

Cold Work Qualification of UNS N08935 for Use in Chloride and Sour environment

Karen Picker
Sandvik Materials Technology
8618 W Little York Rd
Houston, TX 77040
United States of America

Luiza Esteves
Sandvik Materials Technology
8618 W Little York Rd
Houston, TX 77040
United States of America
luiza.esteves@sandvik.com

Marcelo Senatore
Sandvik Materials Technology
8618 W Little York Rd
Houston, TX 77040
United States of America

ABSTRACT

Twisting and U-bending of heat exchanger tubing are common practices employed to enhance operating conditions and plant design. Both methods result in cold plastic deformation which can have an impact on the mechanical and corrosion properties of the material. This paper is focused on the effect of the cold plastic deformation on austenitic stainless steel (UNS N08935) and the necessity of subsequent solution annealing. The material qualification was evaluated by mechanical and corrosion properties using results of hardness, pitting corrosion resistance (ASTM G48 Method C), and stress corrosion cracking in sour conditions (NACE TM0177). The results will be able to demonstrate if the cold work deformation on alloy 35Mo will affect the use of this alloy in heat exchangers applications in the refinery industry in the cold-worked condition without the need of re-solution annealing.

Keywords: Twisted Tube, UNS N08935, pitting resistance, stress corrosion cracking testing, sour condition, bending, solution annealing, super austenitic, Nickel alloy, refinery

INTRODUCTION

UNS N08935 is a new versatile super austenitic alloy with extreme pitting resistance as indicated by its pitting resistance equivalent number (PREN) of 52. It can be used in a broader temperature range than superduplex and hyperduplex stainless steels, offers good weldability and is more cost-effective than Nickel-based materials which make the grade a good candidate for O&G applications, refineries, and chemical industries.^{1,2}

© 2022 Association for Materials Protection and Performance (AMPP). All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means (electronic, mechanical, photocopying, recording, or otherwise) without the prior written permission of AMPP.

Positions and opinions advanced in this work are those of the author(s) and not necessarily those of AMPP. Responsibility for the content of the work lies solely with the author(s).

In heat exchangers, twisted tube technology and U-bundle design are used to achieve better heat transfer efficiency. Shargay *et al.* showed that heat treatment of UNS S32100 austenitic stainless steel twisted tubes is required to have equivalent chloride stress corrosion cracking resistance to non-twisted tubes.³ The tensile residual stress introduced by cold deformation will usually reduce the pitting corrosion resistance.⁴ As twisting and U-bending is a common practice to enhance operating condition and plant design, especially in the heat exchanger, this investigation is evaluating the effect of cold-working or plastic deformation on pitting corrosion resistance and the stress corrosion cracking resistance in sour conditions. For this reason, the aim of this paper is to evaluate the effect of cold deformation on the mechanical and corrosion properties of UNS 08935 alloy and to demonstrate if this alloy is still suitable to be used in heat exchangers applications in the refinery industry in the cold-worked condition without the need of re-solution annealing. The susceptibility of pitting corrosion, chloride stress corrosion cracking, and sulfide stress corrosion cracking will be performed in the twisted tubes and-bends specimens of UNS 08935. In addition, welded tubes of UNS 08935 will be evaluated.

MATERIALS AND METHODS

Materials

Twisted tubes, u-bend specimens each bent to 1.5D, 2D, and 3D, and welded tube corrosion testing specimens were produced from 1.000 inches ODx0.083 inches AW (25.4 x 2.11 mm) Sanicro 35[†] (UNS 08935) straight tubes. The chemical composition of the alloy is shown in Table 1. Two specimens from each as well as two straight reference specimens were employed in the test. The welded specimens were produced according to the welding parameters:

- TIG welding
- Shielding gas (98% Ar + 2% N₂)
- Filler Metal: UNS N06059
- Interpass Temperature: max. 50 °C

Table 1
Chemical composition (wt. %)

Alloy	C	Ni	Cr	Mo	N	Cu
UNS 08935	≤0.030	35	27	6.5	0.3	0.2

[†] Trade Name.

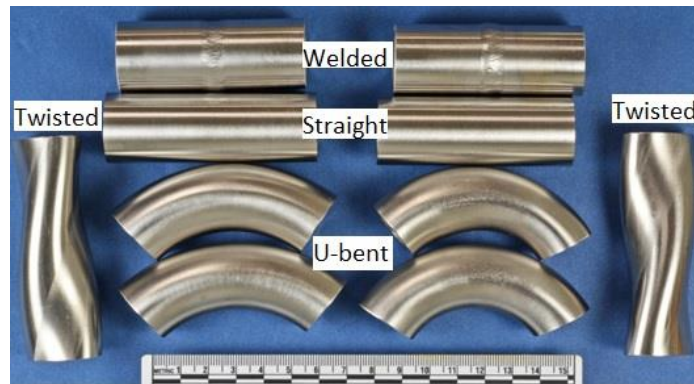


Figure 1: Specimens of UNS N0835 (alloy 35Mo).

Hardness

U-bend UNS 08935 (Alloy 35Mo).

Vickers hardness was measured using hardness tester under the applied load of 500 g. The straight specimens were measured at three different locations: sub-surface of tube OD, mid-wall, and sub-surface of tube ID. The bent specimens were cut and a whole tube cross-sectional area was mounted, and polished as shown in Figure 2 (a). Then, each cross-section was measured at the tension point (outside of the bend with maximum tension stress), compression point (inside of the bend with maximum compression stress), and neutral point (theoretical neutral location of the bend). Additionally, each of these hardness testing locations (tension, compression, and neutral) was divided into three sections: sub-surface OD, mid-wall, and sub-surface ID (Figure 2 (a)), and five hardness measurements were taken at each section using the Vickers scale with a load of 500 g as shown in Figure 2 (b).

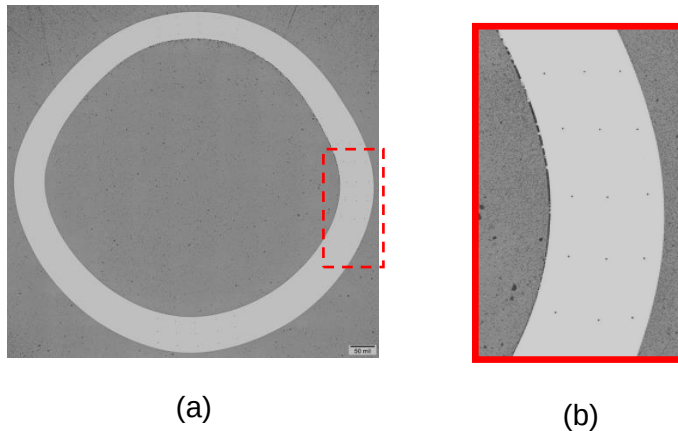


Figure 2: (a) Cross-Sectional Area of tube mounted and polished showing the three testing locations: tension, compression, and neutral points of the bends and (b) micro-hardness indentation showing three sections and five measurements points per section.

Twisted UNS 08935 (alloy 35Mo).

The Vickers hardness of the twisted tubes was also measured using a 10 kg weight in the following positions as shown in Figure 3.