Proceedings of the Seventeenth (2007) International Offshore and Polar Engineering Conference
Lisbon, Portugal, July 1-6, 2007

ISBN 978-1-880653-68-5; ISBN 1-880653-68-0(Set); ISSN 1098-6189 (Set)

On the Relationship between Yield Ratio, Uniform Elongation, and Strain Hardening Exponent of High Grade Pipeline Steels

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ABSTRACT

Physical parameters characterizing the deformation capacities of high grade line pipes were normally yield ratio, uniform elongation, and strain hardening exponent. The purports to control these parameters were presented in the paper and the demand of line pipes to resist plastic deformation was analyzed. By means of statistics and regression analysis of test data, the relationship between uniform elongation, strain hardening exponent, and yield ratio were developed.

KEY WORDS: yield ratio; uniform elongation; hardening exponent; high grade; line pipe steel

INTRODUCTION

Physical Significance of Yield Ratio, Uniform Elongation, Strain Hardening Exponent

Yield ratio is the ratio between yield strength and ultimate strength. Combined with yield strength, the yield ratio represents the capacity of the material to carry the load from yield initiation to fracture.

In a uniaxial tension test, most material can still sustain larger load after initial yielding and show considerable plastic deformation capacity. From the concept of plastic mechanics and material physics, it is the result of strain hardening. If the increase of yield strength caused by strain hardening is greater than the increase of stress caused by the load and the reduction of load-bearing area, localized plastic deformation will not occur and the plastic deformation.will be uniform. However, if the plastic strengthening cannot match with the stress increase, the plastic deformation will be localized. Necking can occur and stress will reach ultimate strength.

The plastic deformation can be expressed by elongation δ, including uniform plastic deformation δB and localized plastic deformation δN. The δB represents the total plastic deformation before reaching the ultimate strength and reflects the strain hardening exponent (n) of the material. In the engineering point of view, the strain hardening exponent indicates the materials' resistance to plastic deformation. It enables the materials to sustain overload and raises the safety margin.

In general, the true stress-true strain curve of polycrystal materials after yielding is paracurve. Within its uniform deformation stage, the relationship between the true stress (σ) and true strain (ε) can be fitted into the Hollomon relationship: $\sigma = k\varepsilon^n$, in which k is strain hardening factor. The strain hardening exponent, n, can be determined from the stress-strain curve by the above equation. The existence of yielding platform and Lüders elongation resulting from stacking fault energy will affect n greatly. With higher stacking fault energy, slip deformation is characterized by smooth slip band. On the contrary, it is characterized by ripple slip band when the stacking fault is low.

The parameters characterizing plastic deformation are not independent. The yield strength, strain hardening exponent, and uniform elongation can determine ultimate strength and yield ratio. For instance, there is a close relationship between the yield ratio and the strain hardening exponent and uniform elongation. It's meaningful to understand them, because the testing of yield ratio is more convenient than that of strain hardening exponent and uniform elongation. Now the yield ratio has been widely used in most oil/gas pipeline technology specifications to measure uniform deformation capacity indirectly, due to its direct and simplified vision.

Significance of Controlling Plastic Deformation Capacity

Safe operation is the basic requirement to oil/gas pipeline projects. Fracture accidents of pipeline will cause serious economic and social loss. Rational design guidelines are of important significance to pipeline construction and service.

Uniform deformation of material will affect processes like plastic