Development of YP390MPa Steel Plate for Shipbuilding with Superior Low Temperature Toughness for Large Heat Input Welding

Koichi Nakashima¹, Kazukuni Hase¹, Shigeru Endo¹, Taiki Eto², Hideaki Fukai², Hiroshi Shiomi³

¹) Steel Research Laboratory, JFE Steel Corporation, Kurashiki, Okayama, Japan
²) West Japan Works, JFE Steel Corporation, Fukuyama, Hiroshima, Japan
³) Plate Business Planning Department, JFE Steel Corporation, Tokyo, Japan

ABSTRACT

YP390MPa steel plate with superior low temperature toughness for large heat input welding has been successfully developed by applying an advanced micro-alloying design. Multi-pass welding was conventionally used to YP390MPa class grade F steel, because large heat input welding deteriorates the toughness of heat affected zone (HAZ) and the strength of welded joint. The microstructure control of HAZ through advanced micro-alloying design enabled to improve the property of large heat input welded joint. The main concept of HAZ microstructure control in this development is optimized dispersion of martensite-austenite constituent (M-A). Suppression of M-A formation in the coarse-grained HAZ and promotion of M-A formation in the FGHAZ were achieved simultaneously. From the viewpoint of HAZ microstructure control, it was found that controlling Mn-Cu-Ni balance is effective to improve the HAZ toughness and the strength of welded joint. The YP390MPa steel plate with 50mm thickness was developed by an actual plate mill. The developed steel satisfied the target properties of the base metal and low temperature toughness at -40 degrees C of the large heat input welded joint.

KEY WORDS: shipbuilding steel plate; YP390MPa; large heat input welding; heat affected zone; martensite-austenite constituent; low temperature toughness; strength of welded joint

INTRODUCTION

As the sizes of trading ships become larger to improve transportation efficiency, high strength and heavy-thick steel plates have become to be required. Large heat input welding such as electro gas arc welding (EGW) is preferred to weld these heavy-thick plates for the view point of reducing construction time. To take a case of the grade E steel plate, YP390MPa and YP460MPa steels for EGW with more than 50mm in thickness have been developed and applied to actual hull structures (Suzuki et. al., 2005; Ichimiya et. al., 2008; Abe et. al., 2005; Kaneko et. al., 2008; Minagawa et. al., 2004). Recently, the operating environment becomes severe because the northern sea route is developed and the gas or oil fields are now shifting to the cold area. Therefore, the steel plate with excellent low temperature toughness is required to satisfy these demands.

In the case of grade F steel plate for low temperature use, high strength steel up to YP390MPa class for gas metal arc welding (GMAW) has been already developed. The heat input of EGW is very large and it enable one pass welding, however, it causes the decrease in toughness and the strength of welded joint through the grain coarsening and the enlargement of softening region in the HAZ. Although increasing the hardness of softened region in HAZ is effective to increase the strength of welded joint, it leads to the toughness decrease in HAZ at the same time. Due to this difficulty, YP390MPa grade F steel plate for large heat input welding has not been developed. By applying advanced micro-alloying design, YP390MPa class grade F steel for EGW has been successfully developed. Key technology of this development is to control the dispersion of M-A in the coarse grain region and in the softened region in HAZ, respectively. That is to say, reduction of M-A in CGHAZ and increase of M-A in the softened region has been achieved at the welding process in the same plate. In this paper, the basic alloy design concept of the developed steel and the properties of the steel produced in the actual mill are introduced.

ALLOY DESIGN

Subject for developed steel

When the steel plate is welded, original microstructure of the plate formed in TMCP process is cancelled and various types of microstructure are formed depending on its thermal cycle in HAZ. A region near the fusion line, grain coarsening occurs and toughness is decreased (Fig.1(a)), while a region heated just above Ac3 temperature is softened (Fig.1(b)) and this leads to the decrease in strength of welded joint. In case of large heat input welding, the time heated at higher temperature below the melting point is longer and the deterioration of these properties is emphasized. In order to obtain the high strength steel plate with superior toughness for large heat input welding, it is important to achieve the microstructure refinement of CGHAZ and the suppression of HAZ softening simultaneously. In this development, dispersion of M-A is optimized in addition to the previously established technique for controlling HAZ microstructure (Suzuki et. al., 2005; Ichimiya et. al., 2008).

Technique of HAZ microstructure control

Figure 2 shows a concept of HAZ microstructure control in this development. From the viewpoint of improving CGHAZ toughness, JFE EWEL technology (Suzuki et. al., 2005; Ichimiya et. al., 2008) has been already developed (EWEL is a registered trademark in Japan). In the technology, CGHAZ microstructure is refined through the retardation of grain coarsening by TiN and promotion of intragranular ferrite formation by addition of B, Ca. In addition to this matrix