The Rolling Process Study and mechanical property of 460MPa Class Steel Plate used for Hull Structure

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ABSTRACT

Targeted on grain refinement, the effects of different rolling process conditions on mechanical property of 460MPa class steel plate, in terms of tensile and yield strength, low-temperature toughness, arrestability and microstructure, are studied. The rolling process conditions are surface-layer with ultrafine grains process (SUF) and traditional thermo mechanical control process (TMCP). As for SUF process, better surface strength and toughness can be achieved. Yield strength is generally higher than 540MPa. -60\degree C impact value of SUF2 is higher than 280J. The surface nil-ductility transition temperature (NDTT) of SUF condition have reached less than -80\degree C. The fine grain microstructure formed at the surface layer, which is about 4mm thick, contributes to better mechanical property than that in other layers. The microstructure varies gradually from the surface to the centre. There are proeutectoid ferrite and bainite at 1-4mm thickness of surface layer. The microstructure in the 4-10mm thickness layer consists of polygonal ferrite and a considerable amount of bainite. As for the TMCP process, relatively homogenous strength and toughness can be achieved across thickness direction, featuring with higher strength and lower toughness at the surface layer, and lower strength and higher toughness at centre layer, when compared to that of SUF process. The microstructure of the TMCP sample varies gradually from the surface to the centre.

KEY WORDS: steel; TMCP; 460MPa; low carbon bainite; Hull structure; toughness

INTRODUCTION

The Among all ship categories, bulk carriers, oil tankers, and container carriers have always occupied the vast majority of the market share. They account for about 87\% of the world’s fleets (Guoqing Zhang et al., 2009). Among these three types of ships, the construction of large and ultra-large container carriers is generally regarded to be the most difficult and has the highest technical requirements. The shape of the container carrier is narrow and long, with a single deck and straight upper deck. The cargo hatch is generally 70~80\% of the width of the ship. The upper hull structure is located at the stern or the back of the middle to allow more decks to be stacked. 2~4 layers of containers can be stacked on deck and 3~9 layers of containers can be stacked in the cabin. In recent years, around 70~90\% of general merchandise imported and exported by US, Britain, Japan and other countries are transported in containers. With the development of 6th-generation container carriers, the size of container carriers has also increased year by year (Nippon Kaiji Kyokai, 2009; Yamaguchi Y et al., 2010). Large container carriers more than 10000 TEU are called “Mega Container Carriers”. It has been reported that about 500 container ships of 10000 TEU or more were put into operation all over the world as of 2018 (Dynamar data, 2018). Moreover, the world’s first container carrier, 18000 TEU was constructed in 2011 for transport efficiency improvements, and in China the first mega container carrier of 18000 TEU was built by SWS (Shanghai Waigaoqiao Shipbuilding) in 2015.

High strength Steel plates applied for the upper hull structure of large container carriers, such as upper deck and hatch side coaming, are becoming thicker and higher in strength to ensure the structural stability due to the rising requirement of large cargo opening structure. YP40 and YP47 have been developed and put into massive use for upper deck and hatch coaming in container carriers of 8000 TEU and 12000TEU, respectively (Ichimiya, K et al., 2008; Kazukuni et al., 2015; Choo, WY et al., 2011). These thick steel plates need to ensure outstanding fracture toughness for the safety consideration of the hull structure. Particularly, brittle fracture, which can be disastrously deteriorated and lead to catastrophic ocean accidents, should be strictly prohibited. However, despite careful attention being paid to the welding procedure, it is almost impossible to suppress crack initiation in weld joints thoroughly. As a result, steel plates with excellent crack arrestability should be massively employed in key positions of shipbuilding in terms of hatch coaming and upper deck to forbid the expansion of brittle crack propagation even when cracks have initiated at weld joints. The requirements for EH47 are listed as following:

1. Mechanical properties as shown in Table 1:
2. Nil-Ductility Transition Temperature (NDT) ≤ -60\degree C;
3. -10\degree C crack arrestability KC,a≥6000 ~8000N/mm\textsuperscript{1/2};
4. Carbon equivalent Ceq≤0.49\%

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