ABSTRACT

Recent sulfide stress cracking failures of Thermo-Mechanically Controlled Process (TMCP) pipelines have been associated with thin surface layers of high hardness termed Local Hard Zones, which develop during TMCP manufacturing. The use of TMCP pipe for sour applications thus requires a fundamental change in the associated qualification procedures. This paper presents a case study of a new qualification approach, designed to optimize TMCP processing windows and reject plates that may contain Local Hard Zones. Critical materials are sampled and then tested according to the requirements of NACE MR0175/ISO 15156. The updated components of manufacturing and testing will be highlighted.

KEY WORDS: TMCP; pipe; sour service; sulfide stress cracking; Full Ring Ovalization Testing; hard zones.

INTRODUCTION

Recent high-profile failures of sour service pipelines have led to concern in the oil and gas industry surrounding the use of Thermo-Mechanical Controlled Processing (TMCP) steels in severe sour service applications. Failures identified in bulk line pipe have been attributed to regions of high surface hardness (North Caspian Operating Company Sustainability Report, 2015). When exposed to severe sour environments, hard zones on the inner diameter surface of line pipe can initiate sulfide stress corrosion cracks (SSC), ultimately leading to pipe leakage (Baxter, Ostby, Chong, Venas, 2018). Hard zones observed in the field tended to be infrequent, random in location, and very thin (≤ 0.5 mm in thickness). These traits make identification and prevention of hard zones in manufactured line pipe using conventional material qualification exceedingly difficult. The use of TMCP line pipe for sour service applications, therefore, requires a thorough investigation of potential hard zone formation mechanisms.

Two causes of hard microstructure in TMCP steels (carbon contamination, dual-phase microstructures) have been previously understood in the steelmaking industry. More recently, and as evidenced by the previously noted failure, a hypothesis has been put forth that hard zones can also arise from the Accelerated Controlled Cooling (ACC) stage used immediately after plate rolling. These thin surface layers have been termed local hard zones (LHZs) to distinguish them from previously known phenomena. In the LHZ root cause, localized overcooling is promoted by inhomogeneities in the oxide scale present on the plate surface and how these surface conditions interact with the water applied during ACC. A more detailed explanation of the LHZ mechanism is available elsewhere (Fairchild, Newbury, Anderson, Thirumalai, 2019).

Years of study to understand the LHZ mechanism has led to a customized qualification program designed to detect, and perform SSC testing on, potential regions of LHZ formation (Newbury, Fairchild, Prescott, Anderson, Wasson, 2019). When successfully carried out, the program (hereafter called the Sour Service Line Pipe Qualification Program) establishes new acceptance criteria to be used during TMCP manufacturing that prevents the installation and operation of line pipes containing LHZs.

The following paper describes a case study of a successful application of the mill qualification program, carried out at JFE Steel’s TMCP manufacturing facilities in Fukuyama, Japan. Special focus is placed on the unique elements used during the pipe manufacturing and testing stages.

SOUR SERVICE LINE PIPE QUALIFICATION PROGRAM

Plate Manufacturing and Qualification Testing Philosophy

The first stage of the mill qualification was to produce X65M (L450M) grade pipes of 28” outer diameter (OD) and 30mm wall thickness (WT). Most of the stages followed standard plate- and pipe-making practices, so the following description will focus on those aspects that were unique. Two heats of steel were developed (see chemistries in Table I) to cast a series of 21 slabs, and standard TMCP rolling techniques were used to produce mother plates. The ACC stage used to achieve the desired microstructures was modified for the purposes of the qualification program. A majority of the mother plates were cooled using standard ACC process conditions, i.e. settings representative of sour service grade steel manufacturing. A small subset of plates were manufactured using higher levels of cooling that would be either at, or just beyond, production cooling protocol. These two conditions were labeled the