Microstructure, Texture – Mechanical Properties Relations for Steel Grades API-X80 and API-X70.

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Abstract□**Steel grades of API X80 and X70 are commonly used for pipeline gas transport. The most important mechanical properties for this application are the fracture toughness and the strength. A remarkable directional anisotropy of toughness was found in the studied materials and various microstructural characterization techniques (Optical Microscopy, Electron Back Scattering Diffraction, XRD and the recently developed 3D-EBSD technique) were applied to link the microstructure and microtexture with the toughness anisotropy. As result the effective grain size, grain boundary misorientations, grain shape orientation, microstructural constituents and aspect ratio of the grains were quantified. The results displayed that anisotropy of the impact toughness could be linked to the microstructure anisotropy whereas the crystallographic texture of the plates plays secondary role.**

Keywords□ **Charpy toughness, microstructure characterization, microconstituents, low bainite.**

I. Introduction

High strength and toughness are the most common requirements for the pipeline steels but often they display very high anisotropy which mechanism is not well understood. This study aims to find the relation between the microstructure/texture of pipeline steels and the Charpy toughness anisotropy. The later is commonly measured by the amount of energy absorbed by a Charpy V-Notch specimen during impact testing.

II. Experimental

A. Material and test procedure.

Charpy impact test was carried out on samples taken from 2 industrial grades pipeline steel-X70 and X80. To describe the anisotropy from each plate were tested 3 samples with long axes oriented at 0°, 22.5°, 45°, 67.5°and 90° with respect to the plate rolling direction (RD) at 5 different temperatures varying from room temperature to -196°C.

B. Microstructural Characterization and Quantification.

Optical microscope study was executed in 9 different points for each sample orientation in bright field after 2% nital etching for 6-8s. High resolution FEG-SEM was used for characterization of the fine microstructure of the plates.

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The microtexture and microstructure for each sample orientation were determined by EBSD (Electron Back Scatter Diffraction) technique, using the OIM® system (Orientation Imaging Microscopy) attached to a FEI XL30 ESEM with LaB_6 filament after mechanical polishing. For each Charpy sample orientation, three EBSD measurements with dimensions 30x60 μm^2 and a step size of 80 nm were made in section parallel to the fracture plane .The orientation data were processed with the commercial TSL® OIM software.

Microstructural characterization method for both studied materials, API-X80 and API-X70, was carefully developed based on Crystal Misorientations and Image Quality of Orientation Imaging Microscope in order to first identify every microstructural constituent and second to find a quantitative description of a microstructural parameter or set of parameters which are responsible for variations of the Charpy impact toughness.

Macrotexture measurements were carried out by a Siemens D5000 difractometer. The ODFs were calculated by means of MTM-FHM software.

III. Results and Discusion

A. Charpy Toughness anisotropy

The steel grade API-X80 presents temperature dependent toughness anisotropy (Chart 1). The anisotropy is characterized by decrease of the toughness in the transition temperature interval (-40°C, -60°C and -80°C) for samples with the long axis oriented 45° with respect to the rolling direction.(cf.Fig1)

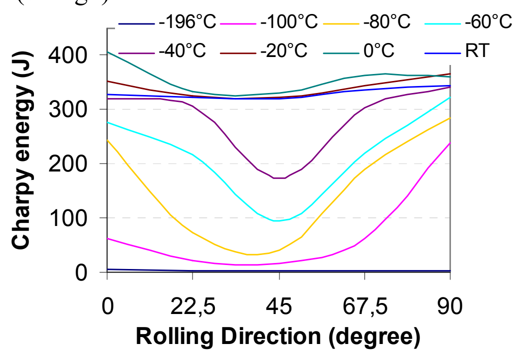

Figure 1. Anisotropy in Charpy impact energy for steel X80

The temperature dependence of toughness anisotropy of pipeline steel grade API-X70 is very weak and orientation dependence is characterized by decreased toughness in the transverse direction. (Fig.2). It is important to mention that the material displays very high toughness even at -100°C i.e. probably the transition temperature is not reached.

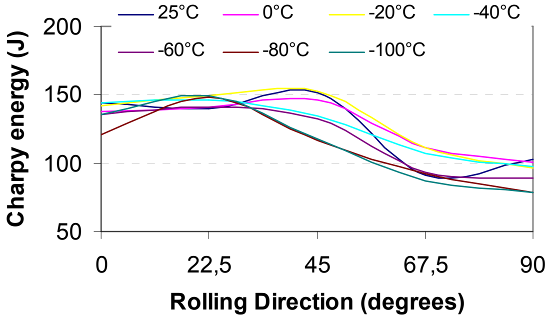

Figure 2. Anisotropy in Charpy impact energy for steel X70

To explain the observed anisotropy a detailed microstructure and texture characterization was executed where every microstructural constituent was identified qualitatively and quantitatively. High resolution FEG-SEM images (Fig.3) discovered the fine and mixed up microstructure of those materials.

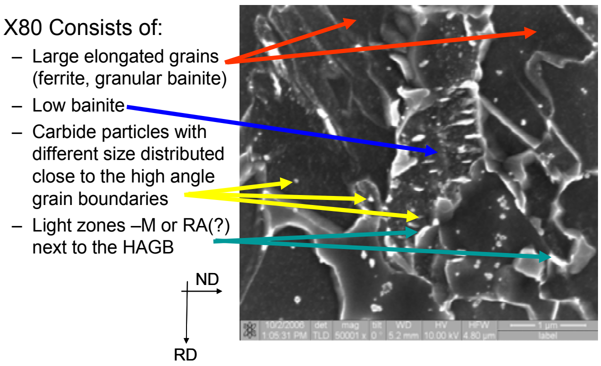

Figure 3. X80. Microstructure Characterization. Micron bar is 1μm.

Microstructural characterization method based on crystal misorientation [1] was developed adapting the method from Zajac *et al.* to the studied materials and applied to the EBSD data. The method identifies the various microstructural constituents with a characteristic crystal misorientation (Fig.4).

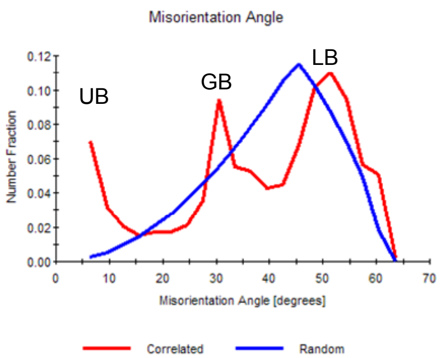

Figure 4. Misorientation angle distribution criteria for different microconstituents observed in the steels- Upper Bainite (UB), Granular bainite (GB) and lower bainite (LB)

The microstructural parameters were analyzed by Image Treatment and Orientation Imaging Microscopy (OIM) in order to quantify the effective grain size, grain boundary misorientations, grain shape orientation, volume fraction of microstructural constituents and aspect ratio of the grains. Results of those quantifications show up the relation between the volume fraction of lower bainite and the toughness anisotropy, since the influence of the remind microstructure parameters investigated could not be linked with the anisotropy. The influence of crystallographic texture was investigated by means of approach proposed by Leon-Garcia *et al* [2] and it was found that its influence on the anisotropy is negligibly small.

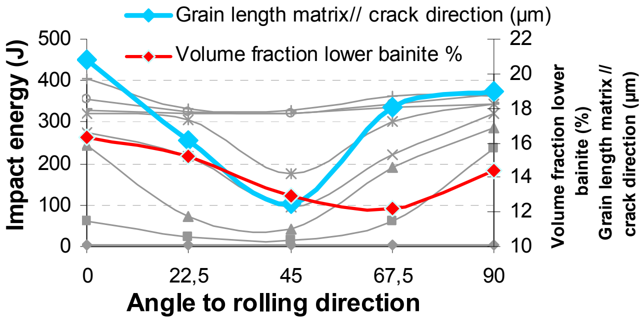

Figure 5. X80. Quantification of microstructure parameters plotted versus sample orientation.

The red line represent the variations of the volume fraction of lower bainite for which is known to have positive effect on the Charpy impact toughness [3]. The decrease of the fraction in orientation 45°RD corresponds to decrease in the toughness. The same general tendency was observed also in steel X70.

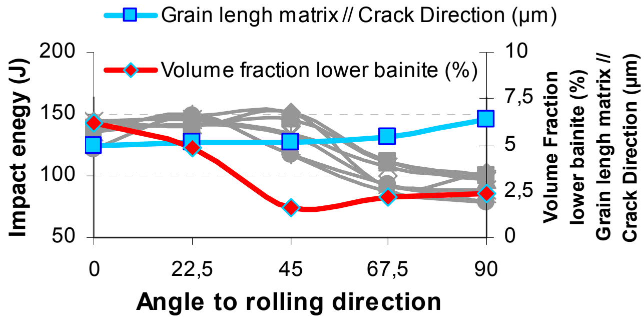

Figure 6. X70. Quantification of microstructure parameters plotted versus sample orientation.

IV. Conclusions

The in plane anisotropy in Charpy impact toughness in both investigated steel grades X70 and X80 is more microstructure than texture dependent.

The observed anisotropy could be well correlated to the distribution of the lower bainite constituent, which has strengthening effect and supports ductile fracture.

Acknowledgements

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References

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