POSSIBLE REPLACEMENT OF SPECIAL STEELS IN HULL REPAIRS

Danka RAKUSOVA

Danka Rakusova, Faculty of Special Technology, Trencin, University of Alexander Dubcek, Pri parku 19, 911 06 Trenčín
Corresponding author E-mail address: danka.rakusova@tnuni.sk

Abstract
Vessels, pontoons, armoured vehicles and much other special equipment had been produced from steels we do not have any more an access to. Budget restrictions limit a purchase of new ones. Sometimes we are able thanks to our capabilities to repair, restore or renovate them, sometimes we are allowed to do it through a licence. However, political and marketing barrier is so strong, that sometimes we have to spend huge investments only because of some small exchangeable or reparable parts. Availability of standards makes a decision about a new purchase easier. Even nowadays more information is available on internet; the manufacturers do not provide technological information if not related with a contract. Changes in property rights also hamper a process. Post production analysis of material is very demanding and needs special equipment to define a structure of steels having been used on a vessel structure. Quality of material on a hull of a vessel is crucial not only for passenger vessels, but also for vessels whose hull is stressed much more because of navigation conditions, such as ice breakers on river in winter time. Worn steel plates on a hull must be regularly checked and if needed replaced. However, quality of the steel plate being used must not be lower than a previous one. Paper provides some comparable marks of steels that could serve when replacing one mark for another one and in repairing procedures on a vessel hull.

Keywords: standards, quality, steel features, hull which express the principal topics of the paper.

1 Introduction

Ship structures are determined by the ship's mission and intended service. Iron hulls (Fig.1) replaced wooden hulls in the second half of the 18th century, to be followed up by steel. Since then seagoing ships and inland barges are being regularly designed with several steel grades and shapes. Steels are the most common materials being used for shipbuilding. These steels are rather to meet strict requirements such as strength, flexibility, high manufacturability, weld ability, and cost, reparability, etc. Steels used in the shipbuilding industry also need high cold-resistance, good welding characteristics and increased fracture strength. These determine a ship's size, complexity and the function of the structural components. Depending on the part of a vessel, various materials are used, but hull of the vessel has been mainly made of steel. When choosing a mark of material to be used for production of any ship product (hull detail, mechanism, equipment) the regulations stated by registry , state, department standards providing basic requirements for products being used in vessel operation [1].

Fig. 1 *A ship hull*

2 Comparable marks of steels for hull repairs

Ship structures are determined by the ship's mission and intended service. Iron hulls replaced wooden hulls in the second half of the 18th century, to be followed up by steel. Since then seagoing ships and inland barges are being regularly designed [2] with several steel grades and shapes. Steels are the most common materials being used for shipbuilding. These steels are rather to meet strict requirements such as strength, flexibility, high manufacturability, weld ability, and cost, reparability, etc. Steels used in the shipbuilding industry also need high cold-resistance, good welding characteristics and increased fracture strength. These determine a ship's size, complexity [3] and the function of the structural components. Depending on the part of a vessel, various materials are used, but hull of the vessel has been mainly made of steel. When choosing a mark of material to be used for production of any ship product (hull detail, mechanism, equipment) the regulations stated by registry , state, department standards providing basic requirements for products being used in vessel operation [4].

Steels look the same, but when used in the design of a ship, much greater loads are imposed on the special steel; loads which probably could not sustained if conventional steel was substituted by mistake. Special steels include

1.1. Thermo-mechanical control process steel plates (TMCP) for container ship

1.2 Anti-corrosion steel plate (NAC5). NAC5 (New Anti-Corrosion No.5) that can extend the service life of deck plates by approximately 5 years, with the use of ship primer. NAC5 also has excellent weld ability, which is an essential property in shipbuilding materials.

1.3 Tubular products include JFE-MARINE-COP for anti-corrosion pipes for crude oil tankers

1.4 Cladded steel plates

1.5 Longitudinally profiled steel plates (LP) plates, also called taper plates)

1.6 Steel Plate for High Heat Input Welding EWEL

3 The general characteristics of steels used in shipbuilding and ship-repair

Basic material for construction and repair of vessels is a carbon steel [5], for many sea and river vessel – low carbon content steel, characterized by an increased strength and enabling to make the hull lighter. During vessel repair, some basic standard provide the needed information as GOST 5521-67.

Ship steel plates depending on basic characteristics and assignment are designated as following marks:
Carbon steel- C, VMStZsn (as by GOST 380-71) Low alloyed 09G2, 09G2S, 10G2S1D, 10XSND (as by GOST 5521—67). In addition to VMStZsp steel, metallurgical works produce steels: VMStZps, VMStZkp, VKStZsp, VKStZps, VKStZki (as by GOST 380—71).Carbon steel of an S mark is used for ship building and sea ship repair, carbon steel VMStZsp of a common quality – for ships of inland and combined (river-sea) navigating. Ship steel plate should be resistant to corrosion (in water and in air); to sustain processing in hot and cold conditions; to be weld able with electric arc;
to sustain bending to 180° in cold condition after a bending triblet. Low alloyed steels (the above mentioned marks) differ through a low content of carbon (not more than 0,12%); The carbon steels differ with a small content of carbon (0, 14—0,22%), sulphur and phosphorus – cold shortness (not more than 0,05% of each). Sulphur gives hot shortness to the metal, and phosphorus – cold shortness. At the hot shortness the metal cracks and breaks in a warmed up condition; cold shortness is an ability of the metal to bring the viscosity down at lowered temperatures alloying elements: silicium, manganese, chrome, nickel added to steels.
Steel (as by GOST 5521—67) is produced in form of steel plate and sectional steel; steel is distinguished as a thick plate steel (thickness of plates ranges from 4—56 mm); thin plate steel (thickness of steel metal sheet ranges from 0, 9—3, 9 mm); profile steel (Fig. 4): isosceles steel angle, non-isosceles steel angle, beam (trough section profile), I-beam, angle bulb, bulb iron, symmetric bulb iron, semi-circled sections.
Other kinds of steels with special physical or physical-and mechanical features are used in ship building and ship repair wrought steels – for production of tiny details, carbon and alloyed – for ship forged pieces, stainless steels. The latter ones are highly corrosion resistant, well weld able, however they are expensive, and therefore their usage is limited.

Though carbon equivalent (Ceq) is an important property of steel for determining its weld ability, in shipbuilding grades of steels, rather than using the carbon equivalent value when assessing weld ability, the Pcm-value indicated in percentage (susceptibility to cold cracking) is also usually being calculated based on the formula

$$Pcm = C + \frac{\%Si}{30} + \frac{\%Mn}{20} + \frac{\%Cu}{20} + \frac{\%Ni}{60} + \frac{\%Cr}{20} + \frac{\%Mo}{15} + \frac{\%V}{10} + 5 * \%B \text{ , \%} \quad (1)$$

Carbon equivalent, Ceq value for shipbuilding steels is determined by the formula:

$$\boldsymbol{Ceq = C + \frac{Mn}{6} + \frac{Cr+Mo+V}{5} + \frac{Ni+Cu}{15}}, \quad (\%) \quad (2)$$

The area under the upper deck around the diesel engine exhaust gases tube is exposed to mixed atmosphere of exhaust gas and H2S volatilized from the crude oil. As this area is also subject to cyclic condensation and evaporation of sulphur during day and night, a type of corrosion peculiar to the under deck area, called “vapour space corrosion”, occurs. The average corrosion rate in vapour space is about 0.1 mm/y. However, considering the life of a crude oil vessel to be approximately 20 years, the possibility of deck plate replacement increases [6]. Without replacement of deck plate which cost is very expensive, the resulting ship reliability may be lower [7].

4 Ship hull repair

Modern steel repair involves the fabrication of a complex steel structure, into which a wide range of ready-made equipment is fixed. Today the principal raw material is steel plate and the layout of a modern shipyard is arranged to facilitate the flow of steel received from the steel plant through the various processes of making out, cutting, bending, welding, fabricating subassemblies, and final erection of the prefabricated units into the hull and the superstructure.

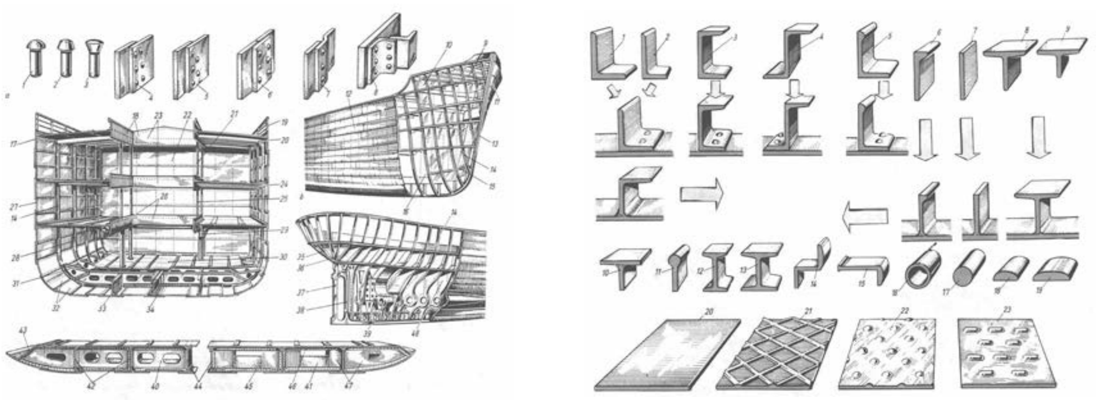

Fig. 2 *Structure of the vessel hull*

In some high strength steels; for example, the quenched and tempered steels [8], a heat input during welding which would be acceptable for conventional steel, would drastically reduce the toughness of the special steel in the heat affected zone.

Fig. 3 *Replacing a steel plate on a hull*

In the river ice-breaker there is a place of an increased wear in a certain level and of a certain width of about 0,5 m and it should be replaced a middle part of the vessel. Designing and checking the quality of the hull lines allows minimizing propeller-ice interaction. The adequate strength is achieved commonly by selecting a proper ice class and following the class rules, which are closely related to quality of the steel used in construction and later on during hull repair. The designer must have some insight about ice loads in order to select the structural arrangement. Repair aspects result from functional specification of the ice breaker, which differs it from other vessels and it requires that the vessel achieves an average escort speed in all normal ice conditions in the operational area. The ship must be fast enough with relation to the level ice ahead with thin snow cover coming into contact with a hull. The ship must be able to go astern, that defines the most vulnerable area of the hull in ice conditions. The load on the hull is increased due to requirements for manoeuvring capability, as the ship must be able to turn on spot in thick level ice with thin snow cover in max. 2.5 minutes. The ship must be able to turn out immediately from a channel with thick side ridges significantly affecting the thickness of steel plates on the hull.

Fig. 4 Area *of a hull destroyed the most by ice*

5 Testing methods

The methods mentioned in this paper for detection of surface imperfections after repair are visual testing (VT), liquid penetrant testing (PT) and magnetic particle testing (MT). The methods mentioned for detection of internal imperfections are ultrasonic testing (UT) and radiographic testing (RT).

Applicable methods for testing of the different types of weld joints are given in Table 1.

Table 1 *Applicable methods for testing of weld joints*

WELD JOINT	PARENT MATERIAL THICKNESS	APPLICABLE TESTING METHODS
Butt welds with full penetration	Thickness ≤ 10mm	VT,PT,MT,RT
	Thickness > 10 mm	VT,PT,MT,UT,RT
Tee joints, corner joints and cruciform joints with full penetration	Thickness ≤ 10mm	VT,PT,MT
	thickness> > 10 mm	VT,PT,MT,UT
Tee joints, corner joints and cruciform joints without full penetration and fillet welds	All	VT,PT,MT,UT

6 Conclusion

The vessel is a long lasting investment. However, the ships having been operated in river-sea conditions and in winter time as an ice-breaker suffer from hard and significantly changing conditions resulting in a decreased thickness of a hull in some places and areas. Regular coating can prolong the period of operation but if not, such negligence might cause degradation of hull thickness and after a long period a total immersion of a vessel and huge damages on property and environment. International consequences related with a blocked navigation would be enormous. The machine part is regularly checked and the hull needs to be checked and maintained as well. The investments into inspection and a partial restoration of the hull is worth of doing it, all the more, there are own repairing capabilities available in river dry docks with experienced workers. The decisions taken about repairing the vessel is often an interaction between the owner and a repairer so many above mentioned requirements should be kept in balance. Often a repairing company is given a free hand how the requirements are met but sometimes the owner has a clear idea of how the ship shall be repaired.

References

[1] D. Rakusova: Pumps and piping systems in a vessel operation and crisis situations. –Proceeding of the 21st International Scientific Conference. Transport Means 2017.

[2] I. Kopecký, P. Lipták, D. Rakúsová: Renewable sources of electric energy for mobile logistic means Iso 1c containers .In: Transport means 2014 : Proceedings of the 18th international conference. - Kaunas : Technologija, 2014, p. 211-214, ISSN 2351-4604.

[3]A.Breznická, P. Stodola, J.Stodola:., Currently concept of risk and application. 11th International Conference on Intelligent Technologies in Logistics and Mechatronics Systems, ITELMS 2016, p. 31-37.

[4] P. Stodola, A. Breznická, J. Stodola: Reliability analysis and testing of special technique. Intelligent Technologies in Logistics and Mechatronics Systems, ITELMS 2015 - Proceedings of the 10th International Conference

[5] P. Kardasz: The potential use of waste oil. Journal of Ecological Engineering. Volume 14, Issue 3, 2013 Open Access, DOI: 10.5604/ 2081139X .1056050, p. 77-82, ISSN: 2081139X.

[6] P. Liptak, I. Kopecky, D. Rakusova: Variability of application, special equipment operation using renewable sources of energy .In: Materiály a technologie ve výrobě speciální techniky. - Brno : BVV, 2015, p. 72-78, ISBN 978-80-7231-999-2, CD ROM.11. P.Liptak, J. Stodola: Errosion wear.- Transport Means - Proceedings of the International Conference, 2014-January, p. 335-338.

[7] J. Turza, J. Eliáš, B. Kopiláková, D. Rakúsová,. Modelling of an explosion of an improvised explosive device a vehicle [online]: http://pubs.sciepub.com/ajme/2/7/8/index.html. In: American Journal of mechanical engineering. 2014, Vol.2, No.7(2014), p.209-215, ISSN 2328-4102.

[8] D. Rakusova, P. Liptak, I. Kopecky: Zariadenia na udržiavanie bezpečnosti korýt riek = Equipment keeping safety of river basins, 2016. In: Vedecké práce a štúdie - 12. – Trenčín, TnUAD, 2016, p.122-127, CD ROM, ISBN 978-80-8075-772-4.