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Toughness of Steel Plates for Offshore Structures Manufactured by TMCP

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ABSTRACT

This study focuses on the characteristics of the toughness of a base plate and weld heat affected zone (HAZ), because its importance is becoming bigger in terms of a structural integrity. Several factors, such as reheating temperature, reduction per pass in the recrystallization region, and finish cooling temperature were varied to understand their effects on the base plate toughness. In order to examine how alloy elements can affect the toughness of the weld HAZ, a simulated HAZ technique was utilized and their effects were investigated by carrying out CTOD and Charpy impact tests. In addition, thick steel plates of 76.2 mm in thickness were produced and the toughness of the base plate and weld HAZ was evaluated to make sure if the factors which were proven to be effective on small scale specimens have an identical influence on the thick steel plates.

KEY WORDS: Simulated heat affected zone (HAZ); Crack tip opening displacement (CTOD); Charpy impact test; Thick steel plate; TMCP.

INTRODUCTION

Industries for the production of oil and gas in the offshore region have been demanding thick steel plates with high strength and excellent toughness, because offshore environment where offshore structures operate is becoming severer, for example, getting deeper and colder. High strength is required for offshore structures which operate on the deep sea and toughness properties are considered as the most important requirement for structures operating on the cold seas, such as Sakhalin and Alaska.

As the offshore structures become bigger, steel plates used should be thicker, stronger and tougher. Generally, the increase in strength and thickness has a negative effect on the toughness of steel plates. The microstructure of higher strength steel is likely to have more brittle phases, making brittle crack initiation much easier, compared to that of lower strength steel. In addition, a thick steel plate has lower toughness than a thin plate, since the former has generally coarser microstructures than the latter, and even if their microstructures are almost identical, the thick steel plate has lower resistance to brittle fracture, due to the higher constraint (Anderson, McHenry, and Dawes, 1985) or the greater chances of finding microstructures susceptible to brittle fracture, as a result of larger volume at the crack front (Wallin, Saario, and Torronen, 1984). Therefore, in manufacturing high strength and thick steel plates, securing toughness properties is very crucial, considering inherent characteristics of lower resistance to brittle fracture of high strength thick plates.

It is important to understand that the toughness of a base plate and a weld heat affected zone (HAZ) is dominated by different mechanisms. Weld HAZ toughness generally depends only on chemical compositions of a steel plate, while the toughness of a base plate is controlled by not only chemical compositions but also TMCP parameters, such as reheating, rolling and cooling conditions. In designing a new steel plate, chemical composition is designed from the viewpoint of how good HAZ toughness will be and then TMCP parameters are modified for attaining the required properties for the base plate. Thus, different methodologies should be applied to improve the toughness of the base plate and weld HAZ.

In this study, several important factors, affecting the toughness of a base plate and weld HAZ, were investigated by performing crack tip opening displacement (CTOD) and Charpy impact tests.

EXPERIMENTAL PROCEDURES

In order to examine the effects of TMCP parameters on the toughness of a base plate, a 300 mm thick slab produced in the production mill was prepared and divided into halves in the thickness direction. Subsequently, they were rolled down to 30 mm steel plates in the laboratory. During plate making process, several TMCP parameters, such as a reheating temperature, a rolling reduction per pass in the recrystallization region and a finish cooling temperature (FCT), were changed.