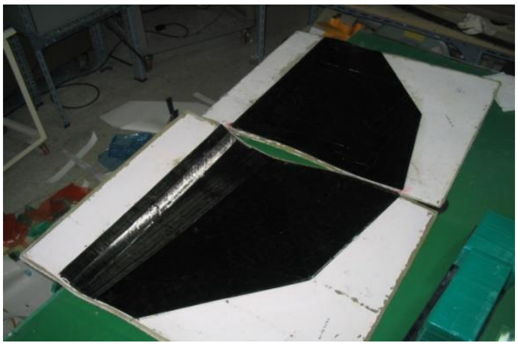

Fig. 8 Laminate Process of Subscale Main Wing

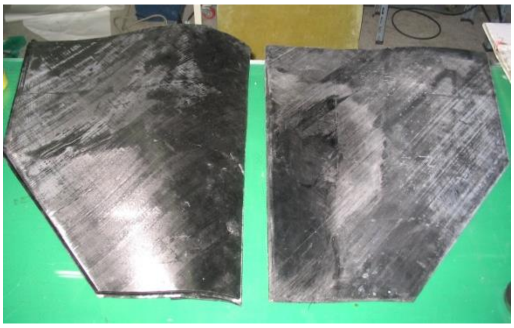

Fig. 9 Manufactured Upper and Lower Surface

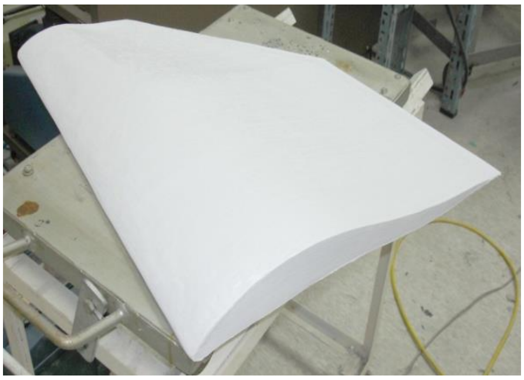

Fig. 10 Manufactured Subscale Main Wing

Fig. 11 Strain measurement from structural test

Table 1 Comparison between the tested and predicted stress results

Item	Analysis results	Test results
Upper Surface	3.26MPa	9.85MPa
Loser Surface	4.64MPa	12.32MPa

5. Conclusions

In this study, a structural design for main wing of a 20 seats WIG vehicle was performed. The structural configuration adopted a skin-spar-foam sandwich type composite structure was applied on upper and lower surfaces of the wing to improve buckling behavior and vibration absorption capability. In order to improve strength weight ratio as well as stiffness weight ratio the carbon/epoxy composite material which is mostly used in aerospace vehicle design was selected.

Before manufacturing the full scale wing of WIG craft, the manufacturing and test was performed by a subscale main wing for evaluation of the proposed structural design and analysis process. Through this comparison, even though there were some differences between them, it was confirm that the proposed design method is appropriate for the composite wing structure of WIG craft.

References

[1] Nikolai Kornev, Konstantin Matveev, Complex Numerical Modeling of Dynamics and Crashes of Wing-In-Ground-Vehicles, *AIAA*, vol. 600, 2003.

[2] Kund Benedict, Nikolai Kornev, Michael Meyer, Jost Ebert, Complex Mathematical Model of The WIG Motion including The Take-off Mode, *Ocean Engineering*, vol. 29, pp.315-357, 2002.

[3] Michael. C. Y. Niu, *Composite Airframe Structure*, McGraw-Hill Book Company, 1950.

[4] C. Kong, Structural Investigation of Composite Wind Turbine Blade Considering Various Cases and Fatigue Life, *ENERGY*, vol. 30, pp. 2121-2114, 2005.

[5] C. Kong, H. Park, J. Yoon, K. Kang, Conceptual Design on Carbon-Epoxy Composite Wing of A Small Scale WIG Vehicle, *Key Engineering Materials*, vol. 334-335, pp. 353-356, 2007.