Development and practical application of 7%Ni-TMCP steel for large capacity LNG storage tanks

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ABSTRACT

A new low-nickel steel plate has been developed for liquefied natural gas (LNG) tanks, which has excellent performances equivalent to those of the conventional 9%Ni steel under ultralow temperature. For LNG tanks, a double integrity structure has been proposed to prevent peremptory fracture. Therefore, in addition to the properties that suppress the initiation of a brittle crack, properties that prevent the propagation of a brittle crack, even when a crack contingently takes place, are required for the steel plates. In this study, various kinds of fracture evaluation tests were conducted using the developed steel plates. It was confirmed that the new steel plate has fracture performances equivalent to those of the conventional 9%Ni steel, and safety evaluations for its applicability to LNG tanks were discussed based on fracture mechanics. After approval of Ministry of Economy, Trade and Industry (METI) in 2011, the new steel with Ni composition of 7.0%-7.5%, 7%Ni-TMCP steel, was applied to the aboveground type LNG tank of Osaka Gas for the first time. The new steel for LNG tank within the range of Ni composition of 6.0%-7.5% was standardized in JIS, ASTM, and ASME, and approved to be registered in API. Furthermore, in addition to Class 9 of ASTM, Class 10 having higher strength was specified. Further expansion of the application of the new steel for LNG tanks is expected all over the world.

KEY WORDS: 7%Ni-TMCP steel; LNG tank; brittle crack; arrest toughness; welded joint; fracture mechanics; safety evaluation.

INTRODUCTION

Steel plates used for liquefied natural gas (LNG) storage tanks are required to have high strength and fracture performances under ultralow temperature. 9%Ni steel (Brophy et al, 1946; Itoh et al, 1965), which exhibits excellent performances under ultralow temperature, has been applied to LNG storage tanks for more than half a century. Numerous test data on fracture characteristics, including the fatigue properties of 9%Ni steel were obtained by several research institutes (Shingai et al, 1974; Sakai et al, 1975; Ogawa et al, 1978; Saitoh et al, 1993) and the applicability of the steel to LNG storage tanks was discussed in terms of prevention of peremptory fracture (Consortium of Five Japanese Companies, 1986; Machida et al, 1991; Machida et al, 1993; Nishioka et al, 1996; Kubo et al, 1998).

For LNG tanks, a double integrity structure has been proposed to prevent peremptory fracture (Consortium of Five Japanese Companies, 1986). Therefore, in addition to the properties that suppress the initiation of a brittle crack, the properties that prevent the propagation of a brittle crack, even when a crack contingently takes place, are required for the steel plates. These properties are required for both the base metal and welded joint.

Although high safety is required for such steel plates, from the viewpoint of decreasing the construction cost of an LNG tank, the amount of expensive Ni used, whose price often fluctuates, needs to be decreased. Nippon Steel & Sumitomo Metal Corporation developed a new steel plate with reduced Ni content (6.0%-7.5%Ni) for LNG tanks (Kamo et al, 2011; Furuya et al, 2011; Kagaya et al, 2015). The developed steel plate shows excellent performance equivalent to that of 9%Ni steel owing to the fine microstructure of the steel plate achieved by applying the latest thermo-mechanical controlled process (TMCP) technology and the optimization of the chemical composition.

Through a joint research project of Osaka Gas, Toyo Kanetsu, Nippon Steel & Sumitomo Metal, and academic experts, the performances of the new steel plate with Ni composition of 7.0%-7.5% (defined as 7%Ni-TMCP steel) was evaluated and its applicability to LNG storage