The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM)
ISSN: 2602-3199

The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM), 2023

Volume 26, Pages 272-278

IConTES 2023: International Conference on Technology, Engineering and Science

Verification the Stressed State of the Ships' Hull during Separate Water Descent

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Abstract: This study evaluates the stressed state of the ship's hull during its welding of separate water descent parts. Separate descent of ship hull is applicable for small and medium sized ship yards (SME), where shipbuilding facilities have restrictions on length and lifting capacity. In the paper different scenarios are developed for verification. It is assumed that separately launched sections of the ship's hull are free of heels and trim, i.e., pre-ballasted, and any initial deformation in connected structures has been eliminated during the stage of hull assembly. In different scenarios, there are varying factors directly related to the strength of the ship, its construction materials, as well as those that have an impact on the production processes. Two of most used welding methods in ship building are analyzed- submerged arc welding and gas metal arc welding. The analysis shows that the stressed state of the ship's hull closely depends on the initial tense state, thickness of plate elements and welding method.

Keywords: Small and medium sized ship yard, Launching, Hull assembly, Thickness, Welding, Strength

Introduction

The pursuit of constantly increasing the deadweight(DWT) of ships on a global scale has an influence on the market conditions of shipbuilding companies. Increased DWT improves operational efficiency of the ship [https://www.dnv.com/expert-story/maritime-impact/Ticket-to-trade-increasing-deadweight-for-improved efficiency.html] emissions, which influence the individual CO2 emissions in the atmosphere and is used, monitoring the annual operation performance index. Increasing the deadweight is not always achieved at the expense of the length. It can also be accomplished by increasing the draft and reducing the freeboard, but this is within certain limits. This measure is easily implementable for already constructed ships. However, for ships that are yet to be built, this measure has certain limitations in ship yard production facilities.

With the emergence of this trend, a significant number, including the smaller and medium-sized shipbuilding enterprises, have become non-competitive in the market. Each shipbuilding company has developed and successfully implemented technological processes for ship hull construction as a whole. The main methods for constructing ship hulls are block, sectional, and block-sectional. Analysis of sectional and block-sectional shipbuilding methods with preliminary developed and evaluated criteria is done in (Денев, 2020). Some ship yards need to reorient their activities or seek ways to withstand this global trend. One possible solution to overcome the problem is the separate launching of the ship into the water. This method allows the construction of relatively larger ships under limited production conditions.

Hull Separate Water Descent

The separate launching of the ship's hull into the water and the subsequent assembly and welding of the individual parts together is a complex technological process compared to performing these tasks in a dry dock.

- Selection and peer-review under responsibility of the Organizing Committee of the Conference

The main stages of the process are presented in Fig.1. to Fig.4 (Шевелевич, 1974). Separately launched parts are with different light weights and they are with trim independently of each other, Fig.1.

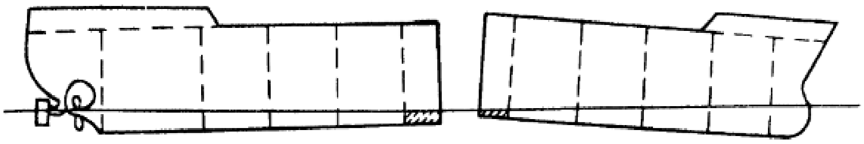

Figure 1. Ship's hull parts launching

To eliminate the trim and for easy connection of each part, they are ballasted. Ballasting is carried out by forcibly filling the tanks based on a pre-calculated calculation, fig.2.

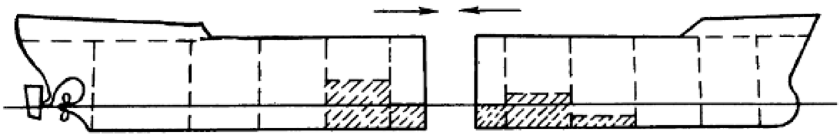

Figure 2. Ballasting the separately water descent parts

When the ballasting operations are finished, the next step is that parts connect each other by help of fixed strips and elastic jacks and partly welding seams, fig.3.

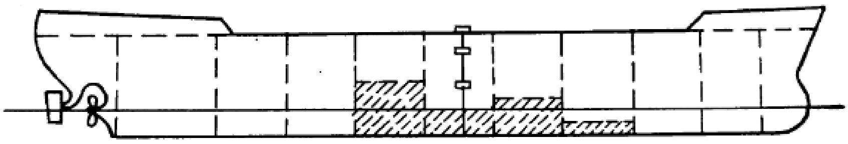

Figure 3. Connected each one to other with fixed devices

Welding process of outer shell plating continues with mounting of additional construction in connected areas providing water tightness of the welding seam and partly ballast discharging, фиг.4. One more method for welding is underwater welding of bull weld seam but it requires additional equipment and personal skills.

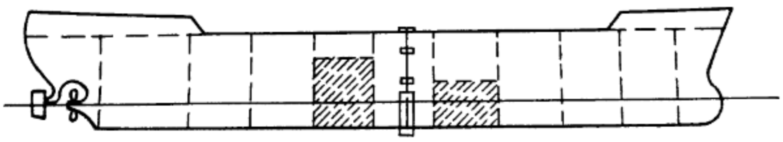

Figure 4. Welding and partly debalasting of hull parts in welding seam area

The most appropriate welding method for this case is shielded metal arc welding and the gas metal arc welding process.

Methodology

Separately, water descent ship hulls parts have to be welded together to provide structural strength and identity. For manual metal arc welding (SMAW) and gas metal arc welding (GMAW), processes are calculated and we analyzed. The welding parameters are calculated for plate thickness range from 8mm to 20 mm.

Considering that stressed ship condition closely depends on actual forces in the shipbuilding process, which are mainly welding forces, it is necessary for a proper calculation of welding current the value depends on heat input in the area of the welding seam. Welding current value is selected based on shielded electrode diameter, while electrode diameter is selected by plate thickness and seam area. The heat input in welding seam is calculated by:

$$q_e = I * U * \eta, W$$

Where: I- welding current, A; U- voltage, V; η- efficiency coefficient, form MMAW η=0.7, while for GMAW η=0.8 (Weman, 2003). https://www.materialwelding.com/what-is-efficiency-in-welding-welding-efficiency-for-smaw-gmawtig-fcaw-and-saw/

Shown in fig.5, the curves for SMAW are nearly parallel and double S- shaped. In areas between 12 and 14 mm and 18 and 20 mm, there are no none from the curve. That corresponds with non- changing welding parameters for thicknesses in relevant areas.

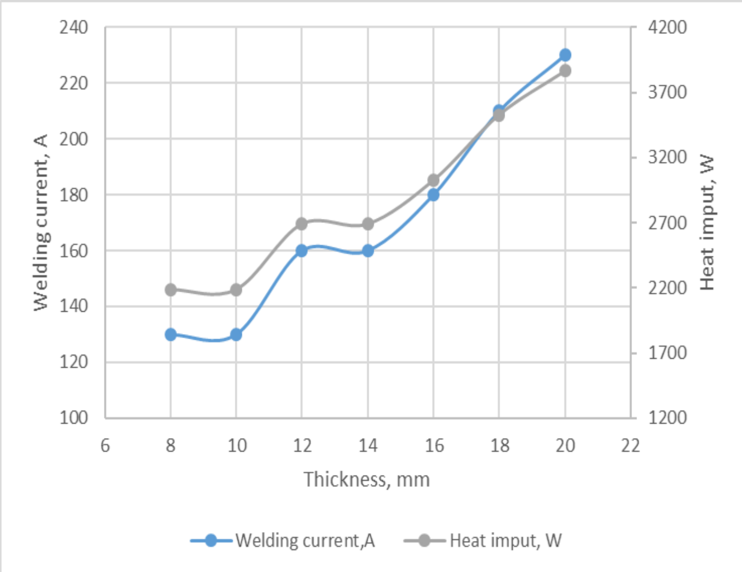

Figure 5.Welding parameters in SMAW process

Different are curves of GMAW, shown on fig.6. Their shape is not a double S- curve. It is noticed that at 14 mm thickness the curve of welding current and heat input are very closely side by side. Welding parameters, current, wire diameter and voltage for GMAW are selected from a tabular from reference literatüre(ESAB, n.d.,& Miller, 2018). Heat input is calculated by formula (1).

Figure 6. Welding parameters in GMAW process

Verification of Stressed Ships State

After hull parts separate water descent launching follows their watertight connected one to other by welding process. In the welding process, as a result of the high amount of heat input, stress is generated, leading to deformations in the ship's hull. Considering that the maximum allowable value of normal stresses in on the ship hull closely depends on material, for steel ships with length more than 90m, according[GL rules] is calculated by following formulae:

$$[\sigma] = \frac{175}{k}, N/mm^2$$

Where: k- material factor, k=1 for shipbuilding steel(St235),
The permissible value of normal stress for ships with length less than 90m is calculated by:

$$[\sigma] = \frac{18.5\sqrt{L}}{k}, N/mm^2$$

Where: L- ships length, m

The full separate water descent process is applicable for ships with lengths more than 90m fabricated from shipbuilding steel ST235. In this context, in fig.7 and fig.8, are shown the distribution of normal stresses on the bottom and side of the ship the hull related to thickness of plates in the area of the butt welds. The actual stresses are compared with processes permissible in two welding processes.
Actual stresses in construction are calculated by:

$$\sigma = E * \frac{\Delta l}{l}$$

Where: E- Young modulus, for shipbuilding steel E=0.002kN/mm2; Δl- construction deformation, mm; l- construction welding length, mm;
Construction deformation is calculated by [Бельчук, 1961]:

$$\Delta l = \Delta_c * L, mm$$

Where Δc- construction deformation according center of gravity, L- all length of construction;
Construction deformation according center of gravity is calculated by:

$$\Delta c = \frac{3.6 * 10^{-6}\, q_e}{F}$$

Where: qe- heat input in welding seam, W; F- area of ship midship section, m2;
Increase of normal stresses on the side by about 11% in areas with higher plate thickness, Fig.7. This is due to higher welding current value and input heat, corresponding to easy melting of welding seam metal.

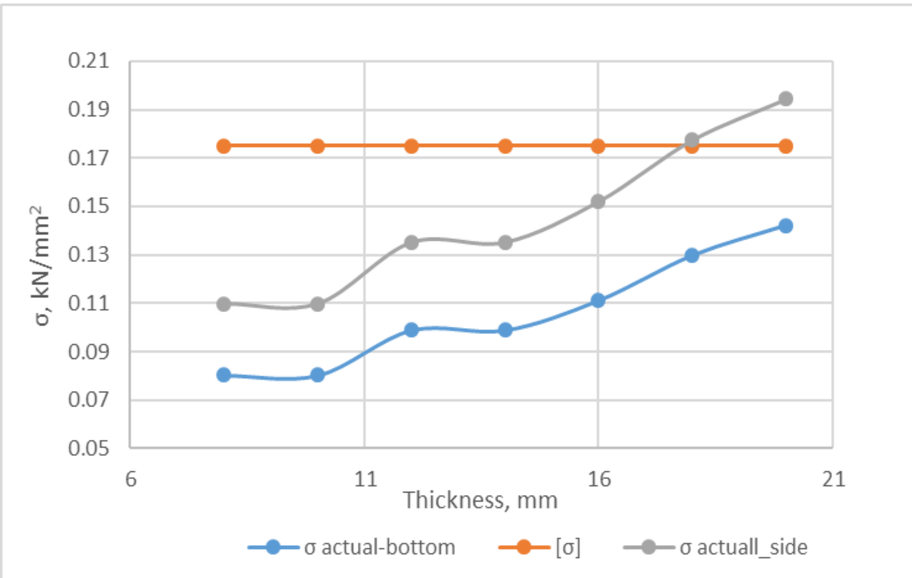

Figure7. MMA welding

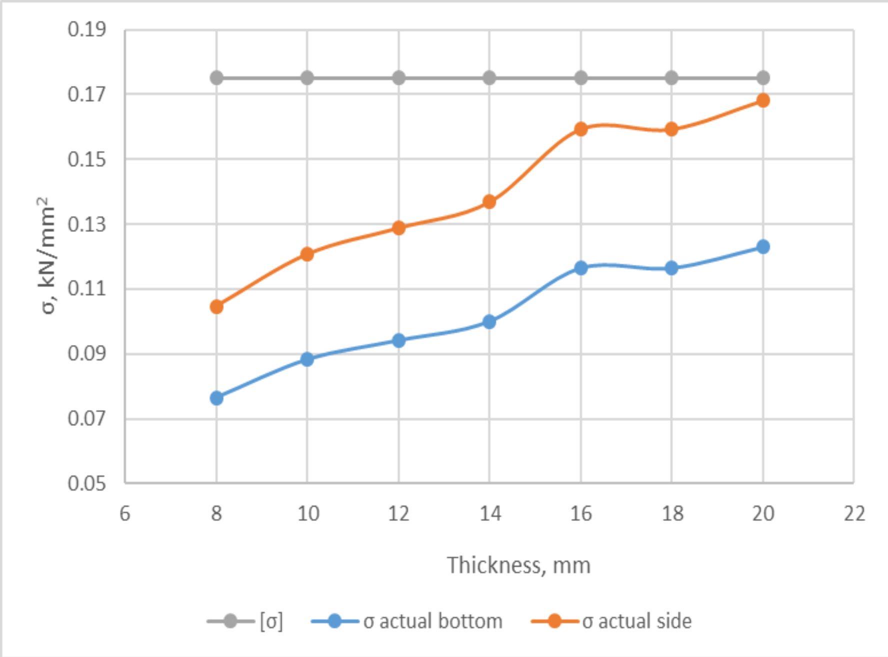

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Figure 8. Gas metal arc welding

The actual stresses and stress on the hull in the bottom region is less than the maximum permissible stress value. This is due to the actual position of the ship's center of gravity and neutral axe position. The results obtained in fig. and fig. are related to the ship's hull as a whole. There is a requirement for ship hull welding afloat. The level of longitudinal stress during the welding operation is to be below 50 MPa in the concerned area; however, lower limits may be requested by the surveyor depending on the specificities of the ship and/or welding.(Bureau Veritas, 2022). For the analysis and evaluation of whether this requirement is met during welding activities for separately lowered parts of the ship's hull in Fig.9 and Fig.10, different scenarios for performing the welding operations are presented. The main task is to investigate the optimal lengths of the welds so that the stresses generated by them are minimal or absent altogether.

Different welding lengths are studied. For the bottom part of the ship's hull they are 2000, 4000 and 6000 mm, while for the side parts they are 3000, 6000 and 9000 mm and the thickness range from 8 to 20mm. In fig. and fig., maximum precaution is shown [σ]= 0.05kN/mm2. In fig. and fig. with σb2, it is noticed that this is actual stress on the bottom when we weld 2000mm of seam, σs3 is noticed that this is actual stress on the side when 3000mm is welded. In all thickness range when welding in bottom seam is by 2000mm length actual stress didn't exceed permissible,

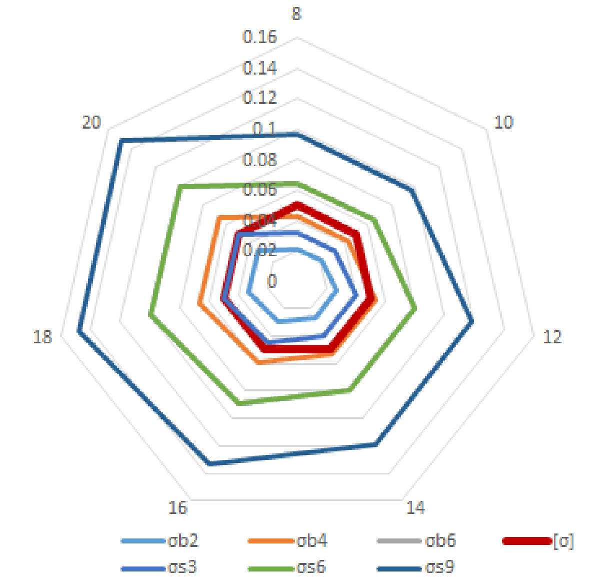

Figure 9. MMA welding

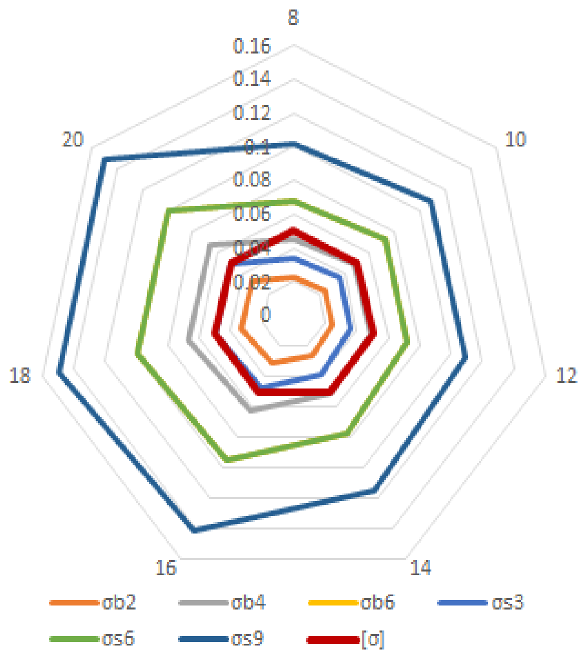

Figure 10. Gas metal arc welding

When welding on the side with a 3000 mm seam, actual stress up to 14 mm didn't exceed permissible. In other thickness ranges they are equal or near to permissible. The actual stresses on bottom and side with welding length equal and more than 6000 and 9000 mm widely exceed permissible, fig.9 and fig.10. The maximum permissible value exceeded in MMA welding is about 11% at 20 mm thickness and 9000 mm welding length at side area,fig.10. When GMAW process is used there are not waste material for environmental pollution compared with SMAW.

Conclusion

The study presents a technological possibility for shipbuilding in the conditions of small and medium-sized businesses, considering contemporary trends and environmental requirements in navigation. The proposed method enhances the competitiveness of SMEs in the market. An analysis was conducted on the stressed state of the ship's hull during the welding process of its separately lowered parts.

The normal stresses during welding were analyzed and compared with the maximum allowable values using two different methods: manual shielded metal arc welding and welding in a protective gas environment with a consumable electrode. The current stress values were examined over a wide range of thicknesses and different welding sequences in terms of the length of the weld. It was found that for weld lengths greater than 6 and 9 meters for the bottom and deck areas, the stresses exceeded the allowable limits by almost twice for both welding methods. Optimal, in terms of subsequent stress occurrences and consequent deformation occurrences in the entire thickness range, is the execution of welds with a length of 2 for the bottom area and 3 for the ship's side area.

Scientific Ethics Declaration

The author declares that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the author.

Acknowledgements

* This article was presented as an oral presentation at the International Conference on Technology, Engineering and Science (www.icontes.net) held in Antalya/Turkey on November 16-19, 2023.

* Infrastructure for sustaınable development of marıne research and partıcıpatıon ın the european ınfrastructure euro-argo – masrı is a project of the National roadmap for scientific Infrastructure (2020 – 2027) of Republic of Bulgaria

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To cite this article:

Denev, Y. (2023). Verification the stressed state of the ships' hull during separate water descent. *The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM)*, *26*, 272-278.