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Structural Design on Joint Component of Composite Wing of WIG Craft

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Abstract

This study proposed a specific preliminary structural design procedure of the main wing for a small scale WIG vehicle to meet the target weight of the system requirement. The high stiffness and strength Carbon-Epoxy material was used for lightness, and the foam sandwich type structure at the upper skin and the spar webs was adopted for improvement of structural stability. After structural design, wing joint part was designed. Through investigation on structural design result, design modification was performed. After design modification, even thought the designed wing weight was a little bit heavier than the target wing weight, the structural safety and stability of the final design feature was confirmed.

Key Words : Joint Structure, Sandwich composite structure, Structural design, Structural analysis

1. Introduction

In the present study, preliminary structural design of the main wing for a small scale WIG(Wing in Ground Effect) among high speed ship projects, which will be a high speed maritime transportation system for the next generation in Rep. of Korea, was performed[1].

The high stiffness and strength Carbon-Epoxy material was selected for the major structure, and the skin-spar with a foam sandwich structural type was adopted for improvement of lightness and structural stability. As a design procedure for this study, firstly the design load was estimated through the critical flight load case study, and then flanges of the front and rear spars from major bending loads and the skin and the spar webs from shear loads were preliminarily sized using the netting rule and the rule of mixture[2][3].

In order to investigate structural safety and stability, stress analysis was performed by commercial finite element code such as NASTRAN/PATRAN. From the stress analysis results for the first designed wing structure, it was confirmed that the upper skin between the front spar and the rear spar was unstable for the buckling. Therefore in order to solve this problem, a middle spar and the foam sandwich structure at the upper skin and the web were added. After design modification, even thought the designed wing weight was a little bit heavier than the target wing weight, the structural safety and stability of the final design feature was confirmed. Moreover, in order to fix the wing structure at the fuselage, the insert bolt type

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structure with six high strength bolts was adopted for easy assembly and removal.

2. Design Procedure

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. Fig. 1 shows the flow of structural design and analysis, and Fig. 2 shows the 3-D CATIA models of the whole vehicle structure and the wing structure.

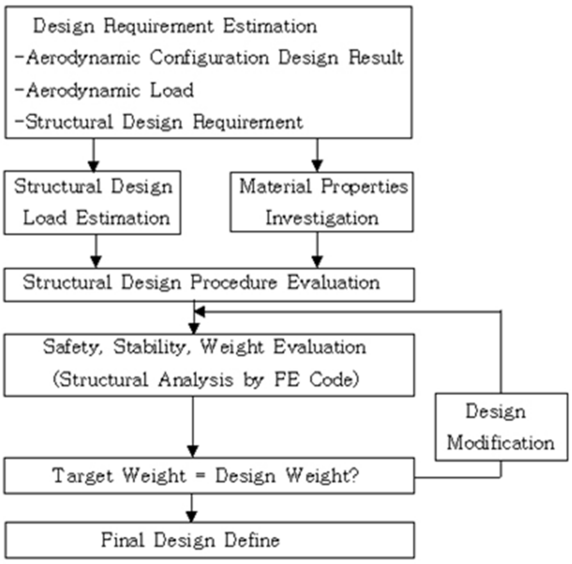

Fig. 1 Structural design Procedure of WIG vehicle

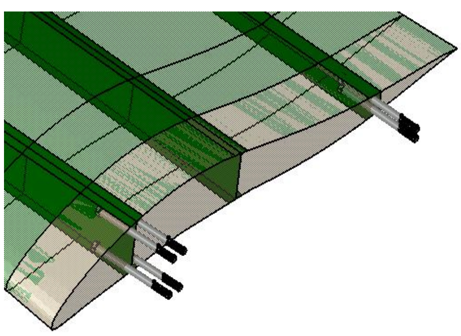

Fig. 2 3-D CATIA models of Joint Part

3. Design and Analysis

Structural design load of the main wing was firstly estimated from aerodynamic design results using the simplified load estimation method[4]. The preliminary structural design was performed by the netting rule and the rule of mixture[3]. The front spar flange thickness was gradually reduced from 7.00 mm at the root to 1.25 mm at the tip of the wing, and the rear spar flange thickness also was decreasingly sized from 11.50 mm at the root to 1.25 mm at the tip. In order to evaluation the structural safety and stability, the well-known commercial code NASTRAN/PATRAN was used. Through stress analysis results for structural safety by Tsai-Wu failure criterion[5], and stability by buckling analysis, it was confirmed that the upper skin between the front spar and the rear spar and the first web and the second web was unstable.

For the wing root joint with fuselage, the insert bolt type was adopted through strengthening the root spar flanges. By considering principal stresses and allowable strength of the insert bolt, the Cr-Mo Steel alloy bolt with the strength of 830Mpa was selected. In case of 4 bolts at the root of front and rear spar flange, the safety factor was calculated as 2.48 for the maximum static load. However in order to consider the dynamic load and the fatigue limit load for more than 20 years fatigue life, 6 insert bolts with 4 bolts at the front root spar flange and 2 bolts at the rear root spar flange were finally determined.

In order to improve the unstable skin structure, the middle spar and the foam sandwich structure at the upper skin and the webs were added. Table 2 and Fig.3 show design modification results of the wing structure. Fig. 4 shows stress contour and the first buckling mode shape of the modified wing structure. As shown in the Fig. 4, because maximum compressive stress on the upper skin is 186 Mpa, maximum tensile stress on the lower skin is 223 Mpa, and the first buckling load factor is 1.153, the structural safety and stability of the modified wing structure was confirmed. The calculated weight of the modified wing structure was 417 kg, which is a little bit heavier than the target weight of 383 kg.

4. Conclusions

This study proposed a specific preliminary structural design procedure of the main wing for a small scale WIG vehicle to meet the target weight of the system requirement. The high stiffness and strength Carbon-Epoxy material was used for lightness, and the foam sandwich type structure at the upper skin and the spar webs was adopted for improvement of structural stability. The preliminary structural design was performed by the rule of mixture and the structural analysis was done by Finite Element Method. Through investigation of structural instability on the upper skin, the wing structure was properly modified to meet the design requirement.

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