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A Structural Analysis of Aluminum Heli-Deck

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요　약: *선박해양 구조에 사용되는 대부분의 알루미늄 헬리데크는 외제로 관련 구조해석에 대한 정보도 일차적으로 외국의 전문업체가 제공하고 있고, 조선소에서는 필요시 주로 하부구조 해석을 보완하고 있다. 본 논문에서는 외국의 해석기술을 분석하고, 데크를 구성하고 있는 알루미늄 플랭크와 하부구조에 대한 구조해석을 수행하여 유사한 결과를 도출하였고, 해석에 관한 경험을 축적하였다.*

1. Introduction

Aluminum has a lot of merits in the aspect of quality, productivity and the cost. Aluminum alloy is light and has advantages in its strength, corrosion resistance, ability to be used for various kinds of products (complex extrusion profile), easy forming, recycling and etc. Among these advantages, the possibility of a extrusion through die makes it possible to do section design which reduces the amount of welding and stress concentration (Seo, 1998, Lee, 1999). In order to design proper and necessary profiles, the acquisition of design techniques such as the limitation of dimension, capability and methods for the extrusion is needed.

Aluminum alloy is not currently being used as a main material of ship and ocean structures, but it sometimes plays an important role in big luxurious passenger vessels. In case of such vessels, the application of lightened and fashionable material directly affects the design and weight of vessels and, therefore, demands would be necessarily. All aluminum structural materials are imported and fabricated at ship yards to make heli-decks. Since the supplier provides it according to the type of helicopters and ships and ocean structures, shipbuilding company does not need structural analysis of deck plating. Sometimes shipyards performs structural and vibration analysis of sub-structure of deck when heli-deck has some effects on the ship. For instance, the free vibration analysis of heli-deck was carried out in order to avoid resonance with the major excitation sources. Also the safety of wheel house under the heli-deck is investigated to check the deformation.

The objective of this research is to find the analysis method of heli-deck which is fabricated using the planks at the top of deck. The focus of research is mainly to verify the analysis method of supplier. Instead of applying plate analysis, the plank supplier used beam theory for the stress analysis of planks of which the method is quite distinctive. This study performed structural analysis using finite element analysis (ANSYS, 1999) for the aluminum heli-deck and the results were compared with those of reference provided by the foreign supplier (Raufoss, 1995).

2. Analysis of Heli-deck Profile

In Fig. 1, helicopter landing deck, so called heli-deck is shown where extruded planks consist of deck plate. The top of each plank without drain outlet is hinge-connected without welding and bottom is bolted on the heavy and strong aluminum frames as shown in Fig. 1. The frame is bolted to the steel sub-structure which is welded on the ship.

Structural analysis of the current plank type using beam instead of plate analysis is performed to follow the process performed by the supplier. This is possible by applying helicopter landing load on the narrow strip of planks in the longitudinal direction.

2.1 Analysis of conventional heli-deck planks

2.1.1 Analysis of the applied force and B.C.

When helicopter is landing, the most force is applying on the deck through the tires (CAA, 1998; DNV, 1994). So for the structural analysis, first of all, the method how to compute the maximum landing force needs to be analyzed. Since the width of tire is within the dimension of three extruded planks shown in Fig. 1, we can obtain two cases

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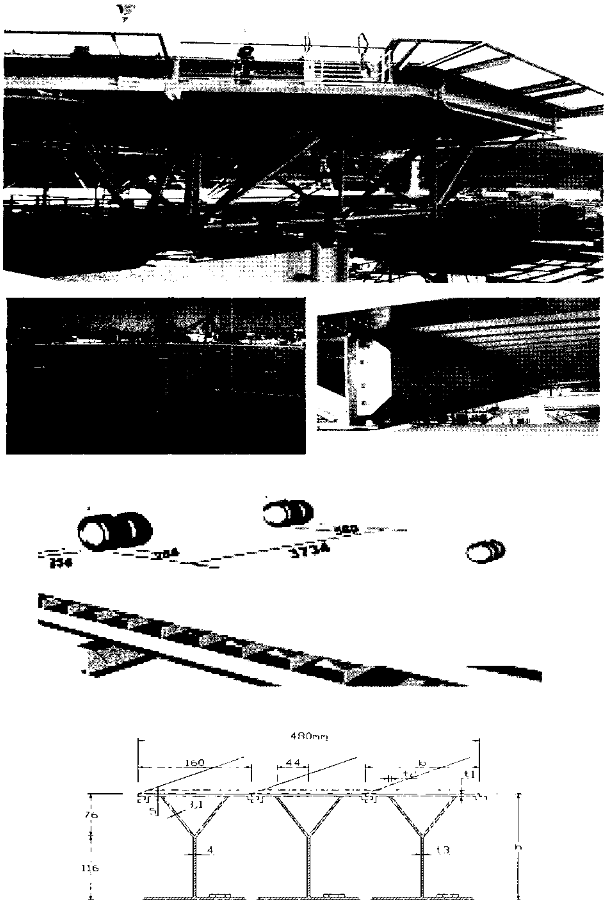


Fig. 1 Aluminium helicopter landing deck (heli-deck) and profile of extruded planks

that load is distributed symmetrically from the center of three planks (Load case 1, in Fig. 2) and load is distributed unsymmetrically (Load case 2, in Fig. 2).

Load case 1 : symmetric case

When Wetland EH101 helicopter is stowed, 140 KN of tire pressure acts on the deck and the design load becomes 140x2.5=350KN. Since the load on each tire is 350/4=87.5 KN and the contact surface of tire is 256x256mm, the unit load on the plank becomes $1.34\,N/mm^2$ (CAA, 1998). Since the width of tire is 256mm, it is landed on three planks as shown in Fig. 1. FEA software ANSYS(1999) is used with beam elements with the density $2.7 \times 10^6\,kg/mm^3$, Young's modulus $70,000\,N/mm^2$ and Poisson's ratio 0.3. Thickness of upper flange is 5mm(t1), V- type web is 3.1mm(t2), support part is 4mm(t3) and the width is 1mm, in Fig. 2. The numbers in the first and second figures in Fig. 2 indicate nodal and element numbers, respectively. The option to apply forces at positions between elements is used.

Load case 2 : unsymmetric case

Distributed landing force $1.34\,N/mm^2$ is applied on the deck in the case that tires are located unsymmetrically on the planks.

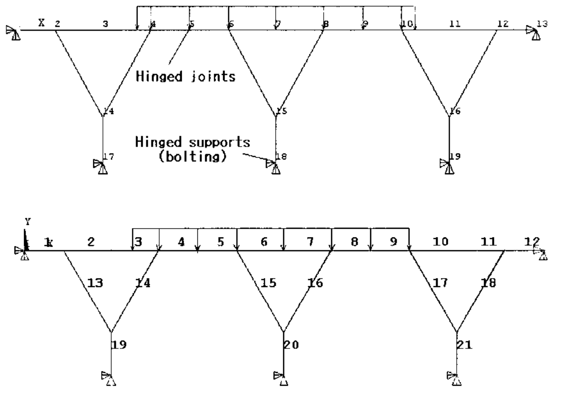


Fig. 2 Load case 1 (symmetric) and Load case 2 (unsymmetric)

Since the planks are hinge-jointed for each one and hinge-supported to the frame, boundary conditions for jointing parts (Nodes 1, 13, 5, 9, 17, 18, 19) of planks need to be defined properly to consider structural functioning. In hinge-supported parts, lower part of plank and frame structure are connected by bolts. In order to find the proper condition, several structural analysis with different boundary conditions was performed and the results were compared with those of supplier. It is found that UX and UY are constrained for Nodes 17, 18 and 19 connected to the frame, for 1 and 13 connected to the neighboring planks and are free for intermediate 5 and 9.

2.1.2 Analysis result of planks without drainage function

The allowable stress of aluminum is $250\,N/mm^2$ and stress unit is (MPa) N/mm^2 in the all following results and Tables.

Load case 1

The biggest stress occurs in nodes 6 and 7 of element 6 and stress is symmetric, too. The maximum stress value on the deck is 223 compared to 232 (Supplier) and the material is safe. ANAYS BEAM3 only provides moment distribution instead of stress as shown in Fig 3. The stress distribution is symmetric as in Table 1 and the moment is symmetric too. The stress range provided by the plank supplier is similar to the analysis.

Load case 2

The maximum stress value on the deck is 232, less than the allowable stress. And it is safe since already design factor 2.5 is included in the applied load. The moment is bigger at the left side due to the unsymmetric load.

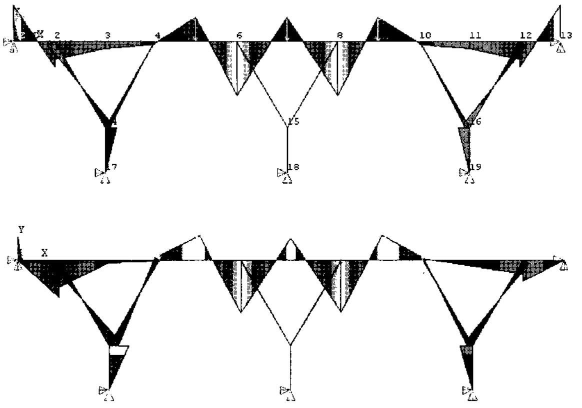


Fig. 3 Moment distribution of symmetric and unsymmetric cases

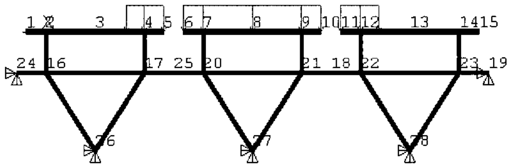
Table 1 Comparison of stresses (N/mm^2)

Elem. No	L.C. 1		L.C. 2	
	Supplier (Raufoss)	Analysis	Supplier (Raufoss)	Analysis
5	232	220	229	232
6	209	223	208	232
7	209	223	204	227
8	232	219	227	227

2.1.3 Analysis result of planks with drainage function

In the hazardous operating condition such as snow, heavy rain in cold weather, drain on the deck is very important for the safety. To overcome this, plank type with drainage as shown in Fig. 4 is used, which is more heavier than that without drainage. Equivalent structural analysis of plank is performed and stress is shown in Table 2. Under the load conditions 1 and 2, both show similar stresses and are all safe. This cannot be compared, since no results are provided in the reference. It is reasonable to get the lower stress of 206.1, since this design is more robust than the plank without drainage with stress of 232 in Table 1.

Load case 1



Load case 2

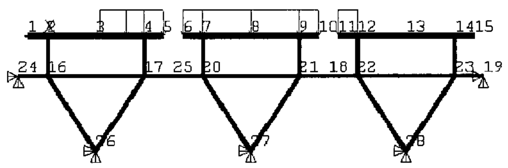


Fig. 4 Load case 1 and Load case 2

Table 2 Stress results (N/mm^2)

Nodes	L.C. 1		L.C. 2	
	tension	comp.	tension	comp.
7	198.7	-205.7	199.2	-206.1
8	196.3	-203.2	196.3	-203.2
9	198.7	-205.7	198.5	-205.1

2.2 New extrusion profile of plank

In case of avoiding possible design patent of plank, it is necessary to invent new design for domestic usage. The optimum design process may be necessary to find the solution. It is required to develop intelligent numerical process with the control of height, 'thickness, numbers and angles of internal supporting components for the optimal cross-sectional shape. For instance, the design variables can be t1, t2, t3,(thickness of flange), h(height of profile), b(space) and angle shown in Fig. 1. However, the optimization for the change of the location and angle of internal compartments may be numerically formidable. So, instead of such conventional optimization process(Seo et al., 1998), new designs are invented with the consulting of experts in aluminium industry. For this, technical knowledges such as the extrusion limits of cross-sectional dimension and weight are considered. Two types, with and without drain functions are designed.

2.2.1 New plank design without drainage

The FEA model of lightened design is shown in Fig. 5. When comparing unit mass with previous one, the ratio is 0.011/0.012 = 0.9167, so about 8.3% of mass is decreased. The result of stress analysis (the position and maximum stress value) is shown in Table 3. The stress of 195.4 in element 8 is less than the stress 223 of the original design in Table 1.

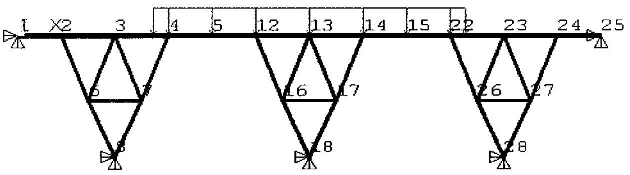


Fig. 5 FE model of new plank

Table 3 Stress without drainage (N/mm^2)

Nodes	L.C. 1		L.C. 2	
	tension	comp.	tension	comp.
14	185.9	-195.4	187.1	-196.5
15	145.6	-155.3	148.4	-158.1

2.2.2 New plank design with drainage

The lightened design with drainage is shown in Fig. 6. The maximum stress value of new plank is 237, larger than 206.1 of the original design in Table 2. Unit mass (0.014kg) is 22% decreased (0.018kg). Since it is less than 250 N/mm^2, it is still safe. But as mentioned before, rigorous optimal design process and fatigue analysis need to be applied for more academical research.

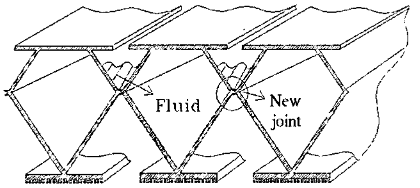


Fig. 6 New plank design with drainage

3. Analysis of Heli-deck with Sub-structure

Finally, structural analysis of heli-deck with sub-structure (Fig. 7) which supports deck is performed. The purpose of the analysis is to verify the result of deck supplier who provides only the result without detail analysis information. In the reference(Raufoss, 1995) spar element is used in the analysis. Sub-structure is a built-up structure assembled with aluminum longitudinals and steel columns. The aluminum heli-deck is connected by sub-steel structure with bolts and steel structure is fixed on ship by welding. Three load combinations could be applied for the structural analysis of total heli-deck including sub-structure to consider various ship motion, weather and landing conditions(Raufoss, 1995, CAA, 1998). In case of Westland EH101 helicopter, Load Combination 1 includes accidental landing load of 456, dead load(self weight) of 737, live load of 215, wind load of 23 KN at 30m/s and there are five different landing loads according to the position of helicopter. Load Combination 2 consists of maximum ship motion, sea pressure, dead load, wind load and helicopter stowed load. In Load Combination 3, ice load substitutes sea pressure. Herein, the most severe load, Load Combination 1, with the accidental landing load at the edge of deck is applied. Fig. 7 shows the ANSYS beam model with 86 nodes and applied forces. Note that edge force is severe where a helicopter landed.

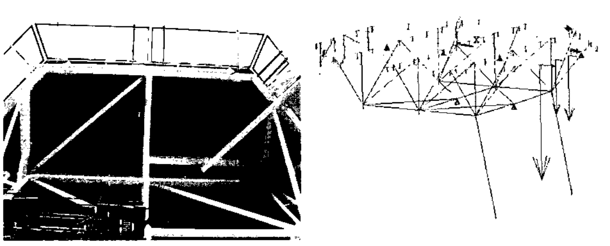


Fig. 7 Sub-structure of heli-deck

In Table 4, nodal stresses are shown and results of this analysis [B] are compared with that of supplier [A]. Note that the structural analysis process is not explained precisely in the reference (Raufoss, 1995), and this may not be not the final result to be used at yards. For example, it is not quite normal to have stress value of 687 MPa at element 242 in the reference. Two results show similar behavior except element 169. It can be thought that this reference is the intermediate report since there is a remark that more reinforcement will be performed to reduce the stress. Deformed shape is shown in the first of Fig. 8. So, this analysis can be thought as acceptable and similar to the reference. Since some of stresses are more larger than the allowable stress and excessive displacement occurs at the edge when a helicopter landed accidentally at that position, structure is reinforced at the weak points. Two frames are reinforced in front of deck, (i.e., right corner of deck) and stresses [C] are reduced drastically in Table 4 and deformation is also reduced as shown in the second, Fig. 8.

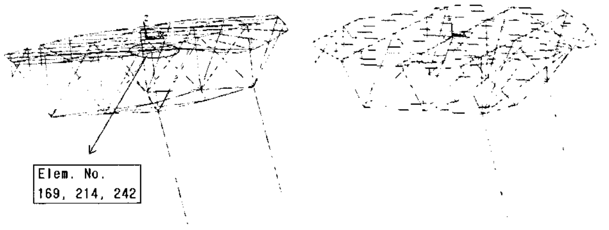


Fig. 8 Deformed shape of original and reinforced heli-deck

Table 4 Comparison of stresses (N/mm^2)

Old model [A]			Analysis [B]		Reinforced Sub-structure [C]	
Eleme no	Stress 1	Stress 2	Stress 1	Stress 2	Stress 1	Stress 2
145	106	91	64	68	75	71
162	105	89	74	75	97	95
169	98	53	378	670	131	354
174	183	232	120	126	112	108
179	206	232	378	225	168	121
206	12	110	146	27	33	8
208	114	526	38	527	17	228
214	33	188	199	709	487	256
242	564	687	583	782	251	351

4. Conclusions

In this study, the structural analysis of the aluminium heli-deck is performed. Since the foreign heli-deck supplier does not provide the detail process for the structural analysis and design of heli-deck, some efforts are required to define load, boundary conditions and analysis process.

Mostly, the analysis of deck plating, the top of heli-deck, may be not required in the ship yard, since the supplier provides design and material with enough experience and certification. A heli-deck may affect the vibration and strength of crew or operation room and ship hull, yard analyzes the effect of it and makes a robust structure. Through the analysis followings are found and experienced.

(1) Through the analysis, similar stress results are obtained for deck planks and sub-structure compared to that of the supplier. That is, the analysis process performed herein can be acceptable for the design of aluminium heli-deck. Current deck plating is quite safe, since the design load has the factor of 2.5.

(2) New design of planks with and without drainage are devised. Domestic design is necessary to substitute the foreign design and material. For both cases, weights are reduced, but stress becomes higher for the drainage case. More rigorous optimal design process and fatigue analysis need to be applied to find the usable design. As shown, more reinforcements are necessary to make a robust heli-deck.

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