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COMMITTEE V.3

MATERIALS AND FABRICATION TECHNOLOGY

COMMITTEE MANDATE

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

CONTRIBUTORS

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1 DISCUSSION

1.1 *Official Discussion by Anto Tusun*

1.1.1 Introduction

As it was mandated the report contains an overview of new developments in field of ship and offshore materials and fabrication techniques written in clear and understandable form. Review of new trends in material and fabrication methods worldwide was done with reflection to the effects of global economic crisis and the recovery period from year 2010 onwards. Fabrication technology has focused on welding thick steel, aluminium and corrosion protection techniques. Significant part of report has been reserved for composite materials and its potential for practical applications and still with some actual obstacles for wider application. Standards comparison has pointed out some differences and evidently some points that are causing confusion with interpretations by surveyors and shipyards. At the end of the report, most important topic was reviewed; the issue of linking design and production, through computer applications with a goal to increase efficiency.

1.1.2 New Trends in Material and Fabrication Methods

World

Current state of world market is showing signs of recovery, but the effects of crisis will be still visible for some time, therefore it is very important to point out some issues.

The report has mentioned for most shipyards very unfavorable position with great number of deliveries and just a few new orders. But still, those shipyards must consider themselves very lucky, when compared with situation of no job at all. From one side we have to keep production operation at highest possible level to achieve deliveries deadlines, and on the other side have to maintain preproduction activities in top form with no challenges, new orders. With that respect it is obvious that the positive approach is to try to find new and innovative products and to try to find some more reserves and possibilities inside companies by applying new methods. Yards are looking for new opportunities and trying to adjust their technology in order to compensate for new requests. Probably it can be investigated that each company has unique reaction time in which it can adjust itself to new requests, also we can say that larger companies have shorter reaction time, and the reason is that they invest more effort in innovative technologies, but there are still opportunities for smaller companies, since they can transform themselves faster.

Second issue that needs to be addressed is market disturbances caused by national interventions in order to keep strategic status for their own shipbuilding industry. It is obvious that interventions of this kind do not help recovering from economic crisis and we have false sense of market competition. Market share shifts and changes are partly related to this issue.

For each shipyard we can say “you are what you build”, and your size and location are key parameters when discussing production technology. In short, European yards sophistication for wide range of complex ships and Asian productivity through mass production lead to two different approaches toward innovative technology methods.

Asia

Japans record production of 20 million GT in year 2010 is very significant as a great pressure on shipbuilding industry to try to compensate lack of new orders.

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The report has mentioned that one of goals is better ship building accuracy. That is to be achieved by application of laser cutting, 3-D measurements, deformation simulations and by better block division. This is clear example how to find some more reserves inside company, and effect of this is not only related to hull production. The word simulation is used in context of welding distortion prediction, but it can be used in context of improvements in block splitting.

The real power of world largest Korean shipyards can be seen in actual development areas of distortion control, welding automation, welding equipment and plate forming. But market share changes are forcing change of direction toward technically complex ships, and above-mentioned power will be surely used to developments in area of green ships and green energy.

Expansion since year 2000 has evolved into respectable 185 million DWT in year 2010, the expansion has changed market share in Chinas favor. Recent information's about wages, steel prices are pointers that situation will develop in direction of expansion slowdown.

Europe

The sustainable growth has yielded with better business results with stabile capacity. What is most important there is respectable orientation toward innovative technology and innovative ships. Scarce natural resources are pushing Europe toward sophisticated ships.

America

Brazil's great reserves of oil and gas are economy booster, emerging but closed market, with shipbuilding of strategic importance. In some way as China, in last 10 years the capacity has increased, but not fully supported to last, what can be seen through fact that they need to come to the level of development to recognize that they need orientation toward innovation.

1.1.3 Fabrication Technology

Discussion about fabrication technology in recent years has become related to reacting to changing requirements and demands, which are reflected to fabrication technology fields like welding and corrosion protection. On one side fabricator needs to develop, prepare, approve and efficiently use welding technology for new material type or range; for new requirements on force by Contract and sometimes new production standard when switching between shipbuilding and offshore production. On the other side growing ecological awareness has been reflected in rising level of acceptable primary and secondary surface preparation for painting process for wet spaces. Moreover, we are experiencing rising requirements for dry spaces also.

In short, in order to accept new materials you need to invest and develop, and in area of surface preparation you need to find opportunities where to reduce rising production costs.

Welding Thick Steel

It can be discussed why we see rise of usage of thick steels, but again we come back to differences in approach for shipyards around the world "you are what you build". For Asian part we can see developments related to the container ships, LNG carriers. But it must be pointed out that usage of thick steel is also related to the special applications on sophisticated ships, since most of them have certain parts of ship construction heavily stressed and therefore it is necessary to make decision to use thick high tensile steels.

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Welding Extreme Thick Plates Report starts with three important areas of investigation; brittle crack initiation, propagation and NDT technology. It is necessary to point out that there are some other important aspect, like joint preparations and welding technology with preheating and post weld heat treatment, that are very important factors to complete picture of welding extremely thick plates. Let us mention that on sophisticated vessels these plates are often related to functions that are requiring strict tolerances for dimensions, so we need to consider that the aspect of deformations and shrinkages are also involved.

Nevertheless, it can be seen that differences and challenges are recognized and development is being done in area of investigation of brittle crack propagation arrest, mentioned new method for brittle crack arrest toughness. It is also stated in report that crack initiation mechanism is closely related to imperfections in welded joint, so they need to be addressed in combination. Extensive effort and developments in this field include advanced FEM analysis for prediction of residual stresses, usage of new materials and testing procedures.

Thickness Effect to Fatigue Strength Fatigue strength investigations and developments for thick plates are showing progress toward better understanding of what lay behind its mechanism, and it is good to see that some of new discoveries are becoming part of current rules and regulations. Good engineering practice to keep asking questions will help clear out areas where we use some assumptions based on small number of samples.

Special attention has been paid to the FCA steels, and UIT method. Both of them are examples of engineering answers to problem, loss of fatigue strength when welding thick steel, on their unique way; Fatigue Crack Arrestor steel and Ultrasonic Impact Treatment method.

Welding Aluminium

Aluminium, with its all advantages and disadvantages with respect to the steel is very well known material, but it can be seen that there is still lot of effort needed to change present state of welding technology, full introduction of friction stir welding method, FSW.

Corrosion Protection Techniques

In terms of corrosion protection techniques described in report we can see engineering approach to the subject; understand, apply and analyze in order to confirm and improve. Understanding the subject as always proves to be difficult taking into consideration different materials used and influences that paint is subjected to. In recent years we are witnessing to diversity of paint systems applied to the ship and offshore structures, and it is very important to know to estimate and predict its long term condition.

Corrosion Behaviour This subject starts with aluminium, material which in general isn't so much related to corrosion, but has one important issue to be respected, that is stress corrosion cracking. All developments in that area will find application easily. Usage of titan and super austenitic steels in diesel engine exhaust system is good example of development when corrosion issue is solved by application of material with superior corrosion resistance, but actual application involves also some usual production difficulties. Erosion corrosion proves to have real difference from regular corrosion in certain conditions; therefore reaction was to search for material with natural higher tolerance to wear and corrosion, like elastomeric composite materials.

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Corrosion Protection IMO's PSPC – Performance Standard for Protective Coatings can be described like standard that has made significant impact to shipbuilding production. Report explains fundamental requirement for NaCl in primary and secondary surface preparation, but let us keep in mind some other like relative humidity and temperature. It is mentioned that sum of all requirements has resulted in increased costs, but that in small extent, cause most shipyard has already moved step forward and set a goal that paintworks must be done in controlled conditions friendly toward workforce and to the nature.

But cost have risen because of other requirements, like increased level of inspections, introduction of certified coating inspectors (CI), and above all requirement of allowable percent of paint damage after painting, less than 2%, $25\,m^2$ maximum area, excluding erection joints.

That requirement has to be incorporated into Inspection schedule and has putted additional pressure to outfitting, steel preparation and pressure testing altogether. For some instances even block splitting was subjected to some changes in order to have ballast spaces as completed as possible before final assembly take place.

Further developments, like air mixed high pressure water blasting, on field of primary surface preparation will find their application in future, because it is connected to waste reduction and better working condition, but it still must match abrasive application.

Flush rust and surface roughness investigation are making insight toward real boundaries for requirements for paint application on surface and therefore must have deserved attention. Like mentioned before, we need to keep asking questions and finding answers, this is the way to improvements.

The development of new innovative highly efficient anticorrosion paint systems is underway, and self-healing coatings are things to come. But technologies like thermal spray coating and direct metal deposition are technology of today and have potential for further development. Thermal spray coating, coming to shipbuilding and offshore industry from civil construction applications, must be mentioned for its application for sacrificial anodes and barrier coatings.

Corrosion Analysis Theoretical and practical achievements in this field are important in order to correct the way for further developments. Efforts in developments of Structural Health Monitoring system will help to gather more information about the subject from actual ships.

1.1.4 Composite Materials and their Practical Application

Composite materials in their real wide sense are materials of future, but their way into real-world applications is rough, at least for commercial applications, even if we have in mind their supreme corrosion resistance, light weight, freedom of shape and other advantages. For sake of introduction there are some disadvantages like high initial price and fire safety issues.

Fire safety issues, SOLAS rulers, are most important obstacle for composite material wider application, so this is most important filed of investigation when composites are concerned. But there are some other investigations related to strength under different conditions, and usage of composite materials for repair of steel constructions, especially in events that is not allowed to use hot methods of repair.

We still need some more time collect real-world data regarding usage of composite material before we start optimizing design.

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Recycling is important aspect of composite material, and therefore development has been done to find and optimize method for scrapping composite material and to maximize its reuse.

Hybrid composite materials like metal sandwich panels are finding their way into industry for decks, balconies, stair and hatch covers. Real advance will be to come to the level that composite material can be used as a part of global strength, which development is left to the future.

1.1.5 Standards

Production standards have their important role for many aspects of ship functions and behaviour during its service life. The fact is also that during ship construction we are facing inevitable imperfections that are controlled under standards like IACS, JSQS, CSBC, VSM or IRCN.

In some occasions company must for one product follow one production standard, and for the other different one, as part of Owner request. There is no big or fundamental difference between them but still some differences exists.

The nature of standards is that they are collection of rules and regulations that have been collected from ships in service. In general this system works, but when we are dealing with some specific issues it comes out that standards are simple and do not take into consideration some important factors.

Example of fatigue cracks and its influencing factors show us good correlation with standards in issues, like production tolerances, alignments and shape of welded joint. But, because of the nature of the standards presented before, there are some aspect that can be improved; like usage of high tensile steels.

Experience shows us that in some situations we have mix of requirements from production standard, general tolerances and special demands for accuracy on production drawing, what can be confusing.

Measurements techniques are becoming more and more advanced, possibilities to measure and present the measurements are endless, but we still see no sign of them inside production standards.

Standard Comparison

Standard comparison has pointed out several important aspects and several different views to the subject. In this report we can find elaborated issues like distance between welds, fairness of frames and deviation of rudder from centreline.

Distance between Welds This aspect of production standard comparison is most confusing, so it deserves first position, since some standards do not have this limitation at all.

There are lot of examples where we come across with this requirement, and one of them is interference between structural welds and flush container foundations on container ship. A lot of effort has to be paid so that all fit in requirements, by adjusting block division, by development of full ship accuracy measurements for container foundations close to the structural welds.

In some other examples some simple solutions become complicated since one requirement leads to another and final arrangement can be described as complex.

It is good to see that there are efforts to change this limitation since materials are constantly developing as well as welding.

Fairness of Frames Fairness of the frames on car carrier is good example where we see that requirements are not refined to take into account all instances that can happen in the real world. Distortion of primary supporting members like deck girders is one instance where we have very long slick structural element which is very hard to keep in required tolerance, but its function is not in question.

Another instance are liftable deck guides at the ship sides, heavy web frames with great height, more than adequate for structure reasons and for functional reasons with very well proven system of connection between liftable decks and the web frame.

In this case also is good to see that there are efforts to change inadequate requirements.

Deviation of Rudder from Centreline Discussion about this requirement can start with 8 mm required, but can also start with mentioning all influences to the accuracy. Doesn't matter are you big or small shipyard, you are facing the same problem, how to assemble key elements of propulsion and steering system in required tolerances, in workshop or at the building position.

You need to incorporate some finished elements into functional system and your situation becomes more complicated if instead of rudder you have nozzle and propeller working inside, and you try to reduce amount of machining on site. The only way is to start from this point as a reference point, to do all necessary arrangements with rest of elements in steering and propulsion system. The effort has to be well supported by measurements during all construction phases. In that case the required 8 mm can be satisfied, but for good reason.

1.1.6 Linking Design and Production in Computer Applications for Increased Efficiency

Engineering efforts to perfect the design are reflected in paradigm Design for X. Design for production is most known, but just one of important factors that can be used as X, with Manufacturing, Assembly, Cost, Simplicity, Maintenance, Environment, Safety, Life cycle cost, robustness or Six sigma etc..

When we think about the Design we must understand that it is like iceberg, most of it is hidden from the eyes in first sight, we must be aware of all factors. Like report states; challenge of the future is to incorporate simultaneously as much factors as possible.

We need to take into consideration that world is rapidly changing so its markets also experiencing changes. The decision which factor will prevail needs to be done on basis of solid facts.

Design for Production and Design for Manufacturing (DFP)

Productibility as a design attribute has been pointed out, since ship must be manufactured and assembled efficiently on basis of adequate design. It is very well-known engineering fact that good decision or change in early design stage can save a lot of effort and reduce cost in production stage.

Designs have to promote simplicity and they have to be adjusted to production facilities capabilities. If we take simplicity for start we can make connection to ease of production, standardization and modularization.

Ease of production have to be considered with due respect like the report has elaborated. Flat versus curved where ever applicable; reduce extremes in thicknesses; when using thin plates have in mind work that needs to be done to make them fulfil required tolerances; make good sense when designing plating with different thicknesses; force automatic welding; use symmetry; optimize welding.

Standardization is very old tool to make things less complicated and a tool to make things easily producible. Modularity where ever possible to be able to separately create some parts of project in order to reduce production costs.

Computer Applications

Computer integrated manufacturing represents integration of parts of business process that can offer possibility to increase productivity. Computer aided design, Computer aided manufacturing are basic parts that in basic used to translate engineering idea and requirements into usable data. Product data management is needed to be able to efficiently use vast amount of data. Enterprise resource planning, Computer aided process planning are tools for planning the project execution. And at the end power of today computers has to be transferred into applications able to help us make predictions and decide applicable strategies.

Difficulties to Link Design and Production Abovementioned vast amount of data still represent problem, since it is generated by applications that are self-oriented, like report states, no interoperability. It seems unimaginable that we still need to do compatibility by manual work, but it is a fact and a position for improvement. In all shipyards we can find mixture of applications from different sources starting with small applications related to the specific calculations in early design stage, toward to CAD solutions that shipyards use internally, and CAD solutions that are forces to use to exchange information's with outside word.

One other view to the subject of was amount of data is from perspective of initial design, detail design, engineering technology and production data. All is connected but not all is necessary for each stage. The basis is the same, but time of data generation is different.

Let us mention sensitivity to changes, how system reacts on changes, is it easy or hard to see effect of changes to product that we design. Some changes are unwanted errors but some changes can have different reasons, like improvements or additional functions. System must be able to handle changes of any reason, and we know that it is not always easy.

Examples like Digimaus and 3-D catalogue are applications trying to deal with mentioned difficulties, like in-house solutions.

Linking CAD/CAM to Production CAD/CAM because of its characteristics has become standard, modern shipbuilding already work with 3-D CAD models prepared for CAM use. Approaches are different depending of shipyard history and ability to adapt to modern trends. Goal is to reduce time to product, make production efficient and reduce costs. The fact is also that simulations are not the standard and that all parts of design process iterations are not covered by simulation but just some parts of it.

Application of simulations are endless cause 3-D model for the ship is already present, so the real work has to be done to prepare model of production of other parts of process that needs to be simulated. Linking data to simulations and retrieving simulations results back to the design is part of mentioned vast amount of data that needs to be handled in real time.

Optimization of Schedule, Flow and Resources Shipbuilding operations are complex and are asking lot of work in planning and scheduling. In that respect computers

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are enabling us today to be more efficient when planning and modern concepts like linear programming, concurrent engineering, critical path method, program evaluation and review techniques, discrete event simulation and enterprise resource planning are helping to integrate all important factors when planning.

To have an overview of project with all its aspects, to be able to optimize and forecast, simulate some scenarios means that you have more confidence in meeting the deadlines.

Simulation model of production facilities is important part, but unfortunately amount of work needed for usable model is a task fit for larger shipyards with specialists appointed to the task.

Simplified methods are widely used, scheduling with optimisation, or by using PERT methodology, or combination of linear programming and optimisation algorithms to solve scheduling issues. They are not so expensive and easier to maintain then expensive discrete event simulations.

To be able to simulate influence of product characteristics from earliest design time we must have usable information's to apply them on positions where we do not have exact data, because of early project stage. That usable information's can be gathered by using simulations from previous projects and probably making combinations between different projects.

Discrete event simulations that are developing in direction of simulations of development and production simulations for existing projects and there is still space for improvements in all stages of shipbuilding process.

Outfitting as well as hull production, offer their unique difficulties to simulation tool for optimizing effort that is involved.

1.1.7 Conclusion

The report has been prepared with understanding and good elaboration, so it was very hard to find questionable or even debatable fields.

1.2 Floor Discussions

1.2.1 Naoki Osawa

I congratulate the committee for the great work of publishing a comprehensive and valuable report. Researches and developments related to corrosion protection technique, including new developments in anti-corrosive coatings and thermal spray coatings, are summarized.

In these days, ship's ballast tanks are constructed with ordinary steels, and they are coated by epoxy coatings following the IMO PSPC/WBT standards. This system guarantees an average coating life of 15 years, if applied correctly. Because ship's economical life cycle is around 25 years, it is needed to develop innovative solutions which improve the corrosion resistance of ballast tanks. The application of corrosion-resistant steel (CRS) is a promising technology for this purpose (e.g. DeBaere *et al.* 2011).

Researches and developments of CRS for ballast tanks are carried out by many researchers in recent years. In these works, it is often the case that the corrosion resistance improvement is achieved by the combined uses of a protective coating and a new steel (e.g. Shiotani *et al.* 2010) because the corrosive environment in a ballast tank is so severe that bear steels cannot endure it.

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The quantification of the improvement effect of these new steels in service has not been achieved yet. The incomplete understanding of the mechanisms responsible for the coating failure and under-film corrosion in ballast tanks hinder the progression of technical innovation.

Therefore, I propose followings as a possible contribution for future research work:

1. Understanding and quantification of the mechanisms responsible for the failure of anti-corrosive coatings and under-film corrosion in water ballast tanks.
2. Development of corrosion-resistant steels for water ballast tanks.

1.2.2 Andrea Ivaldi

1. Friction Stir Welding: Despite a large number of publications regarding several different applications of this technology, the actual status is limited to thin aluminium plates, butt welding. What is the trend for the future?

2. Please provide some more references about the matter of distance between welds (ref. 5.1.1 of the Proceedings).

1.2.3 Fang Wang

With the increasing use of thicker and higher tensile strength steels, the synthetic characteristics of the new material must be considered enough. But the characteristics of a certain material may go in absolutely different direction. For example, the increase of yield strength of the material may lead to the decrease of fracture toughness and fatigue strength. Furthermore, the weldability, corrosion resistance, impact resistance, etc. should be considered. So my question is that, is there any synthetic criterion or standard used for evaluation of a new material? Or should we adopt some other analysis methods such as damage tolerance analysis method instead of criterion simply based on strength?

1.2.4 Erkan Oterkus

What is the necessity of technology transfer from aerospace industry in the area of composite materials? Problems regarding the utilization of composite materials, how about the issues related with moisture since ERP's generally made of polymer based materials. In addition to anti-corrosive materials, how about the development of anti-fouling materials? Thank you.

1.2.5 Mirek Kaminski

The report includes macro-properties and effects of materials. I think we should also look outside our field by reviewing research of e.g. material scientists. They are changing chemical composition, tempering process temperature in order to get materials with new microstructures that satisfy our requirements w.r.t. corrosion, resistance, strength and toughness. Would you recommend to modify the mandate and include review of these developments.

2 REPLY BY THE COMMITTEE

2.1 Reply to Official Discussion

We would like to thank Mr. Tusun for his clear and complete review of our committee report. We appreciate your comments to our report.

We agree with you that due to the current market situation it is necessary for yards to find new and innovative ways to open up new opportunities. An open market with

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little national intervention would create a more realistic view on competition and also help the industry to innovate more, since yards then have to be competitive.

Mr. Tusun mentions a use of thick steel plates in sophisticated ships. We agree that large thicknesses can be used in these ships for some local areas. However, large application of thick plates for structural longitudinal strength is mostly seen in container ships and LNG carriers. The thick plates require special welding requirements, but in general it will be easier to prevent deformation and shrinkage in thick steel plates than in thin plates. The latter are more prone to welding deformations.

The increasing diversity of paint systems that the industry is seeing indeed calls for more research and testing of the long term behaviour of these systems. We appreciate the insight of a yard that the cost rise in corrosion protection is mainly due to the restrictions on limits of paint damage and the increased inspections. We believe that experiences like this combined with research on the effect of e.g. the strict requirements should be used to improve/adapt regulations in the future. Although there are many developments in coatings, such as the mentioned self healing coatings etc. we support the statement of Mr. Tusun that the current systems should also be developed further. Within all developments the practical application should be the main point of focus.

The committee fully supports the statement that more time is needed to collect information of the use of composite materials in real structures. It is good that experience is now gained in non-structural elements, such as balconies etc., since this will provide valuable insight in for example the long term behaviour and connection issues with only limited risk. The real advantage of composites will become apparent with the application in global strength. However, this also requires a change in design. Looking at the design from a traditional material approach and applying composites in that design will not show the real benefits.

Standards will probably always be based on experience with ships in service. This makes the incorporation of new materials and technologies sometimes difficult. However, with the trend towards goal based standards, first principle analyses and proof via experiments is normally accepted now. This makes innovations easier. This application of first principles and experimental proof or measurements should not only be applied in the design, but also in production and in in-service conditions.

We fully agree that the requirements in standards should be functional. The safety of the vessel is the first priority, but unnecessary complexity and limitations have to be avoided.

The amount of data on shipyards is indeed a problem. Not only from the amount of manual work that the lack of interoperability causes, but also by the increased possibility of errors due to the switches between programs, different definitions used in programs and adaptations during the building process.

It is true that full production simulation techniques require a lot of effort and simplified methods are more widely used. It can probably be expected that this will change in the future similar to the use of finite element methods (started as a very sophisticated tool used by only a few people, now almost common in designs). The main issue that will remain is the input required, input that is not always known in the early project stage but that can influence the success of the simulation. Learning from experience, but also sensitivity studies can improve the quality of the input and the knowledge on the most critical parameters.

Again we would like to thank Mr. Tusun for his comments and additions to our report.

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2.2 Reply to Floor and Written Discussions

2.2.1 Naoki Osawa

We appreciate the remarks of Prof Osawa on the importance of research in the area of CRS and on the mechanisms responsible for the failure of anti-corrosive coatings and under-film corrosion in water ballast tanks. We advise the next ISSC committee on materials and fabrication technology to include important development in these areas in their report.

2.2.2 Andrea Ivaldi

1. Indeed the largest application now is on butt welding of thin aluminium plates. However, research is done on the use of Friction Stir Welding for stiffener plate connections or corner welds (Figure 1, Martin *et al.* 2011). Also there is some work being done in the welding of steel with this technique. The committee saw some examples of corner or stiffener welds and other materials during their visit to the CEWAC research center in Belgium.

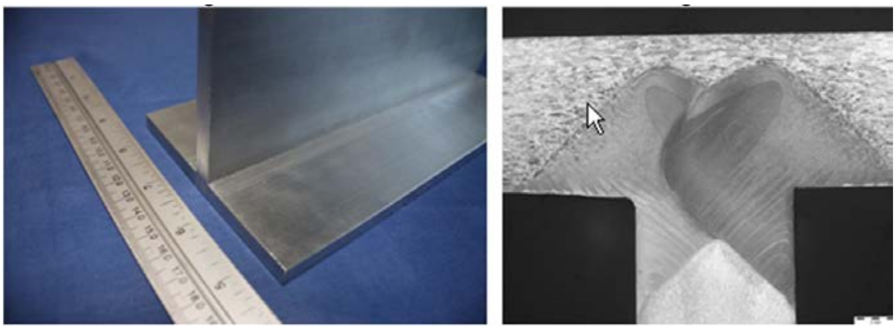

Figure 1: Example stiffener friction stir welding (Martin *et al.* 2011, TWI)

2. This matter about the distance between welds was raised based on shipbuilder's practical observations that overlapped welds cause no structural problems nowadays, although in old days it used to cause problems such as cracking of welds. No references have been found regarding this issue, and one of the reasons why we raised this issue is exactly this lack of research activities into this matter.

2.2.3 Fang Wang

We completely agree with the discusser's point that when a new material is to be actually applied, it is necessary to evaluate the strength and properties of the material from wide varieties of aspects, including facture toughness, fatigue strength, weldability, corrosion resistance, and so on. Some of them can be covered by the Rules of Classification Societies. Anyway, at first, necessary testing and its procedure and criteria must be established in consultation with Classification Societies.

2.2.4 Erkan Oterkus

The committee beliefs that it is important, especially for materials as composites that are often still only used in niche areas of different industries, to learn from each other. Since the application of composites is still relatively limited indeed more long term effects such as moisture, but also uv degradation etc, still need to be studied. It is important that these aspects are studied further in the near future to increase the application of these materials.

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As for anti-fouling materials, a lot of research is still going into the anti-fouling coatings, ultrasonic system and electrolytic anti-fouling devices. Traditionally, self-polishing coatings were used to prevent bio-fouling on marine vessels. Since organotin and copper compounds have a detrimental impact on the environment; some of them have already been banned. Foul-release coatings also have been extensively studied for marine applications. Toxin-free systems such as (a) hydrophilic antifouling coatings (b) low energy, hydrophobic foul-release coatings (c) enzyme-based systems and (d) coatings with covalently attached toxins have been updated. Especially, two types of toxin-free, environmentally benign antifouling coatings: hydrophilic polymer brush and hydrophobic low-surface energy coatings have been developed.

There is an ongoing need to improve the performance of antifouling coatings and to increase environmental safety. More durable systems for hydrophilic polymer brush coatings will be the topic of focus.

2.2.5 Mirek Kaminski

The new steel materials mentioned in the report, such as as YP460 steel, large heat-input extreme thick plate, high arrestability steel, FCA steel and corrosion resistant steel, are all results of microscopic material research activities, and we agree to the discusser's view that reviewing research of material scientists is also important. Nevertheless, our committee believes that the emphasis of the mandate should be practical application of developments to ship and offshore structures and as such would recommend maintaining the mandate and limit the review of material developments to the viewpoint of these practical applications.

2.3 References

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