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Implementation of welding material quantity evaluation system combined with ship design CAD system

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Abstract

These days, the great part of design processes in the field of ship or offshore manufacturing are planned and implemented using the CAD system customized for shipbuilding companies. It means that all information for design and production could be extracted and reused at the other useful fields which need cost considerable time and efforts. The typical example is the field of welding material quantity evaluation which is demanded during the construction of ship or offshore structures. The proper evaluation of welding material to be used and the usage of them at the stage of schedule planning are mostly important to achieve the seamless process of production and costing in advance. This study is related to the calculation of welding length and needed welding material quantity at the stage of design completion utilizing the customized CAD system. The calculated welding material quantity would be classified according to welding posture, assembly stage, block, bevel and welding type so as to improve the accuracy of total cost evaluation. Moreover it is possible to predict the working time for welding operation and could be used efficiently for the cost management using the results of this research.

Keywords: Customized CAD system; Assembly simulation; Welding length; Welding material quantity

1. Introduction

These days, shipbuilding companies have designed 3D CAD models of hull structures and outfitting through a CAD system customized for ship design and production, keeping and actively using large volumes of design and production information via Enterprise Resource Planning (ERP) system (Kim et al., 2013; Ruy et al., 2009; Ruy et al., 2012a,b). In this context, we are attempting to calculate the welding length and welding material quantity when the detailed design has progressed to some degree (Choi et al., 2009; Ruy et al., 2012a,b). Meanwhile, Lee et al. (1998) suggested a concrete method of calculating the welding material quantity by developing a simple formula, although its connection with the CAD system is weak. This paper presents a method of building a practical computerization and automation system by connecting much of the process required for calculating the welding length and welding material quantity with a customized CAD system for ship design and production.

When the detail design of ship and offshore structures is finished at about three months before S/C (steel cutting), the budget and related plans must be established to procure welding materials. Accurate information for actual work is required, and the difference between the plan and actual field work must be minimized. In addition, computerized management is essential for integrated management and information sharing. In most shipbuilding yards, however, the works for procurement must start long before detail designs are finished. Moreover, the welding length is usually calculated manually by the workers based on the 2D drawings, which is highly

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likely to produce calculation errors. The manual calculation of the welding material quantity causes variations depending on the technical level of the worker, and it takes more than two months with three workers on average (Choi et al., 2009), although it may vary by ship type due to many reasons, such as the repetition of manual dimensioning work for each member. On the other hand, the method proposed in this paper can consistently calculate the welding material quantity by using a system, and can radically reduce the estimation work time through computer processing. To produce the Work Package/Work Order (WP/WO) by predicting the design welding material quantity, and to conclude individual contracts by preparing the production scheme, it is vital to calculate the accurate welding material quantity at the right time.

2. System work flowchart

Fig. 1 shows the work flowchart of this system. The information required for the calculation of the welding length, such as the member shape and properties from the DB that has been modeled through AVEVA Marine, is extracted in the ATX, ATT, and DXF file formats. The information on the block assembly hierarchy related to the Detail Assembly Procedure (DAP) drawing is also extracted. The block assembly hierarchy must describe in detail the hierarchy of all the assemblies belonging to the block at the levels of assembly process. As the welding posture is one of the main determinants of the welding man-hour, the base plate setting for each assembly is important. The plate with the largest area is set as the base plate automatically in basic setting, and can be changed by the user as needed (see Fig. 2).

There should be no problem if the modeling work is perfect, but many exceptional situations can occur in the welding length calculation due to the customary rules and the designer's inexperience. To quickly attain precise results, a modeling check system is needed. In particular, errors in the thickness value and duplicate calculations of the welding length must be detected automatically, and the feature that allows the worker to intentionally omit the welding length must be provided.

The block assembly hierarchy diagram contains information about the assembly sequence for producing the assembly, and assembly simulation using this sequence can help in the calculation of the welding length by allowing users to easily check the assembly process. In general, longitudinal stiffeners are assembled after the installation of the base plates. Then the lower assembly of the corresponding step, the members belonging to the assembly, and lastly, the collar plate and others, are assembled. The following chapters are descriptions of the calculation of the welding length according to various classification schemes and the prediction technique. Every output is stored in the corporate backbone system, and it must be possible to print the outputs in a report format.

3. Calculation of welding length

The welding length must be calculated for every member (flat plate, curved plate, reinforcement, etc.). In this study, 18

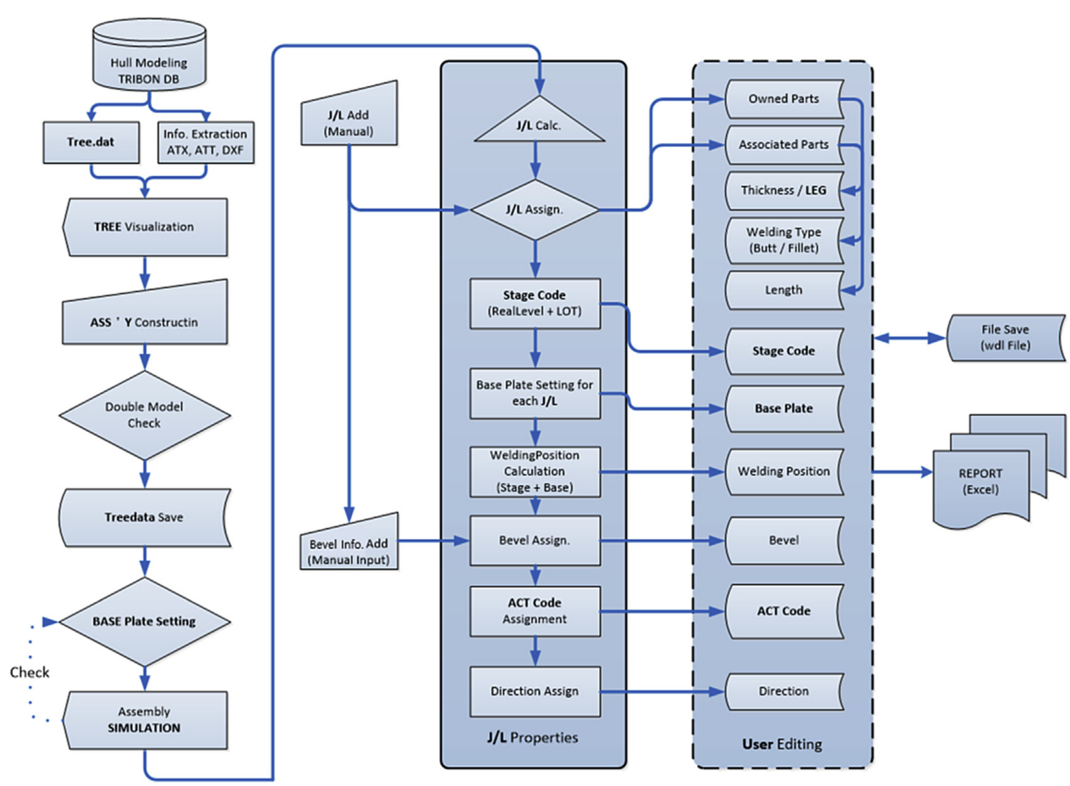

Fig. 1. Workflow of the welding material quantity evaluation system.

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joint types between members were classified in terms of the member shape, which are arranged in Table 1. The calculation of the welding length is not a simple process that requires only the summation of the contact length of the shape, but the process calculating actual welding length considering all the practical things such as notches, scallops, toes, etc. of the joint members.

Even if the welding length is the same, the working man-hour and cost can vary greatly depending on the work environment and welding type. Therefore, special attributes are to be assigned to each welding length based on the regulations and user specifications such as assembly stage, welding posture, bevel, leg length, etc. And also, those are to be easily changeable as needed by the user.

The welding postures can be classified by welding type, joint length location and direction, and base member angle, and they are usually classified into four types: flat, horizontal, vertical, and overhead. It will greatly help one understand the characteristics if the colors of the joint lengths can be activated according to the classification criteria. In the developed system, joint lengths can be highlighted with specific color according to welding posture as shown in Fig. 3.

To weld the bow or stern block, which have relatively large curvatures, a turnover process must be added to the assembly

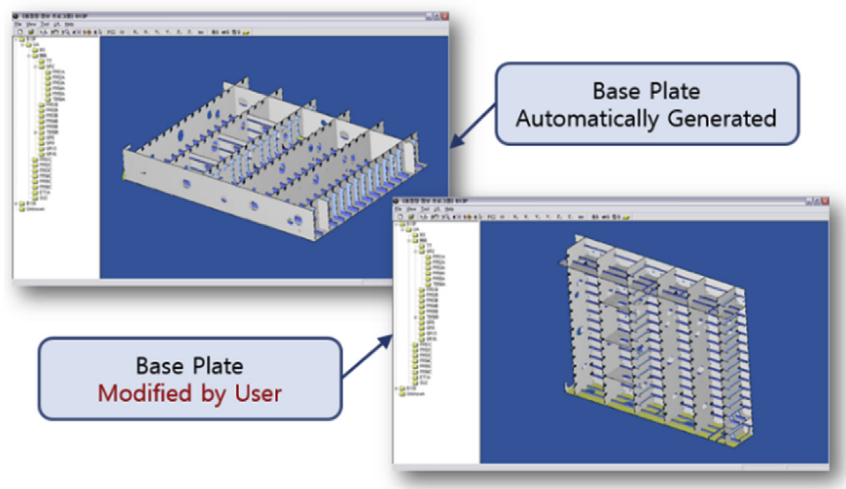
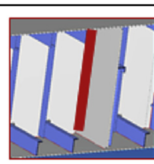
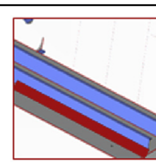
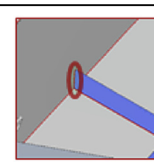
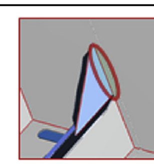
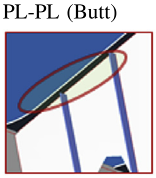
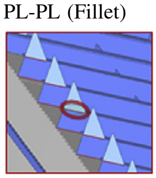
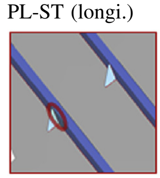
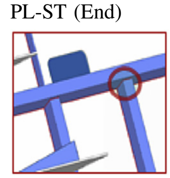
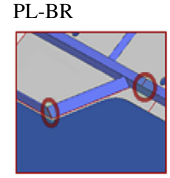
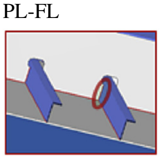
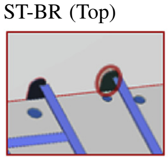
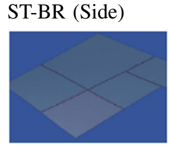
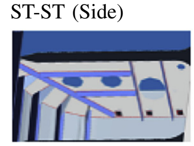
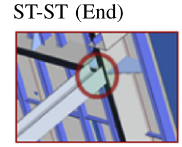
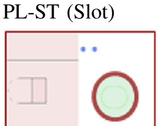
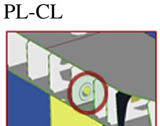
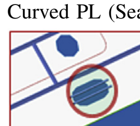


Fig. 2. System function for the base plate setting in assembly process.

Table 1
Classification of joint types for the calculation of welding length.

 PL-PL (Butt)	 PL-PL (Fillet)	 PL-ST (longi.)	 PL-ST (End)	 PL-BR
 PL-FL	 ST-BR (Top)	 ST-BR (Side)	 ST-ST (Side)	 ST-ST (End)
 PL-ST (Slot)	 PL-CL	 Curved PL (Seam)	 Curved PL (Inner)	 Pillar-PL
 Temporary Hole	 Double PL	 Protection Bar	PL: Plate ST: Stiffener BR: Bracket FL: Flange CL: Collar Plate	

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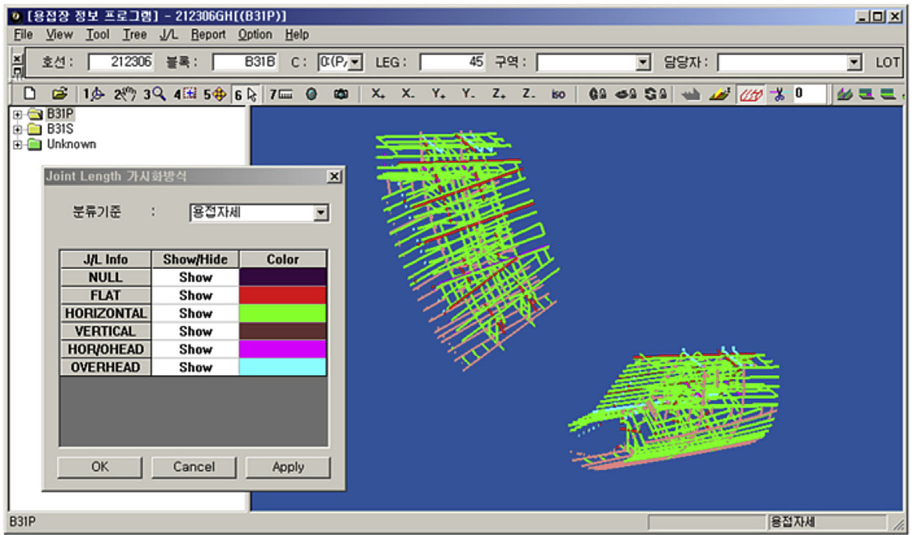

Fig. 3. System function for color highlighting according to welding posture.

process, which affects the calculation of the welding material quantity for each welding posture. Therefore, the system was designed in such a way that welding classification can be automatically made around the turnover. For example, Fig. 4 shows one welding length belonging to the parts that need to be welded before the turnover so as to facilitate the assembly process.

One thing that must be considered in the calculation of the welding material quantity is that the calculation method can vary by factory and equipment of the shipbuilding yard. Every designed member include the property code, and it must be possible to automatically combine these and to classify the stage codes by company through the corresponding pattern. Another important factor in the calculation of the welding material quantity is the type of bevel. The bevel is differentiated by assembly stage, welding type, welding length, welding posture, and thickness of the main plate, and they are mapped according to the rules of each company. When exceptions occur, the users must be able to modify or change the bevel information and welding type by easily accessing the welding length.

Other required convenience features are as follows. It must be possible to see the shapes of the internal structures through the outside plate of the block (see Fig. 5), and to visually check them by welding length type. Furthermore, the produced welding lengths need to be differentiated for Not Welding Range (NWR) or for the classification of the welding lengths that cannot be described by shape. For welding lengths where the bilge shell and floor meet, the side and bottom parts must be classified by welding posture, and must be changeable automatically or manually. In addition, depending on the case, it must be possible to create and add welding lengths which

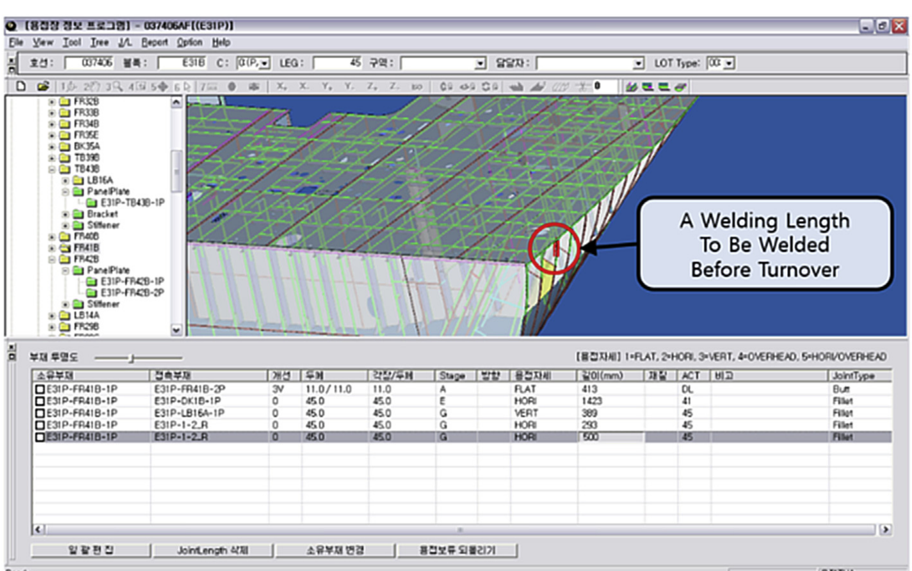

Fig. 4. System function for automatic classification around the turnover operation.

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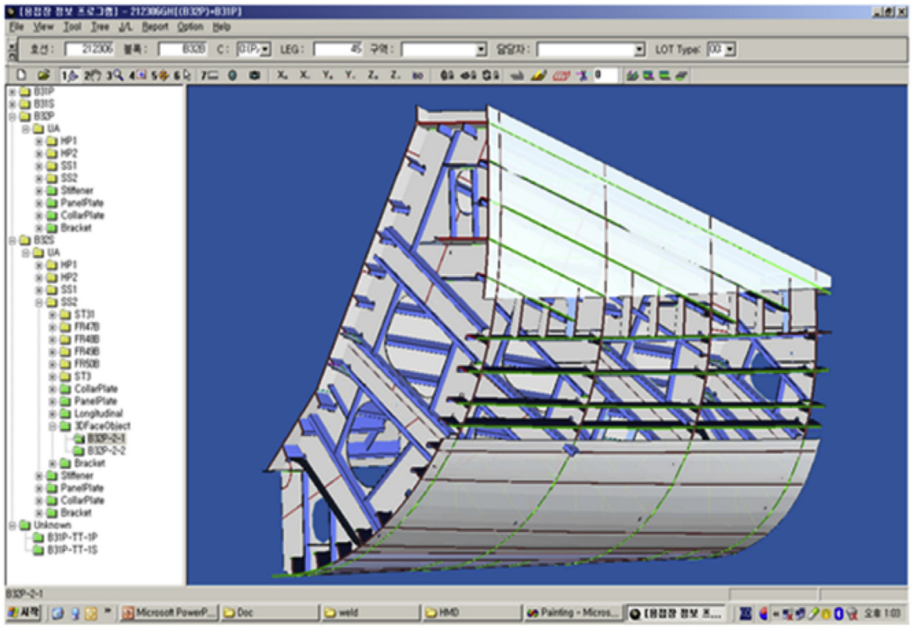

Fig. 5. Example of system functions for various touch-up.

are not registered as shape. These features can be useful when there are structural members that have not been modeled, or when revisions are applied.

4. NWR and extraction of outside shop work welding length

The calculation of the welding material quantity related to the hull must not be limited to the assembly of pre-erection blocks, but the welding between pre-erection blocks and the assembly between blocks in the dock must also be considered. For this purpose, the erection schedule and the working schedule after erection are required. In general, the welding material quantity is estimated in block unit, but the welding length involved in the assembly between blocks does not belong to the block but is to be separately managed. This is called NWR which is butt or fillet welding nearby block boundary. The users must be able to specify NWR for the block assembly, and must refer to them in the blocks of the successive schedule. Fig. 6 shows NWR regions for welding between blocks.

The contact parts between the preceding and following blocks must be managed separately from the welding lengths calculated in the in-shop work, and for reinforcements besides butt welding, it must be possible to manage the longitudinal NWR differently for curved and straight members, according to the yard's standards.

5. Functional relations between welding length and welding material quantity

The welding material quantity is used as an important criterion for estimating the man-hour and the cost of all the production processes, along with the blocks' weight and

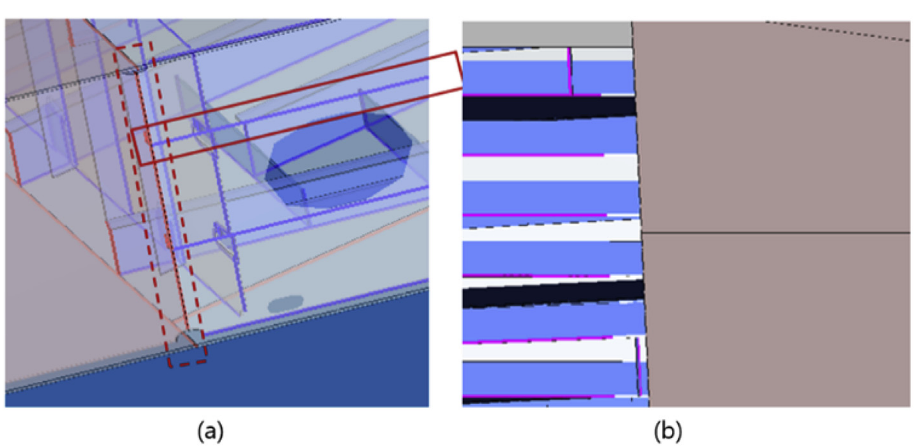

Fig. 6. NWR (a) butt welding region; (b) stiffener welding region.

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painting area. The prediction of the accurate welding material quantity and the estimation of the stock are used as crucial criteria for estimating the man-hour and the cost of the production plan and process on the yard, and are regarded as core techniques for judging the precision level of the yard. Currently, most yards just approximate the welding material quantity using the simple formula or the empirical values of the standard ship.

The welding material quantity can be accurately calculated only if all the block modelings and assembly drawings are completed. Although these drawings are usually completed around two weeks before S/C in the design department, they are required three months before S/C by the production planning department for budget, contract, and material ordering (see Fig. 7). One way of resolving this disagreement is to use an automatic calculation program proposed in this study.

In this chapter, the process of converting the calculated welding length to the welding material quantity will be described in detail. Every welding line is assigned by a corresponding welding symbol, and the designers must follow their experience and the internal standards of the yard. Table 2 shows the representative welding shapes of butt and fillet, which are mainly used in yards, and the codes for various welding shapes and types. The butt codes represent the welding method and the sectional shape of the weld zone. On the other hand, the fillet codes consist of P (partial) or F (full), the number of welding surfaces (1, 2), and the name of the welding surface (F, A, B).

Each weld zone assigned a welding code has a deposition volume and weight per unit length, which can be used to calculate the welding material quantity. The calculation formulae for the welding material quantity used in the developed system are arranged in Table 3 and Table 4. The Greek letters (α, β, γ, ω) are constants that are generally determined by the classification of technical rules and regulations,

Table 2
Welding types and codes.

Type	Welding shape	Code	Type	Welding shape	Code
Butt		CV	B		VF VA VB
		CJ	Fillet		CZ
		FV			P1F P1A P1B
		AI			P2F P2A P2B
		AY			F1F F1A F1B
		AX			F2F F2A F2B

and that are subject to change based on the welding equipment possessed, yard's standards, or a demand of ship owners.

To build a perfect automatic calculation system, a welding code must be automatically assigned to every welding length, but it is difficult to generalize them due to the type of equipment possessed and used by each company. The systems of this study are presented in a table for the users' easy selection, but additional research on the automatic code assignment is necessary.

6. Development environment

To estimate welding material quantity by this study, DBs for hull structure, such as OGDB, CGDB, and PLDB, are needed through the modeling of Tribon M3 and AM 12.0

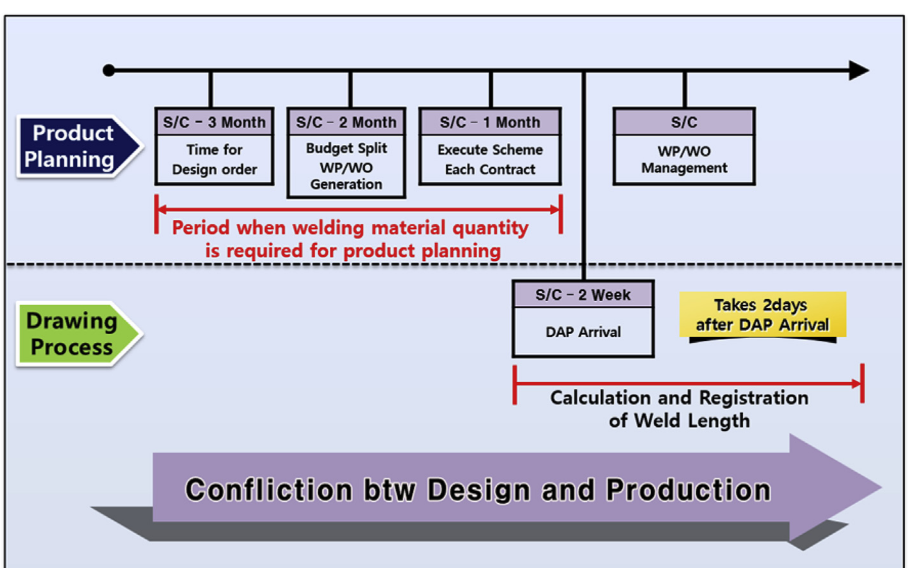

Fig. 7. Confliction between the design and production planning wrt welding material quantity.

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Table 3
Material weight calculation formula for butt joints.

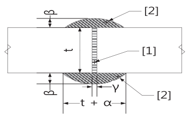
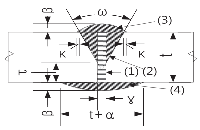
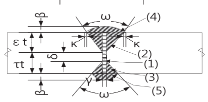
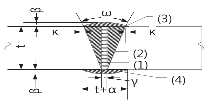
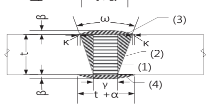
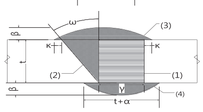
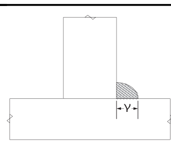
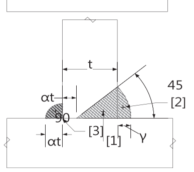
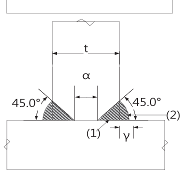
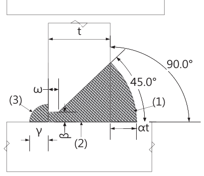
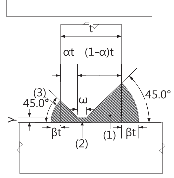
Type	Welding shape	Material weight
AI		$[1]=\gamma t[2]=\frac{2}{3}\beta(t+\alpha)\mathrm{Vol.}=[1]+[2]\times 2\mathrm{Wgt.}=\mathrm{Vol.}\times\rho$
AY		$[1]=\gamma t[2]=\frac{1}{2}\left[(t-\tau)^2\tan\frac{\omega}{2}\right][3]=\frac{2\beta}{3}\left[2(t-\tau)\tan\frac{\omega}{2}+\gamma+2\kappa\right][4]=\frac{2}{3}\beta(t+\alpha)\mathrm{Vol.}=[1]+[2]\times 2+[3]+[4]$ $\mathrm{Wgt.}=\mathrm{Vol.}\times\rho$
AX		$[1]=\gamma t[2]=\frac{1}{2}(\varepsilon t)^2\tan\frac{\omega}{2}[3]=\frac{1}{2}(\tau t-\delta)^2\tan\frac{\omega}{2}[4]=\frac{2\beta}{3}\left[2(\varepsilon t)\tan\frac{\omega}{2}+\gamma+2\kappa\right][5]=\frac{2\beta}{3}\left[2(\tau t-\delta)\tan\frac{\omega}{2}+\gamma\right]$ $\mathrm{Vol.}=[1]+([2]+[3])\times 2+[4]+[5]\mathrm{Wgt.}=\mathrm{Vol.}\times\rho$
FV		$[1]=\gamma t[2]=\frac{1}{2}t^2\tan\frac{\omega}{2}[3]=\frac{2\beta}{3}\left[2(t)\tan\frac{\omega}{2}+\gamma+2\kappa\right][4]=\frac{2\beta}{3}(t+\alpha)\mathrm{Vol.}=[1]+[2]\times 2+[3]+[4]$ $\mathrm{Wgt.}=\mathrm{Vol.}\times\rho$
CV		$[1]=\gamma t[2]=\frac{1}{2}t^2\tan\frac{\omega}{2}[3]=\frac{2\beta}{3}\left[2(t)\tan\frac{\omega}{2}+\gamma+2\kappa\right][4]=\frac{2\beta}{3}(t+\alpha)\mathrm{Vol.}=[1]+[2]\times 2+[3]+[4]$ $\mathrm{Wgt.}=\mathrm{Vol.}\times\rho$
CJ		$[1]=\gamma t[2]=\frac{1}{2}t^2\tan\omega[3]=\frac{2\beta}{3}[(t)\tan\omega+\gamma+2\kappa][4]=\frac{2\beta}{3}(t+\alpha)\mathrm{Vol.}=[1]+[2]+[3]+[4]\mathrm{Wgt.}=\mathrm{Vol.}\times\rho$

Table 4
Material weight calculation formula for fillet joints.

Type	Welding shape	Material weight
TYP		$\mathrm{Vol.}=\frac{\pi\gamma^2}{4}\mathrm{Wgt.}=\mathrm{Vol.}\times\rho$
P1		$[1]+[2]=\frac{\pi}{8}[(1-\alpha)t+\gamma]^2[3]=0.25\pi(\alpha t)^2\mathrm{Vol.}=[1]+[2]+[3]\mathrm{Wgt.}=\mathrm{Vol.}\times\rho$
P2		$[1]+[2]=\frac{\pi}{8}[(t-\alpha)/2+\gamma]^2\mathrm{Vol.}=([1]+[2])\times 2\mathrm{Wgt.}=\mathrm{Vol.}\times\rho$
F1		$[1]+[2]=\frac{\pi}{8}t^2(1+\alpha)^2+\frac{1}{2}\beta\omega[3]=0.25\pi\gamma^2\mathrm{Vol.}=[1]+[2]+[3]\mathrm{Wgt.}=\mathrm{Vol.}\times\rho$
F2		$[1]=\frac{\pi}{8}[(1-\alpha+\beta)t]^2[2]=\frac{1}{2}\gamma\omega[3]=\frac{\pi}{8}[(\alpha+\beta)t]^2\mathrm{Vol.}=[1]+[2]+[3]\mathrm{Wgt.}=\mathrm{Vol.}\times\rho$

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(www.aveva.com). Python 2.6 (Lee, 2005) was used to extract the related information. Furthermore, OpenGL API (Richard and Wright, 1996) in the Microsoft Visual Studio 6.0 development environment, object modeling of all hull panels and reinforcements, and the Object-Oriented Programming (OOP) concepts for the definition of the welding properties were used.

7. Conclusions

This paper discusses the various features needed for a system to automatically calculate the welding length and welding material quantity using the member shapes and various production properties when the modeling of a hull or offshore structure has progressed to some degree. As design and production planning are carried by separate departments, efforts must be exerted to build perfectly compatible information, and the calculation of the welding length and welding material quantity can be a representative example of achieving high productivity and improving the problems related to the non-compatibility between design and production. The elements required for this system can be summarized as follows:

(1) Plug-in module through the customized CAD system for ship design and production (including the member shape, production information, and block assembly hierarchy diagram)
(2) Extraction of the joint length considering the production of the weld parts
(3) Base plate selecting and changing module
(4) Unusual members and duplicate check monitoring module
(5) Calculation of the welding material quantity for turnover work
(6) Classification of the joint length based on various criteria (stage, posture, etc.)
(7) View module through 3D Graphic Library and various convenience features
(8) Manual work features, including manual input and separation of welding lengths
(9) Calculation of the block welding material quantity for outside work separated from in shop work
(10) Assignment of welding code and welding material quantity

The present system requires the intervention of the user in two aspects: the selecting of the welding posture and the assignment of a welding code for the estimation of the welding material quantity. Further studies will investigate the construction of a rule-based system with yard's regulations and standards to minimize the additional work by the users.

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