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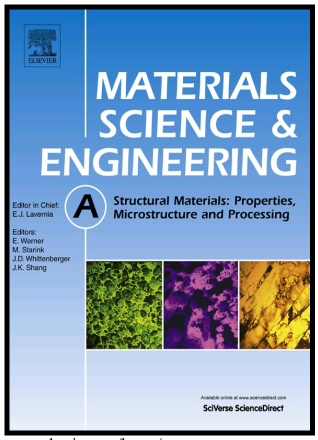

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PII: S0921-5093(16)31113-3
DOI: http://dx.doi.org/10.1016/j.msea.2016.09.045
Reference: MSA34130

To appear in: *Materials Science & Engineering A*

Received date: 6 July 2016
Revised date: 10 September 2016
Accepted date: 13 September 2016

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Abstract

Improvement of the general mechanical properties and in particular sub-zero impact toughness in a 0.2%C-13%Cr martensitic stainless steel has been explored by varying the hot deformation and heat treatment conditions. The deformation conditions include hot rolling an ingot in one case and cogging the ingot to a semis followed by hot rolling in another case. The bars made from both routes were subjected to a single hardening heat treatment at 980°C and 1040°C oil quenched and a double hardening heat treatment at 1040°C followed by 980°C oil quenched. The hardened steels were subjected to a standard two stage tempering at 710°C followed by 680°C. The impact toughness was found to be doubled in the cogged and rolled steel in double hardened condition. Other processing conditions show varying impact toughness levels. The toughness observed was correlated to the grain size and the carbide distribution in the matrix and the fractography features.

Keyword: Martensitic stainless steel deformation, 13%Cr steel, single hardening, double hardening, grain boundary carbide, grain refinement

1.0 Introduction

There are several applications which demand superior strength-toughness and corrosion resistance in industrial sectors such as oil and gas, power generation and petrochemical. The 13%Cr stainless steel is a popular grade in the oil & gas industry [1] due to its lower cost with a combination of strength, toughness and corrosion resistance compared to the other grades of stainless steel family. The popularly used 13%Cr martensitic stainless steel grade contains about 0.2%C content, which on heat treatment exhibit a tempered lath martensitic structure with fine distribution of carbide that strengthens the matrix. The size, shape and distribution of the carbides and the grain size affect the mechanical properties especially sub-zero impact toughness of the steel. The carbide distribution and grain size is influenced by hot deformation and the heat treatment. Straight Cr martensitic stainless steels are easily forgeable and the hot working and deformation characteristics of the 0.2%C–13%Cr steel involves deformation in the fully austenite regime at temperatures between 1050°C to 1230°C, where there is complete absence of delta ferrite [2].

Post hot working the steel is slow cooled to room temperature leading to the formation of lath martensite microstructure. The hot worked steel is softened for fabrication by full annealing between 830 to 885°C [2], where the microstructure obtained has spheroidized carbides in a ferritic matrix. The carbides in annealed condition show up $M_{23}C_6$ type carbide along grain boundary along with presence of M_7C_3 type carbide [3-7]. Increasing the annealing time is reported to convert M_3C to M_7C_3, which after long time exposure form $M_{23}C_6$ carbides. The annealed steel after fabrication is strengthened by hardening and tempering. Hardening is usually carried out by austenitising in the range 965°C to 1050°C followed by air cooling, oil or polymer quenching [2]. At low austenitizing temperature (965°C - 1000°C), the dissolution of carbides in austenite is not complete and residual