Use of Hollomon Equation in Combination with Conventional Equation, for Finding Change in strain Hardening Exponent Value, among Differently Aged and Tensile tested Maraging Steel Samples

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Abstract

strain hardening exponent can be found using all the available tensile data such as Tensile strength, 0.2% yield strength and Strain at fracture. And compare the heat treated sample for change in strain hardening exponent.

Keywords — *Hollomon equation, Strain hardening exponent, Compare aged samples .Calculating the change in length. Fracture toughness from tensile data, Hahn and Rosen field equation.*

I. INTRODUCTION

Maraging steels are high strength and low ductile materials. Usually maraging steels are cold rolled for improving the strength of the product, however maraging steel is poor in responding to cold work and it is evident from literature available [1] thus maraging steels are aged after cold working to improve the strength.

Strain hardening exponent (n) declares the amount of cold work done. If Value nears zero it shows that the material is perfectly plastic and a value one shows that the material is perfectly elastic.

II. JUSTIFICATION FOR COMBININGHOLLOMON EQUATION AND CONVENTIONAL EQUATION WHICH CORRELATES STRAIN HARDENINGEXPONENT AND THE STRENGTH COEFFICIENT WITH THE YIELD STRESS-STRAIN

Cold-rolled maraging steel will have certain amount of strain hardening and aging will definitely introduce retained austenite which may give Transformation induced plasticity.

By combining Hollomon equation with conventional equation for finding, strain hardening exponent (n) we stand a chance of finding accurate value with high accuracy in terms of material property difference.

Hollomon Equation

The true strain to necking, ε_n, in a uniaxial tensile test provides a valuable measure of the stretch formability of a material (1) – the stretch formability increasing with increasing ε_n and it is expressed as. [2]

$(\sigma) = K.\varepsilon^n$ - (1)

n - Strain hardening exponent
K-Strength coefficient (MPa)
ε-True strain at fracture
(σ)-True stress at fracture (MPa)

$\varepsilon = \ln(L/Lo)$
L - Gauge length after tensile testing.
Lo - Original gauge length before tensile testing.

$(\sigma) = \sigma_N.(1+\varepsilon_N)$ (MPa)
σ_N = Normal stress at fracture (MPa)
ε_N = Normal strain at fracture

III. CONVENTIONAL RELATIONSHIP CORRELATING THE STRAIN HARDENING EXPONENT WITH THE 0.2% YIELD STRESS [3]

$(\sigma_{0.2}) = K.(0.002)^n$ - (2)

n - Strain hardening exponent
K-Strength coefficient
$(\sigma_{0.2})$ - 0.2% Yield strength

COMBINING EQUATION (1) AND (2)

$(\sigma) = K.\varepsilon^n$ (1)
$(\sigma_{0.2}) = K.(0.002)^n$ (2)

Equation (1) can be written as (taking natural log)

$\ln(\sigma) = \ln K + n.\ln(\varepsilon)$ (3)

Same way Equation (2) can be written
$\ln(\sigma_{0.2}) = \ln K + n.\ln(0.002)$ (4)

Equate for log K

$$\ln(\sigma) - n.\ln(\varepsilon) = \ln K \qquad (5)$$

$$\ln(\sigma_{0.2}) - n\,.\ln(0.002) = \ln K \qquad (6)$$

TABLE (1) TABULATION FOR SAMPLE DATA AND RESULT. FOR TENSILE TEST /SAMPLE GAUGE LENGTH 25 MM

HT Condition	T.S (MPa)	0.2% Y.S (MPa)	% Elongation
Aged sample	1720	1771	8
Over Aged sample	1626	1696	10

TABLE (2) FINDING CHANGE IN LENGTH

HT Condition	Change in length (ΔL),mm	L (mm)
Aged sample	0.08 *25	27
Over Aged sample	0.10*25	27.5

TABLE (3) FINDING TRUE STRAIN AT FRACTURE

HT Condition	L (mm)	$\varepsilon = \ln(L/Lo)$ (True strain)
Aged sample	27	0.0769
Over Aged sample	27.5	0.0953

TABLE (4) FINDING TRUE STRESS AT FRACTURE

HT Condition	L (mm)	$\varepsilon = \ln(L/Lo)$ (True strain)
Aged sample	27	0.0769
Over Aged sample	27.5	0.0953

Equate for equation (5) and (6) for log K

$$\ln(\sigma) - n.\ln(\varepsilon) = \ln(\sigma_{0.2}) - n\,.\ln(0.002) \qquad (7)$$

HT Condition	ε_N	σ_N (MPa)	$\sigma = \sigma_N.(1+\varepsilon_N)$ (MPa)
Aged sample	0.08	1720	1858
Over-Aged sample	0.10	1626	1788

TABLE (5) RESULTS

HT Condition	(n)
Aged sample	0.0131
Over-Aged sample	0.0138

Legends used in equations	
T.S	Tensile strength (MPa)
0.2% Y.S	0.2% Yield strength (MPa)
Lo	Gauge length of sample (25 mm assumed)
L	Gauge length after tensile testing
ε_N	Normal strain at fracture.
σ_N	Normal stress at fracture.
n	Strain hardening exponent
H.T condition	Heat treatment condition.

IV. CONCLUSIONS

- The strain hardening exponent value (n) can be seen differing for different data values.
- This method of finding (n) can be used for finding the difference among heat treated samples and arriving at conclusions.
- This method may be used for finding, strain hardening exponent (n) to be used in Hahn and Rosenfield equation to find fracture toughness of thin walled materials. [4]

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