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COMMITTEE V.3

MATERIALS AND FABRICATION TECHNOLOGY

COMMITTEE MANDATE

The committee shall give an overview about new developments in the field of ship and offshore materials and fabrication techniques with focus on trends which are highly relevant for practical applications in the industry in the recent and coming years. Particular emphasis shall be given to the impact of welding and corrosion protection techniques on structural performance, on the development of lighter structures and on computer and IT technologies and tools, which are meant to link design and production tools and to support efficient production.

CONTRIBUTERS

Official Discusser: Sang-Beom Shin, *Korea*

Floor Discussers: Robert A. Sielski, *USA*

Reply by Committee:

Chairman: J.-D. Caprace, *Belgium*
B. Mishra, *USA*
F. Pires, *Brazil*
F. Roland, *Germany*
I. Schipperen, *The Netherlands*
J. Andric, *Croatia*
L. Li, *China*
N. Osawa, *Japan*
P. Lindstrom, *Norway*
R. Doig, *Peru*
H. Remes, *Finland*
M.H. Kim, *South Korea*

CONTENTS

1. DISCUSSION

1.1 Official Discussion by Sang-Beom Shin

1.1.1 Introduction

This document deals with the review on the document of ISSC Committee V.3 "Materials and Fabrication technology". As described in the committee document, the recent development in materials and fabrications technology of the shipbuilding and offshore technology are mainly described. The main topics in the report are as follows

- Worldwide trends in materials and fabrication methods
- Developments in metallic and non-metallic structural materials
- Advances in fabrication and joining technologies
- Innovative development about corrosion protection systems
- Application of production simulation and virtual reality to improve the production management of ship and offshore structures.

In addition, an experimental results of benchmark for establishing "a Best Practice Guideline for Computational Welding Mechanics Tools (CWM) in Shipbuilding and Offshore Industry.

1.1.2 Review

– *Worldwide trends in materials and fabrication methods*

In ISSC2015-V.3 document, the trends in material and fabrication methods were described on the basis of the investigation results regarding the market trends in shipbuilding and offshore industry. That is, the research programs performed in each key region including China, Korea, Japan, Europe, Brazil and USA were described with the commercial shipbuilding activities, the global investment in new building market and the market forci in key regions of the world maritime industry. So, it makes help us to understand and predict the technology development trend in the world maritime industry.

Typo
In 2.2.6, modelling → **modeling**

– *Developments in metallic and non-metallic structural materials*

For metallic materials, the outline regarding the application of lightweight materials such as aluminum alloys, sandwich plate with foam and honeycomb and titanium was described very well. However, the application of the various cryogenic materials including 9% Ni steel, AL5082, SUS304L and High Steel were introduced briefly and some revisions or the supplementary explanation shall be required as follows.

1. Application examples of 9% Ni steel to LNG storage system to be added.
   - Adriatic LNG Terminal for offshore structure (Exxon Mobil)
   - KOGAS is building a LNG storage tank with the storage capacity 270,000 m^3 at Samcheok receiv ing terminal in South Korea
2. The detail explanation of the 6% Ni steel to be added
   - 6% Ni steel (??) → 6–7% Ni steel
   - New technology for enhancing the good mechanical properties of 6–7% Ni steel at cryogenic tem perature to be added
   - The information on the application of 7% Ni steel to OSAKA LNG to be added
3. In 3.1.4.3, the paragraph of "High manganese steel can be welded better than stainless steel making it easier to manufacture storage tanks" shall be removed. It is because the further researches shall be required to confirm the weldability of high manganese steel. In addition, the problem raised by fume (High Manganese) during welding of high manganese steel is on-going issues.

Meanwhile, for non-metallic materials, with the advantages of application of the composite materials to the shipbuilding, the relevant codes for their application are manifestly introduced.

Typo
In 3.1, aluminum allows → aluminum **alloys**
In 3.1.1, The traditionally excepted operational and performance → The traditionally expected operational and performance
In 3.1.4.3 High manganese alloy steel → High manganese steel

– *Joining & Fabrication Technology*

✓ *Advances in Joining Technologies*

In the report, the trends in welding automation are properly summarized. Most technologies described in the report have been already applied in shipbuilding and offshore industry and will soon be stabilized and spread in consideration of their needs and expectation effects. Especially Hybrid welding technology will be evolved into more various application and contribute to increase the productivity and the quality in offshore industry before long. Meanwhile, although there have been significant technical advances in FSW over recent years, the problems related to low productivity, high investment cost and limitation of joint thickness are still remain. That is, the additional technical solutions shall be established to apply FSW to shipbuilding and offshore industry.

✓ *Innovations in Fabrications*

The development of automatic line heating system for forming the curved hull plate has been one of issues in shipbuilding industry. In the report, many results of the researches related to the plate heating have been introduced. However, most papers introduced in the report focused on the explanation of heating phenomenon by FEA. Actually, considering various technologies such as the development of curved plate, the heating pattern for double curved hull plate and so on are required to develop the automatic line heating system, the report may need to amplify this point.

The other issues including post-treatment of welded joints and plate edges, hybrid structures and joints, influence of production quality on strength and dimension and quality control are clearly stated in the report.

– *Corrosion and Protection*

In 5.2.1 of the report, the aluminum sacrificial anodes were recommended as the considered alternatives for Zinc anodes. However, according to DNV RP-B101 (6.12.4), the application of aluminum anode to the ballast tank is limited due to the explosion. So, the phrase shall be modified.

Typo and Amendments
In 5.2.2, purifiedor → **purified or**
In 5.2.2, FePO4. FE2O3 → **$FePO_4$, Fe_2O_3**
In 5.2.7," Hull made from special steels designed for optimum strength at low temperatures Air bubbling systems to assist ice-breaking. "→ Hull made from special steels designed for optimum strength at low temperatures**. Air bubbling systems has been adopted to help ice breaking**
In 5.2.7, Extra thick steel is used at the bow, the stern and at the waterline. → Extra thick steel is used at the bow, the stern and at the waterline. **This region is called an ice belt zone which has led to occasionally direct collision with ice**
In 5.2.5, With an upgrade to Polar Class 4 for its classification it will be able to operate in 1st year ice up to 2m thick. → **With an upgrade to Polar Class 4 referred to as "Ice Class", it will be able to navigate in year-round operation in thick first-year ice which may include old ice inclusions (IACS2011)**

– *Manufacturing Simulation*

In chapter 6 of the report, ERP system was only mentioned as the manufacturing system for shipbuilding. However, considering the characteristics of shipbuilding industry such as long life cycle for the manufacturing process and various process management system in the relevant production departments, supply chain management (SCM) system and manufacturing executive system (MES) shall be mentioned as follows.

Amendments

In 6. However, Enterprise Resource Planning (ERP) systems have been developed for shipbuilding and are currently playing a major role in optimizing resources in a shipyard's supply chain, value chain and information chain. → However, Enterprise Resource Planning (ERP) systems, **Supply Chain Management (SCM) systems and Manufacturing Executive System (MES)** have been developed for shipbuilding and are currently playing a major role in optimizing resources in a shipyard's supply chain, value chain and information chain.

– *Welding Simulations*

The issues related to welding simulation are clearly stated in the report.

1.1.3 Summary

ISSC2015 V.3 report clearly stated the issues related to "Materials and Fabrication technology". However, in some parts, the relevant papers are just enumerated. If more detail analyses of new technologies are added. It will be helpful to enhance understanding of engineers in shipbuilding and offshore industry. In addition, typos found in the report shall be corrected by spell checker.

1.2 Floor and Written Discussions

1.2.1 Robert A. Sielski

Question 1
In section 2.2. on the report, the research in fabrication and materials conducted in some countries is reviewed. However, in reviewing the research conducted in the United States, the work of the National Shipbuilding Research Program is not discussed. Is there some reason that the committee considers the work of the NSRP to be irrelevant?

Question 2
To make lifecycle evaluation of ship and offshore structures, the rate of corrosion in the future is based on historical data on corrosion rates that have been observed on different structures in the past. The committee has reviewed the recent progress that has occurred in the prevention or minimisation of corrosion. Can the committee make any recommendation on corrosion rates that should be used for lifecycle analysis of future structures?

Question 3
To analyse structural details for fatigue crack initiation, the residual stress needs to be accounted for. Residual stress measurement by traditional means are not capable of measuring the highest stresses that occur in and near welds. It would seem that computational welds mechanics could provide the stresses that are sought. However, the example sited by the committee used about 130 000 elements to model a simple butt weld. Is the technology mature enough today to analyse the typical structural details used in ship structure?

2. REPLY BY COMMITTEE

2.1 Reply to the Official Discusser

– *Worldwide trends in materials and fabrication methods*

It is appreciated that the Official Discusser find this chapter informative to understand the context and focus areas of technical developments described in the following chapters. Moreover we thank the Official Discusser for the typos.

– *Developments in metallic and non-metallic structural materials*

The 6% Ni steel refers to the work of Furuya et al. for the development and the evaluation of the mechanical properties of 6% Ni steel under low temperature. The new 7% nickel steel have been developed and evaluated by Takahiro et al. They have enhanced mechanical properties of the 7% nickel steel through the adjustment of chemical compositions and TMCP (Thermo-Mechanical Controlled Process). It was dem-

onstrated that the new 7% nickel steel has excellent mechanical properties under cryogenic temperature equivalent to those of 9% nickel steel.

In 2012, newly developed 7% nickel steel was used to construct a new LNG storage tank with tank capacity of 230,000 m3 in Senboku LNG terminal built by OSAKA GAS. Seven percent nickel steel has been used for the Japanese LNG storage tank in Senboku LNG terminal in 2013.

Regarding the weldability issue of high manganese steel, the comment of Oficial Discusser is correct and the following sentence needs to be removed: "High manganese steel can be welded better than stainless steel making it easier to manufacture storage tanks". Moreover we suggest to change the following sentence of the original report: "However, application of high manganese steel have problems associated with *welding fume, lack of weldability and the risk of weld metal cracking*. In this respect, many JDP project which evaluate the mechanical properties and weldability under cryogenic temperature is now under way."

– *Joining & Fabrication Technology*

  - *Advances in Joining Technologies*

Committee agrees with the Oficial Discusser comment that Hybrid Laser Beam Welding (HLBW) will be evolved into more applications. However, it is not sure if hybrid welding is the right techniques for "thick" offshore structures, as it would require high laser power. In Europe, hybrid welding is primarily seen as a means to reduce welding distortion and improve quality of thin sheet (t<6mm) structures. For offshore, other technologies including Electron Beam might be more favourable.

We confirm the assessment of the OD on FSW based on e.g. the just completed European research in the HILDA and MOSAIC projects. The FSW technology is well established for aluminium and has a high potential for highly loaded parts and material mixtures in steel, including offshore. The understanding of critical quality factors and the limits of the technology has significantly improved. However, the tool for FSW of steel remains an unsolved challenge both for productivity and cost and for the reliability of the process.

  - *Bending and line heating*

Various investigations on control aspects of automated line heating have been performed in the past, both in Asia and Europe. In Europe, the practical application is still limited due to two main reasons:

1) A limited throughput of double curved plates in the shipyard favors outsourcing of that work rather than expensive investments and thus, mechanical forming is often traditionally preferred in Europe.
2) Even though technology is developing and e.g. lasers are used for forming in other industries, automatic line heating is therefore seen to have limited potentials due to high cost and low robustness, at least in Europe.

Therefore, the recent research in this field takes place in Asia. The research focus seems to be in the modelling and prediction of line heating, which is the first fundamental step for automatic line heating system. It is agreed that in future this research should cover also other issues such as various technologies and the heating pattern for double curved hull plate.

  - *Corrosion protection*

The Official Discusser comments about typos and sentence structure are appreciated.

  - *Manufacturing Simulation*

Indeed, the chapter title may be a bit misleading, as simulation can be used for a variety of purposes in shipbuilding. The focus of our chapter however was on production flow simulation, which is frequently used for factory and investment planning, scheduling and resource planning in the context of other tools (rarely as a stand alone solution). It is absolutely agreed, that similar techniques can be used for (Enterprise Ressource Planning – ERP), but also supply chain management and manufacturing executive systems and a variety of research on this issue is available.

There are a couple of reasons we did not investigate those applications in more detail in our report:

- There is a wide variety on research on the issue, also in the - related - context of Virtual Reality technologies, internet of things, etc. As the focus of the report in our opinion are on manufacturing technologies with an impact to structural performance (the focus of the Congress), we did not go deeper into this analysis.

- In practical terms, shipyards are using an almost endless variety of tool combinations and procedures for ERP, SCM and MES. Very limited information is available on best practice in the public domain and solutions are highly different depending on type of product, size of shipyards and its preferences. Moreover, research outcomes are often rather far from real practical applications. We therefore decided not to dig deeper into this matter.

2.2 Reply to the Floor and Written Discussions

2.2.1 Robert A. Sielski

– *Question 1 – Research conducted in the National Shipbuilding Research Program*

Thank you very much for your valuable comment. The National Shipbuilding Research Program (http://www.nsrp.org/) co-funded by the United States Shipbuilding Industry and United States Navy has definitively not be omitted voluntary. However, the outcome of the various projects is difficult to analyse as there are no public detailed technical reports and publications. We absolutely agree that this program is relevant for this committee. We suggest a deeper analysis of the outcomes of NSRP in the next Congress.

– *Question 2 – Recommendation on corrosion rates*

It is difficult for the committee to make any quantitative recommendations on corrosion rates to be used for lifecycle analysis of future structures. This is mainly because these data are generally the property of shipowners and Classification Societies. Therefore, it is extremely difficults to find scientific publications that provide these data. Anyway, the committee decided to don't further investigate this direction during that term. A deeper analysis of this topic could be an intresting subject for the new Congress.

– *Question 3 – Is the CWM mature enough today to analyse the structural details?*

The members of the committee definitively agree that the 3D Computation Welding Mechanic simulations are going to be soon mature enough to analyse typical structural details of ship structures. However, the analysis of big structures such as a ship block or even entire ships cannot yet be simulated directly with 3D techniques. Other approaches involving Local-Global methods are currently under developments. Theses methods relates on a local 3D approach for the precise modelling of the physical phenomena induced by welding. Then, the results are transferred in a macroelement which is used in a global shell model for calculating distortions.