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A Structural Analysis of Aluminum Heli-Deck

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BSTRACT: *Most of the heli-decks are constructed with aluminum extrusions. The heli-deck product company supplies structural alysis data to the shipbuilding companies; so, if the shipbuilding co. needs to make up for the weak points in the current system, ey only need to analyze the substructure through the FEA. In this paper, we will concentrate on the following issues: analysis of uminium extrusions regarding the structural analysis data, and check safety about the substructure through the FEA.*

EY WORDS: Heli-deck, Deck Plank, Aluminum Extrusion, FEA

1. Introduction

Aluminum has a lot of merits with regard to quality, roductivity, and cost. Aluminum alloy is lightweight, and has dvantages in its strength, corrosion resistance, versatility, liability, etc. Among these advantages, the possibility of an xtrusion through die makes it possible to do design sections that educe the amount of welding and stress concentration (Seo, 1998; ee, 1999). In order to design proper and necessary profiles, the cquisition of design techniques, such as the limitation of imension, capability, and methods for the extrusion is required. luminum alloy is not currently being used as a main material f ship and ocean structures, but it sometimes plays an important ole in the construction of big, luxurious, passenger vessels. In he case of such vessels, the application of lightened and ashionable material directly affects the design and weight of the essel and, therefore, aluminum alloy would be preferable. All luminum structural materials needed to make heli-decks are mported and fabricated at ship yards. Since the supplier provides aterials according to the type of helicopters, ships, and ocean tructures, the shipbuilding company does not need a structural nalysis of the deck plating. Sometimes shipyards perform tructural and vibration analysis of the sub-structure of the deck hen the heli-deck has some effect on the ship. For instance, the ree vibration analysis of the heli-deck was carried out in order o avoid resonance with the major excitation sources. Also the afety of the wheelhouse under the heli-deck is investigated to heck for deformation. The objective of this research is to etermine the best method for analyzing the heli-deck, which is abricated using the planks at the top of the deck.

The focus of research is mainly to verify the analysis method of the supplier. Instead of applying plate analysis, the plank supplier used beam theory for the stress analysis of planks, a method that 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 the reference provided by the foreign supplier (Raufoss, 1995).

2. Analysis of Heli-deck Profile

In Fig. 1, the helicopter landing deck, so called heli-deck is shown where extruded planks consist of deck plates. The top of each plank without drain outlets- is hinge-connected without welding, and the bottom is bolted on the heavy 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 the helicopter is landing, the most force is applied on the deck through the tires (CAA, 1998; DNV, 1994). So, for the structural analysis, first of all, the method for computing 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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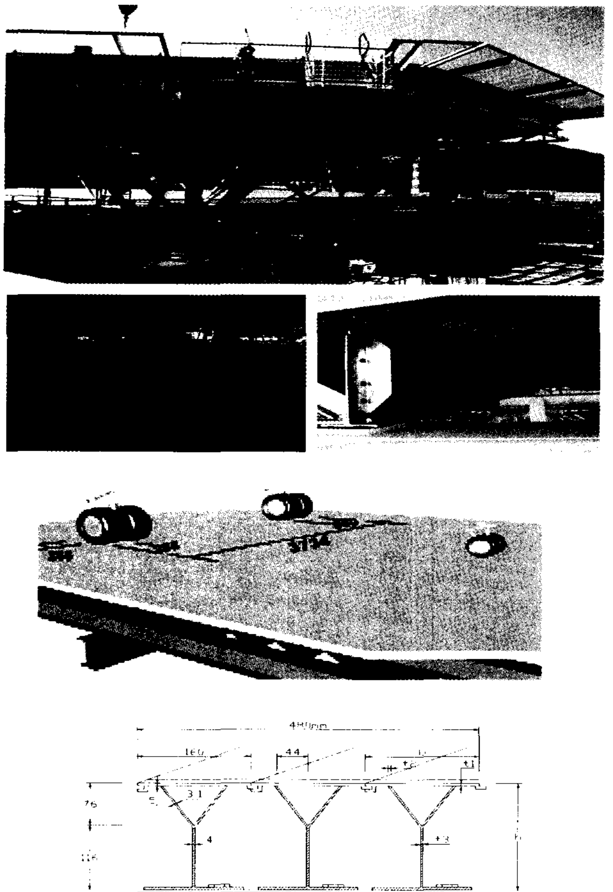


Fig. 1 Aluminium helicopter landing deck (heli-deck) and profile of extruded planks

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

Load case 1 : symmetric case

When the 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 the tire is 256x256mm, the unit load on the plank becomes $1.34\ N/mm^2$ (CAA, 1998). Since the width of the tire is 256mm, it is landed on three planks, as seen 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 : unsymmetrical 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.

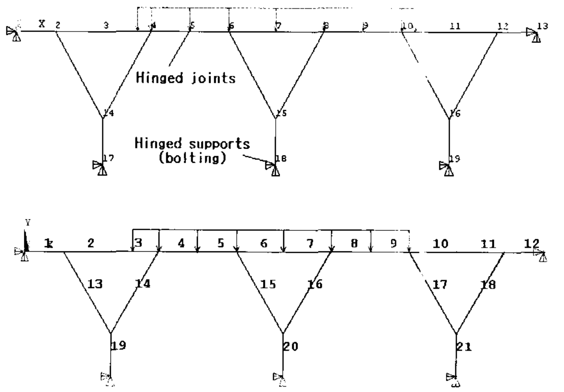


Fig. 2 Load case 1 (symmetric) and Load case 2 (unsymmetric)

Since each of the planks are hinge-jointed 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, in order to consider structural functioning. In hinge-supported parts, lower parts of the plank and frame structure are connected by bolts. In order to find the proper condition, several structural analysis with different boundary conditions were performed, and the results were compared with those of the 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 $250N/mm^2$ and stress unit is (MPa) N/mm^2 in the the following results and Tables.

Load case 1

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

Load case 2

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

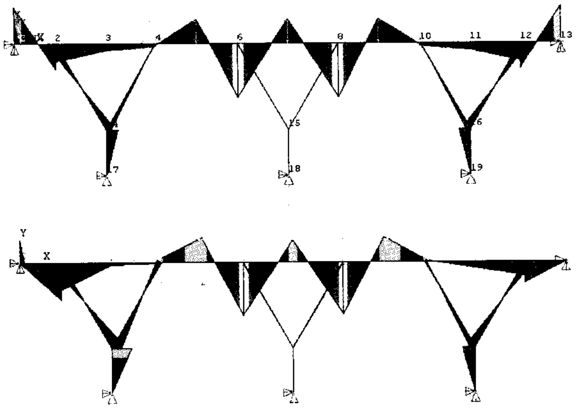


Fig. 3 Moment distribution of symmetric and unsymmetric cases

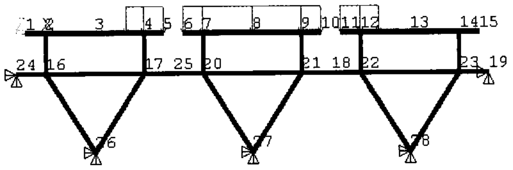
Table 1 Comparison of stresses (N/mm^2)

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 conditions, such as snow, heavy rain, and cold weather, drain on the deck is very important for safety. To overcome this, plank type with drainage, as shown in Fig. 4, is used, which is heavier than the plank type 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 both are safe. This cannot be compared to the supplier's figures, 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, stress of 232, as shown in Table 1.

Load case 1



Load case 2

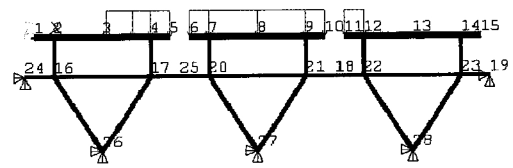


Fig. 4 Load case 1 and Load case 2

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 order to avoid possible design patents of plank, it is necessary to invent a new design for domestic usage. The optimum design process may be necessary to find the solution. It is important to develop intelligent numerical processes, controlling for height, thickness, numbers, and angles of internal supporting components for the optimal cross-sectional shape. For instance, as seen in Fig. 1, the design variables can be t1, t2, t3,(thickness of flange), h(height of profile), b(space) and angle. However, the optimization for the change of the location and angle of internal compartments may be numerically formidable. So, instead of such a conventional optimization process (Seo et al., 1998), new designs have been invented involving the consulting of experts in the aluminium industry. For this, technical knowledge, such as the extrusion limits of cross-sectional dimension and weight, is 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 a 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.

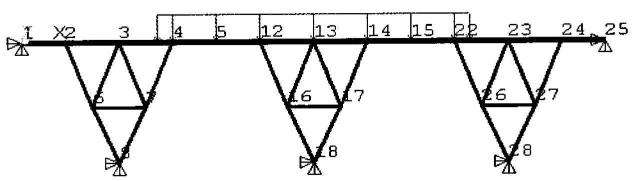


Fig. 5 FE model of new plank

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, which is 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. However, as mentioned before, rigorous optimal design processes and fatigue analysis need to be applied for further academic research.

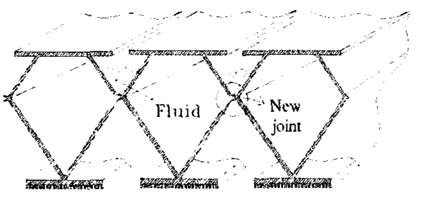


Fig. 6 New plank design with drainage

3. Analysis of Heli-deck with Sub-structure

Finally, as seen in figure 7, a structural analysis of the heli-deck with a sub-structure support deck is performed. The purpose of the analysis is to verify the result of the deck supplier who provides only the results, without a detailed analysis of the information. In the reference (Raufoss, 1995) spar elements are used in the analysis. The Sub-structure is a built-up structure, assembled with aluminum longitudinals and steel columns. The aluminum heli-deck is connected by a sub-steel structure with bolts, and a steel structure is welded upon on the ship. Three load combinations could be applied for the structural analysis of the total heli-deck, including sub-structure to consider various ship motion, weather, and landing conditions (Raufoss, 1995; CAA, 1998). In the case of a Westland EH101 helicopter, Load Combination 1 includes accidental landing load of 456, a dead load (self weight) of 737, a live load of 215, and a wind load of 23 KN at 30m/s; there are five different landing loads according to the position of the 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 for sea pressure. Herein, the most severe load, Load Combination 1, with the accidental landing load at the edge of the 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.

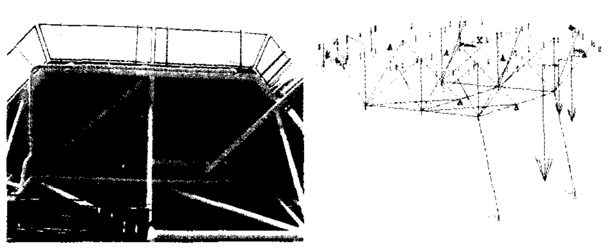


Fig. 7 Sub-structure of heli-deck

In Table 4, nodal stresses are shown and results of this analysis [B] are compared with that of the supplier [A]. Note that the structural analysis process is not explained precisely in the reference (Raufoss, 1995), and this may not be the final result used. For example, it is not quite normal to have a 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 as the top of Fig. 8. So, this analysis can be considered acceptable and similar to the reference. Since some of stresses are larger than the allowable stress and excessive displacement occurs at the edge when a helicopter lands, the structure is reinforced at the weak points. Two frames are reinforced in the front of the deck, (i.e., right corner of deck), and as seen in Table 4, stresses [C] are reduced drastically. Deformation- is also reduced as seen in the Fig. 8.

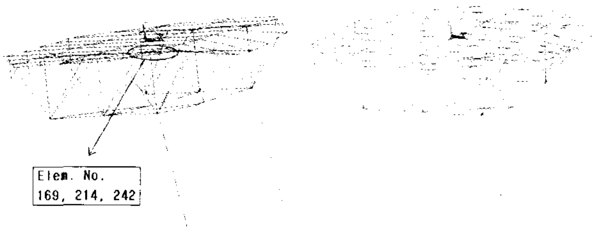


Fig. 8 Deformed shape of original and reinforced heli-deck

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, a structural analysis of the aluminium heli-deck is performed. Since the foreign heli-deck supplier does not provide the details of the process for the structural analysis and design of the heli-deck, some efforts are required to define load, boundary conditions, and the analysis process. Mostly, the analysis of deck plating, the top of heli-deck, may not be required in the shipyard, since the supplier does provide designs and materials with enough experience and certification. In this case, 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 the following is 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 an 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, in case it is necessary to substitute domestic design for the foreign design and material. For both cases, weights is reduced, but stress becomes higher for the drainage case. More rigorous optimal design processes and fatigue analysis need to be applied towards finding the usable design. As shown, more reinforcements are necessary to make to a robust heli-deck.

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