Optimization of Block Division using Nodal Cut Set Method
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Key Words: Block division, Optimization, Product model, Genetic Algorithm, Nodal Cut set

1. INTRODUCTION
The ship hull construction method adopted in modern shipyards is 'Block construction method'. The efficiency of block construction depends on block division. Therefore it is required to develop methods to optimize block division.

In order to achieve an optimum block division it is necessary to generate a large number of block division plans. This can be attained by modifying seam position (Fig. 1(a)) or combination of parts (Fig. 1(b)). Optimization of block division, paying attention to combination of parts is focused in this study and a new concept which is termed as "Nodal cut set method" is presented in this paper. Product model and genetic algorithm are used in the proposed method.

2. BASIC CONCEPT
2.1 Cut set and incidence vector
By the use of graph model, the ship structure is expressed as nodes and links. Parts are represented by nodes where as connections are represented by links (Fig. 2(a)).

A graph can be divided into two portions by removing (or cutting) some links. Cut set of a graph is defined as a set of links, which can be represented by an incidence vector in which '1' means 'cut' and '0' means connect (Fig. 2(b))

When a cut set divides the graph into two portions such that one portion consists of a single node and other portion consists of the rest of the nodes, such a cut set is called 'Nodal cut set'. An example of nodal cut set is shown in Fig. 2(c) with its incidence vector.

(a) Change of seam position (b) Change of combination of parts
Fig.1 Generation of block division plans

Product Model

Graph Model

Incidence Vector

Fig.2 Graph model and cut sets

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3. OUT LINE OF OPTIMIZATION SYSTEM

3.1 Problem definition
- Design variables: Combination of parts.
- Constraint conditions: Block weight and block size are considered as constraints. The allowable value of size and weight are decided based on shipyard facilities.
- Objective function (OF): Weld length between the blocks is the objective function. In an optimum solution weld length should be a minimum.

3.2 System configuration
The optimization system consists of three modules i.e. a product model module, a graph model module and a genetic algorithm module (Fig. 4). The graph model of the structure can be generated using the data extracted from product model.

3.3 Plan generation and fitness calculation
Nodes and links in graph model have pointers to the parts and joints in product model module. In plan generation, only the graph model is modified based on the chromosomes. The required data to calculate fitness, such as weld length, block size, weight etc. can be extracted by the use of modified graph model and pointers to the product model. Therefore both plan generation and fitness calculation can be achieved by changing the graph model. Product model is not modified.

4. EXAMPLES OF THE OPTIMIZATION
In order to show the effectiveness of new method, optimization is carried out for a simple structure (Fig.5) using proposed method and joint hierarchy method. Optimization results are shown in Table 1 and Fig.6. Results show that proposed method is quite faster than previous method because regeneration of the product model is not required. Moreover, convergence trend of fitness is also improved. Generally, number of parts is less than the number of joints, and illegal combination of parts are prevented by using the cut set. It is clear that such characteristics of the new method help to achieve a faster convergence to optimum solution.

Therefore, optimization has been carried out for a large structure (Fig. 7). Optimization results are shown in Fig. 8. In order to achieve the optimum results, 8 hours were taken by a computer with Pentium(R) D CPU 3.00GHz, 3.12 GB RAM.

5. CONCLUSIONS
Nodal cut set method is newly introduced to optimize the block division. In this method block division plans are generated by executing the two kinds of operations on the nodal cut sets. Effectiveness of the proposed method is shown by comparing the calculation time and optimization result with previous method.

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REFERENCES

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Table 1 Comparison of optimization methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Old method</th>
<th>Proposed method</th>
<th>Constraints</th>
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<tr>
<td>Size of biggest block (m)</td>
<td>15 × 15 × 10</td>
<td>15 × 15 × 10</td>
<td>25 × 20 × 20</td>
</tr>
<tr>
<td>Weight of heaviest block (ton)</td>
<td>87.46</td>
<td>87.46</td>
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<tr>
<td>Number of blocks</td>
<td>3</td>
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<tr>
<td>Weld length (OFF)</td>
<td>84.34</td>
<td>49.95</td>
<td></td>
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<tr>
<td>bus / combinations</td>
<td>25/3353432</td>
<td>13/8192</td>
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<tr>
<td>Pop Size × Gen size</td>
<td>500 × 500</td>
<td>500 × 500</td>
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<tr>
<td>Gens. required to reach optimum</td>
<td>102</td>
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<tr>
<td>Regeneration of PM</td>
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<td>No</td>
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<tr>
<td>Run time for 500 gens</td>
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<td>7 minutes</td>
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</tbody>
</table>

Fig.4 System configuration

Fig.5 Structure used for evaluation

Fig.6 Optimization results for evaluation of methods

Fig.7 Block details and constraint conditions

Fig.8 Optimization results

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