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Evaluation on Design and Structure of a Small Folding Boat for Water Leisure Sports

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ABSTRACT

The purpose of this study is to evaluate design and structure of a small frame type boat and a small inflatable boat made of extra-high-pressure space paper which can be simply assembled and easily carried and minimize parts. The manufacture of boat was completed by assembling each complete part with 3D surface using extra-high-pressure space paper according to design. After small boats using inflatable space paper was developed, field tests were performed. As a result, straightness and acceleration of boats were excellent, but vibration and distortion of boats were found. Thus, a small frame type folding boat was developed to compensate above defects. A small folding boat with more stability could be developed to improve vibration and distortion, as it was designed to hold firmly the connection structure of Bottom Frame and Bow & Stern Frame. In addition, the test for structure evaluation on the frame was performed. As a result, it was evaluated to be structurally suitable, as there was no abnormality in the elastic strain region as a whole.

Keywords: Water leisure sports; Inflatable boat; Frame boat; Small folding boat; Space Paper

INTRODUCTION

Because Korea is surrounded by the sea on three sides, it has been blessed by heaven with a wonderful natural environment to enjoy water leisure sports. Inland water leisure sports being performed mainly in four Rivers increase the population participating in it as one form of leisure sport tourism using natural environment and sports. Government actively promotes high value-added water leisure sports industry to make Sea and Rivers as tourism leisure space familiar to people [2].

With this regard, potentially industrial value of water leisure boat industry has been increased and many investments have been made in technology development and infrastructure establishment as a major trend of upcoming water leisure in the future. However, there are only 20 boat manufacturers for water leisure in Korea and the size of supply market is very small. Thus, most of water leisure boats are being imported from other countries and assembled in Korea. It is very difficult to make industrial linkage with industries related to water leisure sports activities such as water leisure boats, telecommunication and fishing equipment. In addition, commercially available materials for boats are made of plastic or composite materials but they are not frequently used due to issues in portability and storage caused by weight and volume. On the other hand, inflatable rubber boats have the great advantage for portability because of small weight and volume. The market for rubber boats is increasing by about 15% in each year [1].

Thus, development and distribution of sports science-based water leisure small boats which are not expensive and are easy to move and store are currently required. It is expected to have qualitative improvement and enlargement of base for water leisure boat industry through this development [3,4].

Therefore, the purpose of this study is to develop a small folding boat which can be simply assembled and easily carried, analyze the problems of a small inflatable boat through field tests and evaluate the optimal design and structure to develop a frame type small folding boat which compensates problems.

2. Methods:

The existing inflatable boat has a rounded shape and occupies a lot of space. It has relatively lower straightness, acceleration and rotationality than those of boats made of other materials. Thus, a boat developed in this study maintains the shape of space

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paper in rectangular surface by using a stitch which held the inside of space paper in order to compensate above defects rather than round surface. In addition, bottom side and wall side which were designed with 3D surface were manufactured according to its drawings and the boat was finished by assembling individually completed parts.

In particular, it was produced hydrohynamically similar to the drawing by securing an ideal shape with speed, because extra-high-pressure space paper was used. The problem of stability was resolved by producing it to withstand high pressure of more than 10 psi.

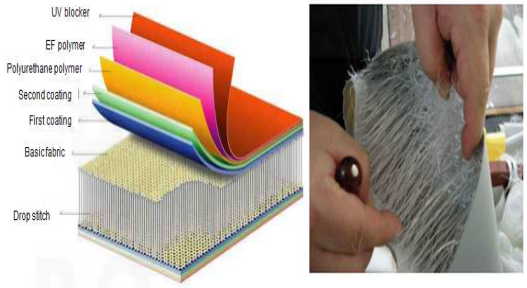


Fig. 1: Configuration and inside shape of extra-high-pressure space paper.

According to specification of extra-high-pressure space paper, it had thickness of 150 mm, weight of 2.5 kg/m2 and maximal pressure of 18 (15) psi. We used 15 psi as the maximal pressure to reduce the risk of damage, although we could use the pressure of up to 18 psi.

In the design, the structure of pure Frame was produced to maintain a sleek hull form similar to that of kayaks/canoes by using extra-high-pressure space paper. A boat was implemented with the structure in which it could be easily and rapidly assembled to satisfy the purpose of this study.

In final, performance test and two field tests were performed on the boat by experts in order to verify its safety. Structure evaluation was performed to verify strain and stress distribution of a frame.

3. Results:

3.1. Design of a small inflatable boat with space paper:

We implemented a sleek hull form which was similar to that of kayaks/canoes in small folding boats with an inflatable type using space paper. It was characterized by minimizing weight and complexity of a boat and shortening the assembly time, because space paper was applied in major supporting parts of all structures and hull.

Inflatable boats made of space paper were mainly characterized by implementation of body and bow using extra-high-pressure inflatable space paper and production of a model with mass production, marketability and originality in the structure to be assembled and disassembled easily while the weight is reduced as much as possible.

A boat made of space paper improved its straightness by making “V” shaped hull floor (Bottom).

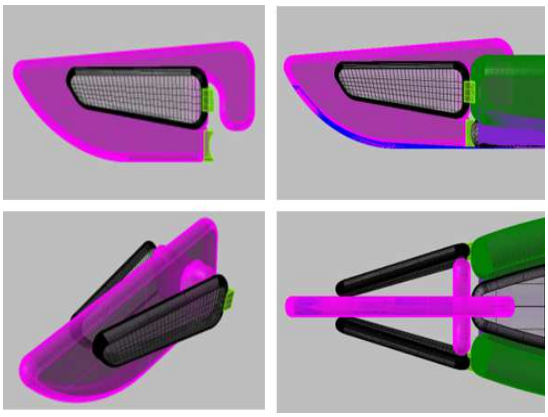


Fig. 2: 3D modeling of inflatable space paper Bow connection.

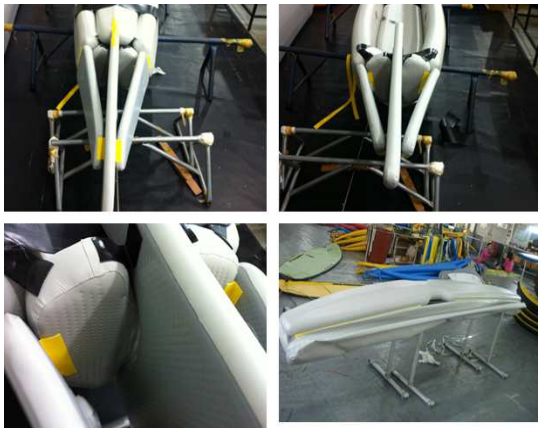


Fig. 3: Production of frame using space paper.

First field test was performed in a windsurfing area located on the Han River in Jamshil, Seoul by eight boat experts. Performance tests were performed on boat A made of space paper and boat B which was previously released.

Fig. 4: A finished small boat made of space paper.

According to specification of product A, it had the full length of 450 cm, internal length of 200 cm, full width of 70 cm, internal width of 38 cm and weight of 13 kg. It was a design product characterized by the implementation of extra-high-pressure inflatable with Frame assembly of Bow & Stern.

According to specification of product B, it had the full length of 385 cm, internal length of 300 cm, full width of 100 cm, internal width of 40 cm and weight of 14 kg. It was a product which significantly improved straightness and drivability by attaching inflatable keel on the bottom of a boat compared to those in existing models.

Fig. 5: Frist Field Test.

According to results of evaluation on a small boat made of space paper through a trial run and evaluation, prototype A showed excellent straightness of a boat and acceleration of speed and paddling, because a “V” shaped hull bottom was implemented. However, it showed the lack of stability due to violent rolling from side to side. In addition, Bow part showed a bias to one side. Product B showed good drivability, but it required more power upon acceleration. It showed excellent stability with less rolling. Thus, it was necessary to improve product A as the ultralight frame boat which could implement more robustness and stability, because distortion may occur due to the flexibility of inflatable boats.

3.2. Design of frame type-inflatable small boat:

A frame-type small boat was designed to hold firmly the connection structure of Bottom Frame and Bow & Stern Frame in order to improve the safety of

an existing small boat made of space paper.

A frame-type boat was mainly characterized by firmly holding the connection of an entire boat using the frame and selecting light materials to minimize the weight of a frame. In addition, the frame was simplified in the structure for easy assembly and disassembly. It was also designed to adjust gap, angle and height in the hull support part of Bow Frame.

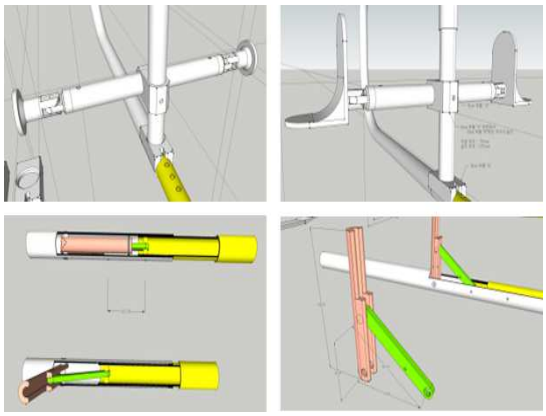


Fig. 6: Length adjustment system for implementation of adjustment of angle and height of a boat and convenience of disassembly.

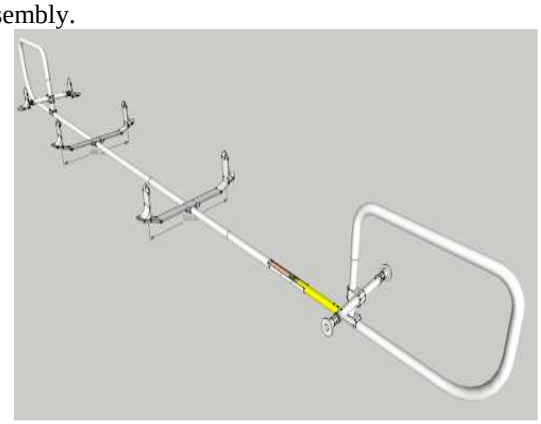


Fig. 7: 3D modeling of Frame structure of a frame-type small boat.

According to specification of a frame-type inflatable small boat, it had the full length of 435 cm, internal length of 305 cm, full width of 75 cm, internal width of 55 cm and weight of 19 kg. The full length was reduced, but internal width and full width were increased compared to those of an existing boat made of space paper. In particular, the weight of frame was reduced to two thirds of an existing frame-type boat. Because the number of parts was reduced, assembly time was shortened. Thus, even a beginner can assemble it in 10 minutes.

Fig. 8: Process of completion of hull.

Second field test was performed on the Han River in Seoul by eight boat experts. It was performed to verify speed, straightness, balance, stability and rationality. The results are as follows.

The frame-type small inflatable boat improved the straightness, because it had a sleek hull form and less resistance by improving external wrinkles of head and tail of a boat. Rotationality was also stabilized when two people got on board. In addition, the safety was secured by compensating the rolling of a boat. Internal height and angle of hull were made easily through adjustment of a frame. However, as the small resistance of water was found in Bow part upon fast running, it was necessary to compensate it in the future.

Fig. 9: Second field test.

3.3. Evaluation on frame structure:

The structural analysis on structure of frame in a finally selected boat was requested to Incheon Techno Park. The results are as follows.

The structural evaluation was performed when adults got on board in order to evaluate the stability of designed frame. Stress and strain of the frame were evaluated under harsh conditions.

Boundary conditions and load conditions used in structural evaluation of this frame are shown in <Figure 10>. One person was referred to as a 70 kg man. It was designed to distribute load on two bottom plate structures located in the middle of the frame, if one adult got on board. In addition, it was designed to distribute load of each person on each bottom plate structure, if two adults got on board.

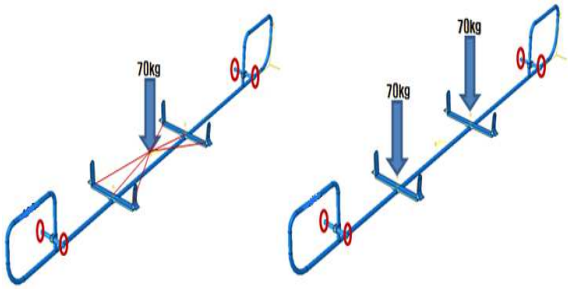


Fig. 10: Boundary/load conditions when one or two adults got on board.

ABAQUS 6.10, linear/ non-linear structural analysis software was used as structural analysis program. Analysis was performed under the static conditions (Barbero, 2013).

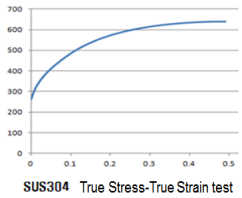
SoftWare	ABAQUS 6.10	
Analysis mode	Static, Nonlinear-geometry	
Geometry condition	3D	
Step	Step1	70kg, 140kg
	Step2	
Material	SUS 304 Elastic-Plastic (E : 212,000MPa, v : 0.3)  SUS304 True Stress-True Strain test	
Mesh	C3D4 Tetra element	
Output	Strain ,Stress distribution	

Fig. 11: Properties and analysis condition applied in the frame.

General SUS was assumed as the material used for this evaluation. True stress and true strain data of plastic zone were entered with consideration of possibility of small strain in the frame.

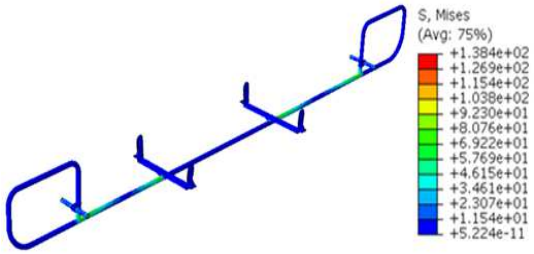


Fig. 12: Strain of frame when 1 person got on board.

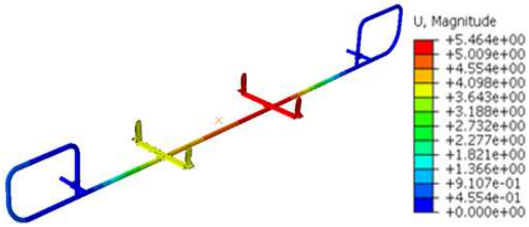


Fig. 13: Stress distribution of frame when 1 person got on board.

Structural analysis on the frame was performed on supposition that one person got on board. As a result, it was found that it was sagging down to 5.464 mm around the middle area of the frame. Maximal stress was 138.4 MPa. In addition, yield did not occur in frame strain and the material was deformed within the elastic range when one person got on board. Thus, it was evaluated to be structurally robust.

Structural analysis on frame was performed on supposition that two people got on board. As a result, it was found that it was sagging down to 15.39 mm around the middle area of frame. It was three times as much strain as one when one person got on board. As maximal stress was about 2.74 MPa, it was evaluated to fall into the yield zone. However, yield zone occurred only in small areas where frame was assembled. When two people got on board, frame was generally deformed in the elastic range and elastic strain occurred in some small areas. When the bottom plate of Kayaks/canoes was combined, the load applied to the frame got smaller. Thus, as it was thought to be structurally safe, structural reliability was confirmed.

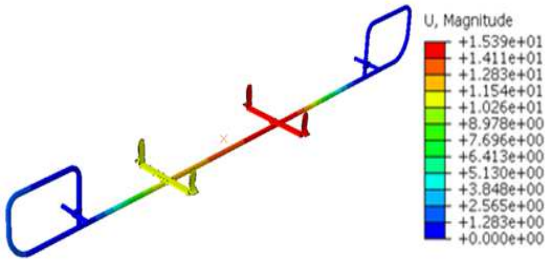


Fig. 14: Strain of frame when two people got on board.

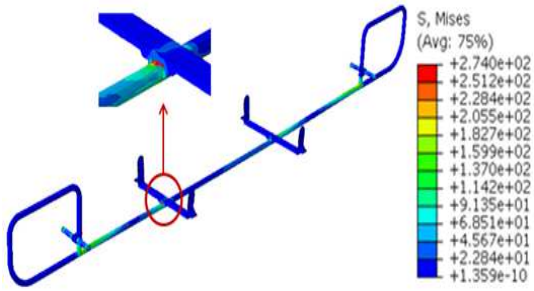


Fig. 15: Stress distribution of frame when two people got on board.

4. Conclusion:

In this study, a small inflatable boat for water leisure sports was developed through 3D surface design to enhance portability and affordability to

meet the domestic situation.

As a result, a folding small boat made of space paper in inflatable type was developed. As a result of the first field test, the weight was light and its straightness and acceleration showed excellent performance. However, rolling and distortion were found in a boat. Thus, a frame-type folding boat was developed to structurally enhance bottom and wall sides through the frame in order to compensate defects. Second field test was performed to test performance and safety of frame-type boats. As a result, rolling from side to side and distortion of a frame-type boat were compensated and both straightness and acceleration were excellent.

In the structural evaluation on boat frame, harsh conditions and strain of only frame were verified prior to the assembly of a boat. According to results, there was no abnormality in elastic zone when one person and two people got on board. Thus, it was confirmed that the frame was structurally suitable.

Acknowledgments

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Conflicts of Interest:

The authors declare no conflict of interest.

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