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Concepts of grade X100 for high toughness and strain based design application

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ABSTRACT

The first studies on grade X100 were focussed on fracture propagation control. Therefore the requirements for intrinsic crack arrest were intensively studied. As a result a first-generation was developed with highest possible toughness.
A second-generation was required for arctic or seismic regions with ground movements. The technology for such regions demands a strain-based design. Low Y/T-ratio and adequate uniform elongation are becoming of vital importance and are in the center of the efforts for the development of.
The demanded properties can be obtained by appropriate design of the microstructure. Especially the second phase becomes of extreme importance. This calls for adequate chemical composition in combination with adapted TMCP processing parameters.
This paper illustrates the different production concepts. Mechanical properties achieved on prototype plate are presented. Microstructures will be specified and related to the properties. As the plate results are affected by the subsequent forming and aging during UOE manufacturing and pipe coating the influence of these production steps on the mechanical properties in the final delivery condition are furthermore summarized.

KEY WORDS: X100; Strain-based design; Toughness; Uniform elongation; Yield to tensile ratio, coating

INTRODUCTION

The application of a very high strength steel of grade X100 is of interest for very long-distance gas transmission pipelines as it promises certain economic benefits. These benefits can be achieved either through the application of higher service pressure or by reduced pipe wall thickness. Such pipelines must be safe and reliable in operation. The required resistance to a propagating ductile fracture crack was a main obstacle to be overcome before the use of such high strength steel. The toughness values required for intrinsic crack arrest were in the focus of studies (Demofonti et al., 2002). As a first target the development of grade X100 with enhanced toughness was defined. Further investigations proved that even if very high toughness steels are applied, not for all the envisaged conditions intrinsic crack arrest is guaranteed and for these cases crack arrestors are called for (Demofonti et al., 2004).

Interesting field of application for economic very long distance pipelines are in seismic and low temperature regions (Glover et al., 2002). For such applications so called strain-based design is introduced and aims to prevent buckling due to ground movement. Specific emphasis is given on the Y/T-ratio, uniform elongation (UEL) and shape of the stress strain curve.

This paper illustrates the different production concepts for steels with very high toughness and strain-based design application. Mechanical properties and microstructures achieved on prototype plates and pipes are presented.

PLATE AND PIPE PRODUCTION

Results from industrial material presented in this paper have been produced applying clean steel practice (Bannenberg, 2001). All steels were produced with lowest contents of P, S and O, are vacuum and Ca treated and received a special cleanness treatment. To prevent accumulation of inclusions all the slabs are cast on a fully vertical type caster with bending and straightening after complete solidification. Selective measures are performed to minimize segregation during casting (Harste et al., 1997).

Metallurgical mechanisms which permit the achievement of the demanded mechanical and technological properties must be activated by alloying and at the different plate making stages. TM (Thermo-Mechanical) Rolling was performed on two 4high rolling stands (roughing and finishing mill) followed by cooling in a MULPIC (Multi Purpose Interrupted Cooling) device (Streisselberger et al., 2004; Kirsch et al., 1999)

The pipes are manufactured by the U-O-E process at the 18 m production line of EUROPIPE Muelheim large diameter pipe mill. After plate input, edge crimping and U-forming, the plates are formed