International Journal of Computationaland ExperimentalScienceandEngineering (IJCESEN)
Vol. 3-No.2 (2017)pp. 33-36
http://iakkurt.dergipark.gov.tr/ijcesen

ISSN:2149-9144

ResearchArticle

Effect of Microstructure on mechanical and Charpy impact properties offerrite-martensite dual phase API X52 pipeline Steel#

Belkacem BOUTESSOUNA*, Sami Zedlman,Omar ALLAOUI

Laboratoire de Génie des Procédés, Université Amar Telidji, Laghouat 03000, Algérie.

*bel.boutassouna@lagh-univ.dz

(First received 25 November 2016 and in final form 20 April 2017)

Presented in "3rd International Conference on Computational and Experimental Science and Engineering (ICCESEN-2016)"

Keywords
Intercritical annealing treatment,
Dual-phase steel,
Tensile properties,
Charpy impact test

Abstract: The microstructural changes that occur during intercritical annealing treatment at 780°C of API X52 steel have been investigated. Three treatments were developed to produce dual phase (DP) microstructure: Intermediate Quenching Treatment/Air (IQ/A), Intermediate Quenching Treatment/Water (IQ/W) and Step Quenching Treatment (SQ).The IQ/W resulted in the formation of fine and fibrous martensite morphology uniformly distributed in the ferrite matrix. However, the IQ/A treatment showed a spherical network of martensite along the ferrite/ferrite grain boundaries. The SQ yielded blockly and banded martensite and ferrite morphology. The experimental results show that API X52 (DP) steel with finely dispersed microstructures (IQ/W) have higher Charpy impact properties and lower ductile–brittle transition temperature (DBTT)than (DP) steel with banded microstructures.A carefully conducted comparison of fracture surfaces of the representative specimens obtained after IQ and SQ treatments has been studied.

1. Introduction

Dual-Phase (DP)steels are constituted by a ferrite matrix with a martensite fraction, givinga good combination of strength, ductility, capacity of energy absorption and strain hardening. Mechanical properties are controlled by martensite and ferrite fractions, martensite carbon content, grain sizes and strength of both phases[1,2]. In ferrite–martensite (DP) steels, the morphology of martensite had a significant impact on the mechanical properties of (DP) steels [3,4]. (DP) steels, with fine and fibrous martensite uniformly distributed in the ferrite matrix, provide the best combination of strength and ductility compared with those that had blocky ferrite–martensite[4,5].This observationsuggests that it may be possible to improve the impact properties by developing microstructures with very fine grains and uniform distribution of ferrite and martensite phases. In this investigation the microstructural changes
that occur during intercritical annealing treatment at 780 °C and the effects of microstructural factors on Charpy impact and tensile properties of API X52 HSLA steel were investigated. The impact properties are discussed, using the obtained Charpy curves. From these curves the ductile–brittletransition temperature DBTT is identified.

2 EXPERIMENTAL PROCEDURE

The chemical composition of the API X52 steel used in this investigation is shown in Table1. The steel was supplied by Pipegaz society (Ghardaia, Algeria). Impurity levels of P and S are very low, especially with regard to the sulphur content. performed in the temperature range from - 60 °C to + 20 °C using a impact tester (model Controlab R0042 N° V12001) of 450 J capacity. In addition aductile–brittle transition temperature DBTT was determined.

***Table 1**. Chemical composition of API X52 steel (wt %)*

Elem	C	M	Si	S	P	Ni	V	Ti	Al

ents		n							
API X 52	0. 12	1. 22	0. 23	0.0 01	0.0 11	0.0 3	0. 03	0.0 02	0.0 34

Fracture surfaces of Charpy impact specimens were analyzed using a JEOL JSM-6360LV Scanning electron microscope.

To obtain dual phase steels with various morphologies, three kinds of heat treatment were used as shown in Fig.1. Specimens were cut from different treatments and mounted for metallographic examination. Standard grinding and polishing techniques were employed, and specimens were etched with 3 pctnital solution. Conventional light microscopy was used to make a comparative examination of the overall microstructure of the API X52 steel. Tensile testing was conducted at room temperature in a computer controlled Mohr FederhaffLasenhausen System Machine. According to ASTM A370, standard specimen for Charpy impact tests were

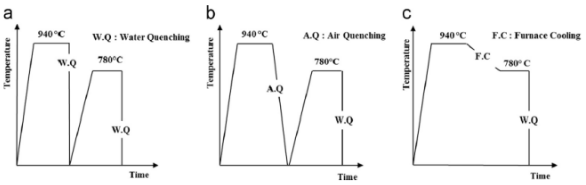

Figure 1.*Schematic representation of heat treatments schedules for (a) IQ-W (b) IQ-A (c) SQ treatments.*

3 RESULTS AND DISCUSSION

3.1 Microstructures

Fig. 2 shows the optical micrographs of API X52 (DP) steel subjected to different heat treatment schedules treated at Intercritical Annealing Temperature (IAT) =780°C. The IQ/W microstructures showed fine and fibrous martensite uniformly distributed within the ferrite matrix (Fig. 2a), whereas IQ/A microstructure showed polygonal

ferrite surrounded by martensite network (Fig. 2b) and SQ microstructures revealed blocky and banded ferrite–martensite phase (Fig. 2c

The difference in the microstructural state of the specimen reached before intercritical treatment may be held responsible for the observed differences in the martensite morphologies and distributions. In IQ/W treatment, martensitic microstructures were annealed in the (α+γ) region which provides numerous sites for nucleation of both the austenite and ferrite phases. The nucleation of austenite from the initial martensitic microstructure starts at the prior austenite grain boundaries, and also at the martensite 1ath boundaries. The microstructures developed with prior pearlite-ferrite phases (IQ/A treatment) consisted of polygonal ferrite surrounded by dark etching martensite network, especially along the ferrite/ferrite grain boundaries, following the location of pearlite in the initial (ferrite+pearlite)microstructure. In the case of SQ treatment

, the initial phase before two phases annealing is austenite. Upon decreasing the temperature to the (α+γ) region, ferrite nucleates at the grain boundaries of austenite and grows within the austenite grains [6,7]. Such a ferrite–austenite structure has resulted into a (DP) microstructure with alternate bands of ferrite and martensite after quenching from (α+γ) region.The martensite volume fractions (MVF) obtained under (IQ), (DQ) and (SQ) treatments were quantified at 52 %, for the annealing temperatures of 760 °C.Similar IAT of 780 °C resulted in identical martensite content for different intercritical heat treatments was reported by Ahmed et al. [7]

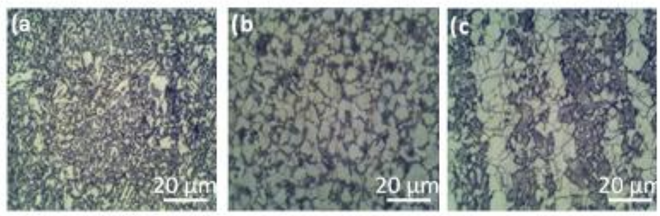

Figure 2: *Optical micrographs of a) IQ/W, b) IQ/A, and c) SQ treatments, showing ferrite (white) and martensite (black).*

3.2 Mechanical properties.

The yield, ultimate tensile strength and elongation of IQ/A, IQ/W and SQ treatments are shown in Table2. The tensile properties change significantly with the heat treatment schedules, which can be attributed to the difference of ferrite-martensite morphologies, and distributions. The highest yield strength (500 MPa) and ultimate tensile strength (800 MPa) was observed with the IQ/water microstructure. Among the different treatments, IQ/W treatment clearly yields the most attractive combination of strength and ductility compared to IQ/A and SQ treatments. The lowest elongation of SQ treatment is probably due to the fact that ferrite grains fracture in a brittle mode prior to the martensite fracture during necking.This is caused by the local internal stress produced in the vicinity of the ferrite/martensite interface during deformation [7].In the IQ/W specimen (Fig. 2a), finer and fibrous martensites restrict the growth of microvoids as they encounter the frequent discontinuities in the ferrite/martensite interfaces which delay the void coalescence resulting into higher values of elongation to failure. However, in the case of IQ/Air microstructure (Fig. 2b), the microvoids formed at the ferrite/martensite interfaces can easily grow along the grain boundaries continuously due to the fact such grain boundaries are having higher concentration of transformation strain and are nearly continuous.

Table 2. *Tensile and Charpy impact properties of X52 DP steels treated at 780°C.*

	YS(MPa)	UTS (MPa)	A (%)	USE (J)	DBTT (°C)
IQ/W	500	800	28	210	< - 60
IQ/A	452	700	19	154	- 50
SQ	485	720	12	23	- 12

3.3 Charpy Impact and fracture properties

In HSLA steels, strength is mainly represented by yield strength, while toughness is largely considered in terms of (DBTT) and absorption energy at a given temperature or upper-shelf energy USE. The variation of Charpy impact energy test data from specimens annealed at 780°C under IQ/A, IQ/W and SQ treatments, as a function of test temperatures are shown in Fig. 3.The data indicate that the DBTT of the IQ/W specimen based on the criterion of 28 J absorbed energy is lower than - 60 °C. The DBTT of the SQ and the IQ/A specimens are -12°C and -50°C, respectively. The USE values of the IQ/A treatment begins at approximatively 0°C with absorbed energy of about 154 J, and the USE of the SQ treatment begins at approximatively +20°C with absorbed energy of about 100 J. The DBTT of the SQ treatment is higher than that of the IQ/W treatment because the SQ microstructure contains a considerable amount of continuous coarse ferrite and martensite with probably large effective grain size.Hence, it can be concluded that higher toughness values in IQ/W specimens are associated with finer martensite.It is interesting to note that the Charpy impact energy value tested at room temperature is higher for IQ/W treatment than for IQ/A treatment and SQ treatment at comparable Vm.

This substantiates the fact that the finely dispersed ferrite is beneficial to toughness [2].
The fracture surfaces of IQ/W, IQ/A and SQ specimens tested at room temperature are presented in Fig. 4.

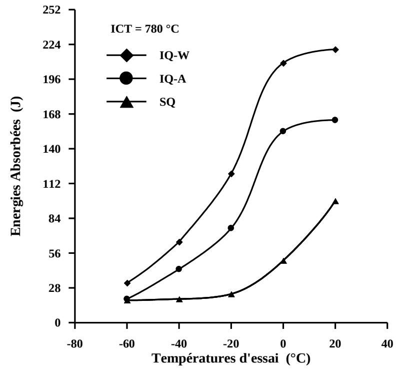

Figure 3.*Charpy impact energy as a function of temperature of all treatment treated at 780°C*

first or by ferrite–martensite interfacial separation [8]. Micro-cracks propagate either by cleavage or by dimple mode, depending on the state of the stress present in the microstructures.
It reveals mixtures of cleavage and dimples for all the specimens. The area of cleavage surfaces increases in the order of SQ > IQ/A > IQ/W treatments, whereas the areas of dimples increase in the reverse order. The size of dimple in the IQ/W treatment is extremely fine compared to the SQ specimen, indicating higher impact energy value tested at + 20 °C for the IQ/W (210 J) than the SQ (99 J). This is probably due to the presence of large blocky martensite zone. The fracture surfaces of IQ/W, IQ/A and SQ specimens tested at -40 °C are presented in Fig. 5. The SQ specimen shows a completely brittle cleavage cracking, and complex river patterns consisting of small cleavage steps (Fig. 5c) while in the IQ/W specimen, both dimples and cleavage facets can be seen.When load is applied to (FMDP) steels, it is anticipated that fracture occurs by fracture of hard martensite

(a)

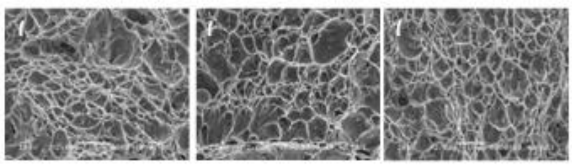

Figure 4. *SEM Fractographs of Charpy impact specimens fractured at R.T.,a) IQ/A, b) IQ/W, c)* SQ

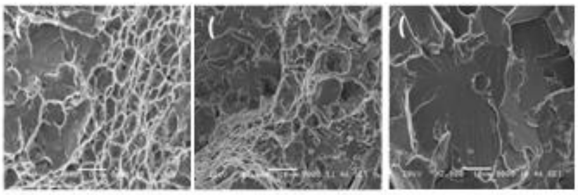

Figure 5. *SEM Fractographs of Charpy impact of specimens fractured at -40 °C,a) IQ/A, b) IQ/W and c) SQ*

4 CONCLUSIONS

On the basis of the experimental work that has been carried out and presented is this article, the following conclusions can be drawn.

1. Prior microstructure has a great influence on the evolution of ferrite and martensite morphologies.
2. IQ/W, IQ/Air and SQ treatments resulted in fine and fibrous martensite uniformly distributed within the ferrite, polygonal ferrite surrounded by martensite network and blocky and banded ferrite-martensite microstructures, respectively.
3. IQ/W treatment provided the best combination of strength and ductility of DP steels with fine and fibrous martensite morphologies.
4. IQ/W treatment exhibited better impact properties than IQ/Air and SQ treatments as expressed by its lower DBTT and higher USE values.

REFERENCES

[1] R.O. Rocha, T.M.F. Melo, E.V. Pereloma, D.B. Santos, Microstructural evolution at the initial stages of continuous annealing cold rolled dual phases steel, Materials Science and Engineering: A, *391* (2005) 296-304.*DOI:10.1016/j.msea.2004.08.081*.

[2] M. Nishiyama, K. Park, N. Nakada, T. Tsuchiyama, Effect of the martensite distribution on the strain hardening and ductile fracture behaviors in dual-phase steel, Materials Science and Engineering: A, *604* (2014) 135-141.*DOI:10.1016/j.msea.2014.02.058*.

[3] A. Bag, K.K Ray, E.S. Dwarakadasa, Influence of martensite content and morphology on tensile and impact properties of high-martensite dual-phase steels, Metallurgical Transaction A 30 (1999) 1193–1202. *DOI:10.1007/s11661-999-0269-4.*

[4] H. Seyedrezai, A.K. Pilkey, J.D. Boyd, Effect of pre-ic annealing treatments on the final microstructure and work hardening behavior of a dual-phase steel, Materials Science and Engineering: A, *594* (2014) 178-188. *DOI:10.1016/j.msea.2013.11.034.*

[5] E. Fereiduni, S.S.G. Banadkouki, Improvement of mechanical properties in a dual-phase ferrite–martensiteaisi 4140 steel under tough-strong ferrite formation, Materials & Design, *56* (2014) 232-240. *DOI:10.1016/j.matdes.2013.11.005*.

[6] A. Karmakar, M. Ghosh, D. Chakrabarti, cold-rolling and inter-critical annealing of low-carbon steel: effect of initial microstructure and heating-rate, Materials Science and Engineering: A*564* (2013) 389-399. *DOI:10.1016/J.MSEA.2012.11.109.*

[7]E. Ahmed, T. Manzoor, M.M.A. Ziai, N. Hussain, Effect of martensite morphology on tensile deformation of dual-phase steel, Journal of Materials Engineering and Performance, *21* (2012) 382-387.*DOI:10.1007/s11665-011-9934-z.*

[8]B. Hwang, C.G. Lee, S.J. Kim, Low-temperature toughening mechanism in thermomechanically processed high-strength low-alloy steels, Metallurgical and Materials Transactions A 42 (2011) 717–728.*DOI:10.1007/s11661-010-0448-3*