NSWC/USNA Workshop on Fracture in the Ductile-Brittle Region

Estimating Cleavage Stress For Ferritic Steels From Measured Jc Values in the Transition Region

Texto completo
considerar os 2 autores
(de acordo c/ o autor)

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CLEAVAGE STRESS ESTIMATION

. Ductile Fracture X Brittle Fracture

  Ferritic Steels; Low Temperatures

  Embrittlement - Neutronic and Thermal

. Transition - Scatter (Vary with the test temperature)

  - Combination of brittle and ductile fracture mechanisms
  - Strong influence of specimens dimension and geometry
  - Statistics - The WEIBULL Probability
  - Constraints

. The Two-Parameter Theory J-Q

. Behavior Prediction in the Transition : The Landes Procedure

. **Cleavage Stress Prediction**

  . Results

K → no plasticity (a very localized one)

J → some plasticity (a limited one)

Usual Approach:

One-Parameter Theory

The Two Parameter Theory (J - Q)

Q - associated with the constraint level in the geometry and it is independent of the radial distance r from the crack tip.

This parameter can be seen as the second term in the expansion of the stress field expressions in a series and can be interpreted as

$$Q = \frac{\sigma_{\theta\theta}}{\sigma_o} - \left(\frac{\sigma_{\theta\theta}}{\sigma_o}\right)_{SSY}$$

; When the constraint are high **Q** → 0.

BEHAVIOR PREDICTION IN THE TRANSITION

To obtain the toughness distribution values Jc2 for a given geometry G2 and temperature T2 from the results Jc1 obtained from another geometry G1 and temperature T1.

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Basic Hypothesis:

a) the cleavage is triggered in the weak-link sites,

b) the distribution of the distances r_{wl} between the crack tip and the nearest weak link is a material property,

c) the stress level to trigger the fracture is the cleavage stress σ_c and once reached the specimen fails,

d) this cleavage stress is a material property and is supposed invariant with the temperature.

Basic Input:

. the toughness distribution Jc1 values for a given temperature T1 and from a given geometry G1,

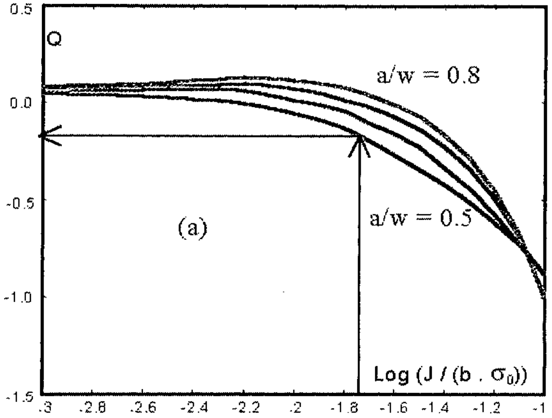
. the σo or σys stress should be known at T1 and T2 and

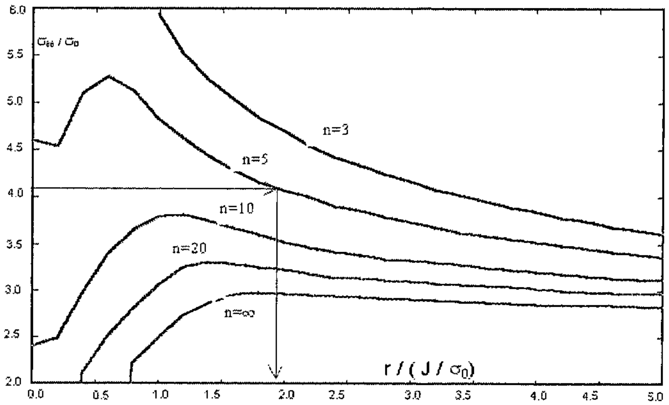
. the Q parameter for the geometries G1 and G1 and the normalized stress fields

. the cleavage stress σ_c $\sigma_{c} >> \sigma_{uts}$

1 - Jc Prediction (Jnew) - Part I: Rwl Calculation

$\text{Log}\left(\frac{J_1}{b.\sigma_o}\right)$	Q_1 (a/w, n)	$\frac{\sigma_c}{\sigma_{o,1}} - Q_1$	$\frac{r}{J/\sigma_o}$	$\frac{J_1}{\sigma_{o,1}}$	$R_{wl} = \frac{r}{J/\sigma_o} \times \frac{J_1}{\sigma_{o,1}}$



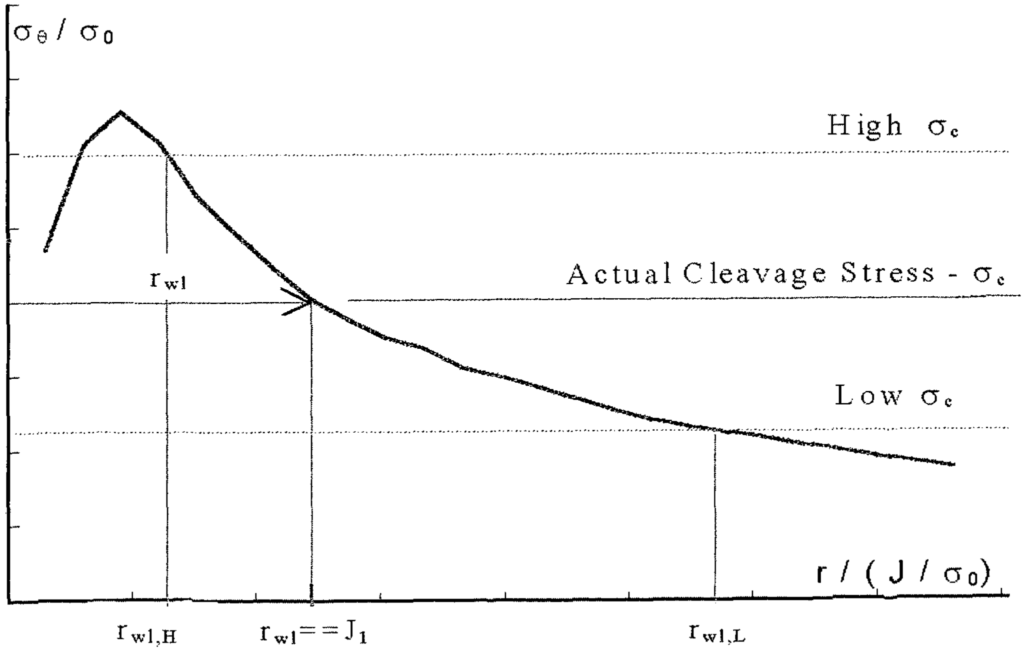


2 - Jc Prediction (Jnew) - Part II: Estimate Q

J_1	R_{wl}	$\frac{Q_{i,2}\ \text{guess}}{\Theta}$	$\frac{\sigma_c}{\sigma_{o,2}} - Q_2$	$\frac{r}{J/\sigma_o}$	$J_{new,i} = R_{wl,1} \times \frac{\cancel{J_1}\ \sigma_{o,2}}{r / (J / \sigma_o}$)

3 - Jc Prediction (Jnew) - Part III: Verification

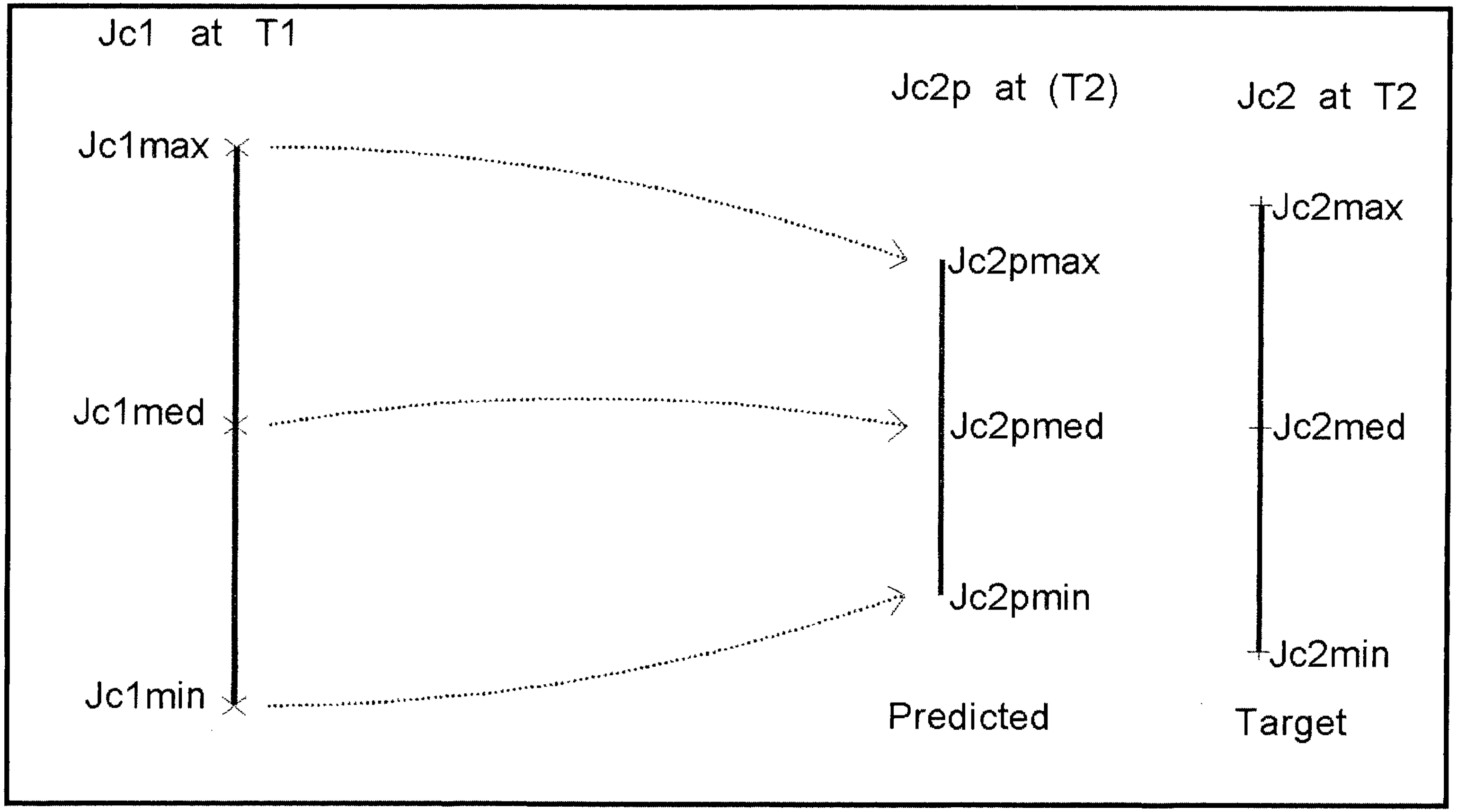
$\text{Log}\left(\frac{J_{new,i}}{}\right)$	Q_i^*	$\Delta Q =$	$\Delta Q \leq \text{tol}$?	Yes : $J_2 = J_{new,i}$



Normalized Stress Field (Schematic)

b. σ_o	(a/w, n)	$\lvert Q_i^* - Q_{i,2} \rvert$		No : $\longrightarrow \Theta$

The Cleavage Stress Prediction Scheme



Jc1 at T1

Jc2p at (T2)

Jc2 at T2

Jc1max

Jc1med

Jc1min

Jc2pmax

Jc2pmed

Jc2pmin

Jc2max

Jc2med

Jc2min

Predicted

Target

PROBLEMS

a) if there are more than one σc value for which there is convergence within the given tolerance?

b) if there is no convergence at all?

Test : 20MnMoNi55 and 1CrMoV steels

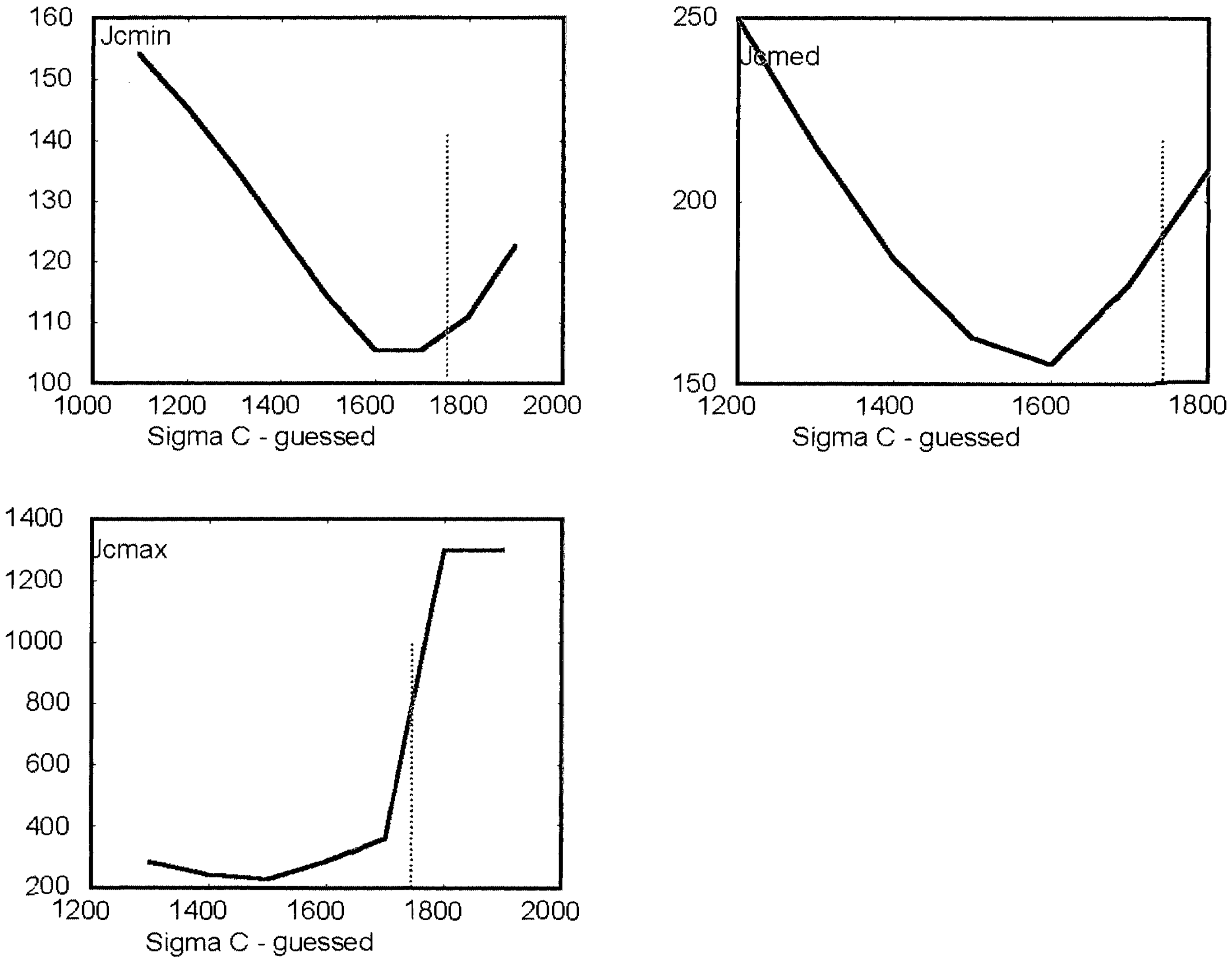
Steel	Average Measured σ_c Value	Average Obtained σ_c Value	**Error**
20MnMoNi55	1750 MPa ---	≈ 1600 MPa	**≈ 10 %**
1CrMoV	1900 MPa ---	≈ 2000 MPa.	**≈ 5 %**

	from T1 = -60. °C to T2 = -90. °C			
Jc minimum	no convergence	Average σ_c	$\sigma c \approx 1750.$	Average σ_c
Jc median	$1300 \leq \sigma c \leq 1800$	$\approx 1550.$	$\sigma c \approx 1600.$	$\approx 1620.$
Jc maximum	$1300 \leq \sigma c \leq 1800$		$\sigma c \approx 1500.$	
	from T1 = -90. °C to T2 = -60. °C			
Jc minimum	no convergence	Average σ_c	$\sigma c \approx 1780.$	Average σ_c
Jc median	$1300 \leq \sigma c \leq 1800$	$\approx 1675.$	$\sigma c \approx 1580.$	$\approx 1580.$
Jc maximum	$\sigma c \approx 1800$		$\sigma c \approx 1380.$	
	From Converged Values		From the Max / Min	

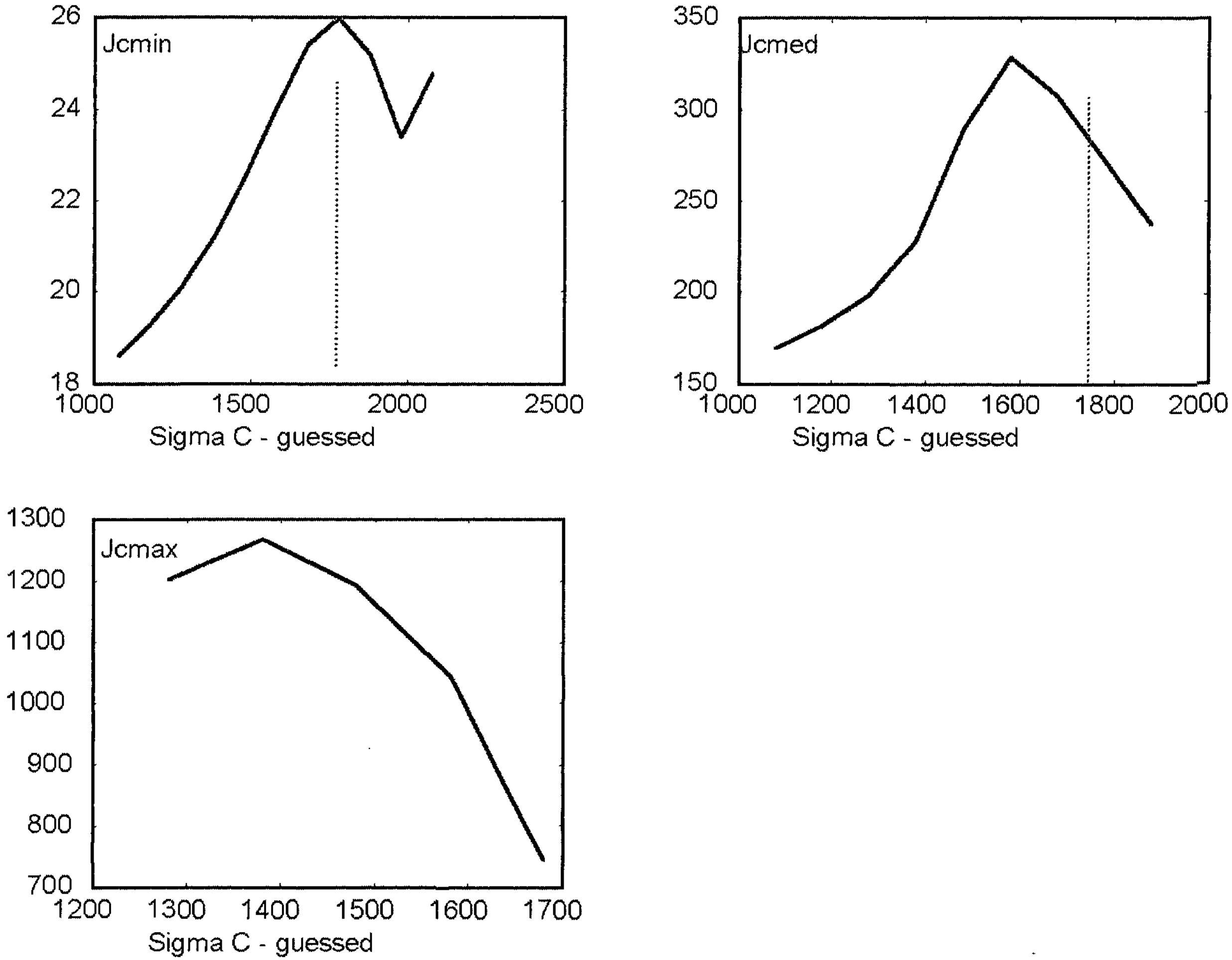
Predicted σ_c values. **20MnMoNi55** steel (MPa)

	from T1 = 80. °C to T2 = 100. °C			
Jc minimum	no convergence	no Average σ_c	$\sigma c \approx 2180.$	Average σ_c $\approx 2110.$
Jc median	no convergence		$\sigma c \approx 2180.$	
Jc maximum	no convergence		$\sigma c \approx 1980.$	
	from T1 = 100. °C to T2 = 80. °C			
Jc minimum	no convergence	no Average σ_c	$\sigma c \approx 2060.$	Average σ_c $\approx 1925.$
Jc median	no convergence		$\sigma c \approx 1860.$	
Jc maximum	no convergence		$\sigma c \approx 1860.$	
	From Converged values		From the Max / Min	

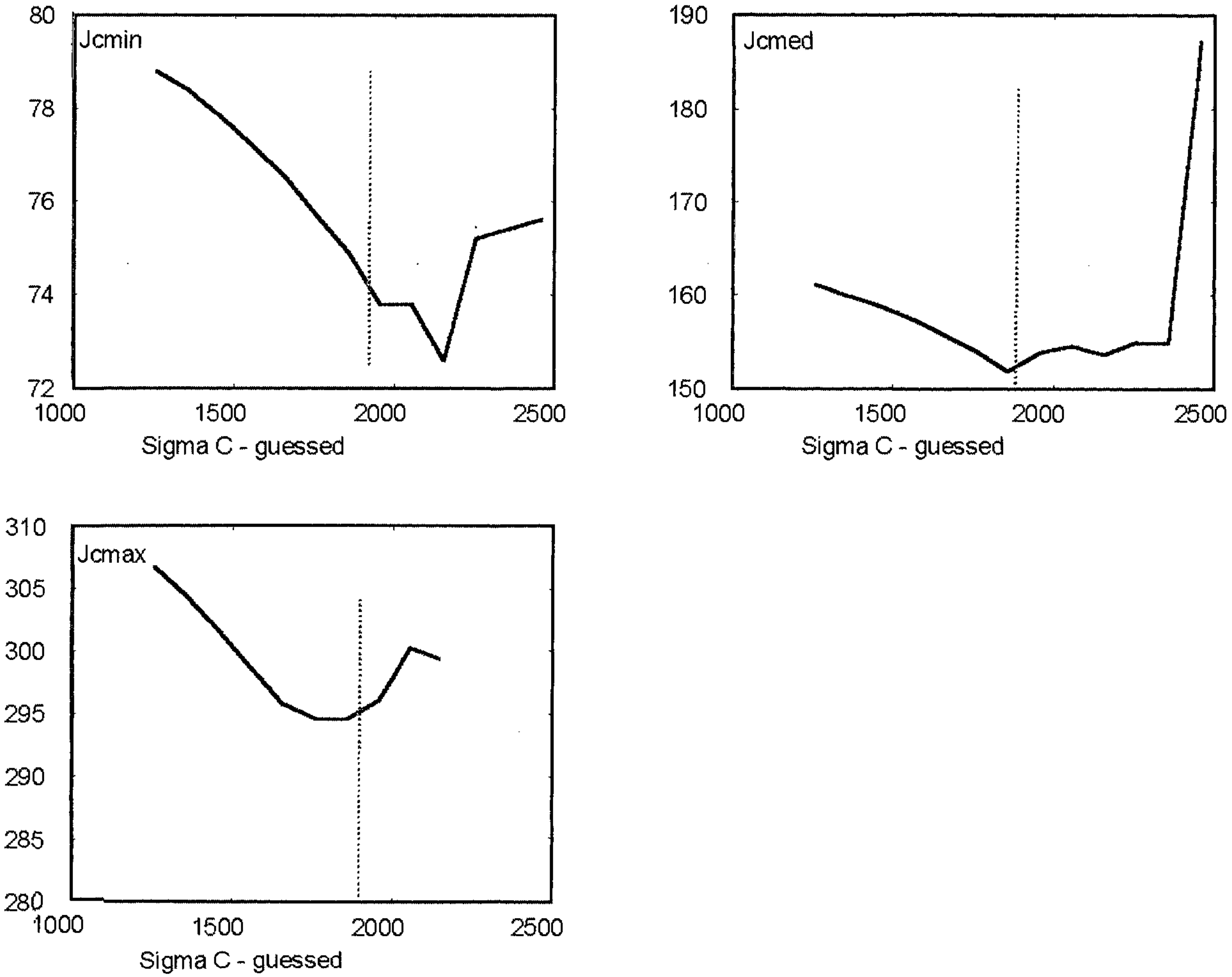
Predicted σ_c values **1CrMoV** steel (MPa)



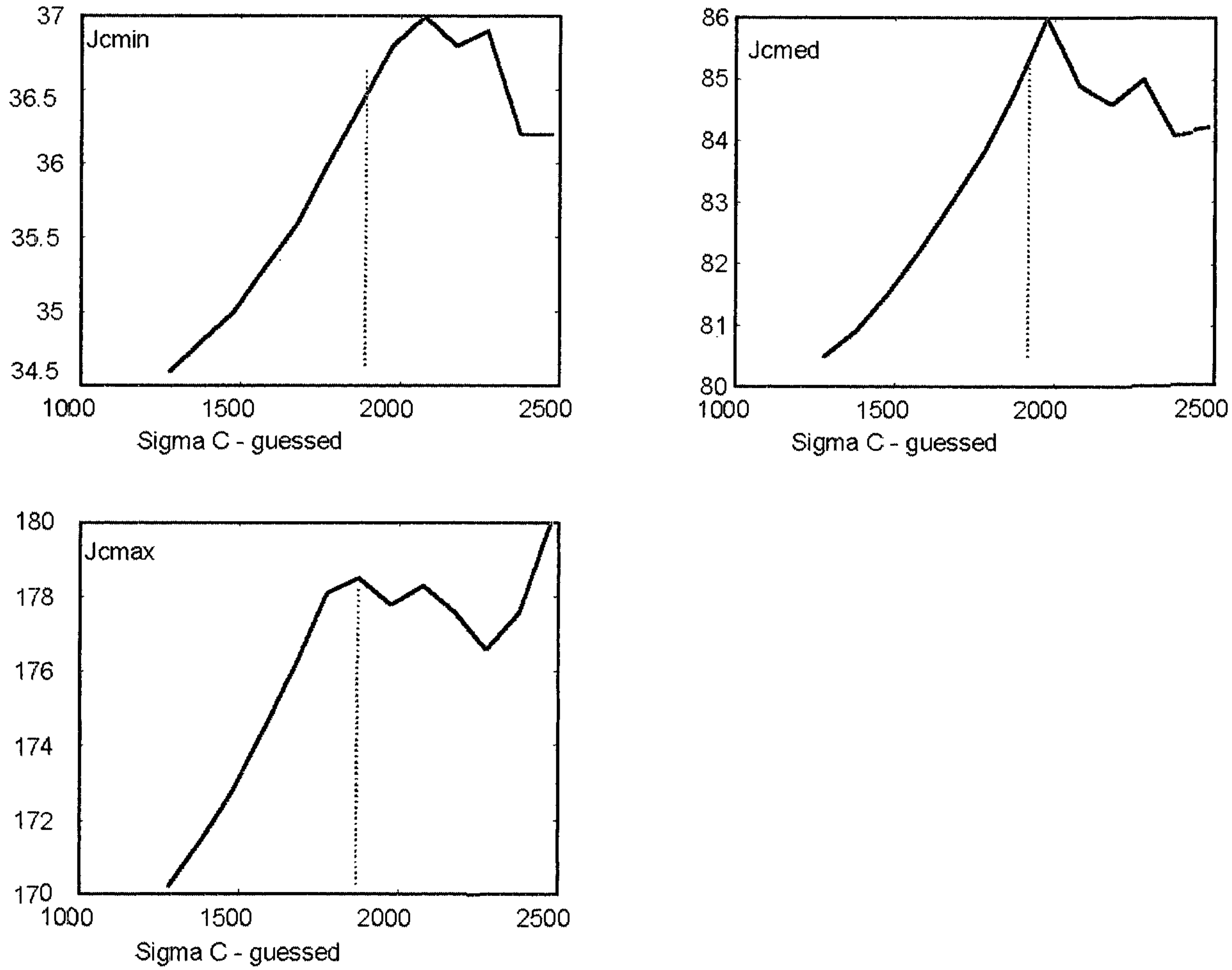
σ_c prediction for the **20MnMoNi55** Steel - T1 = -60 °C, T2 = -90 °C



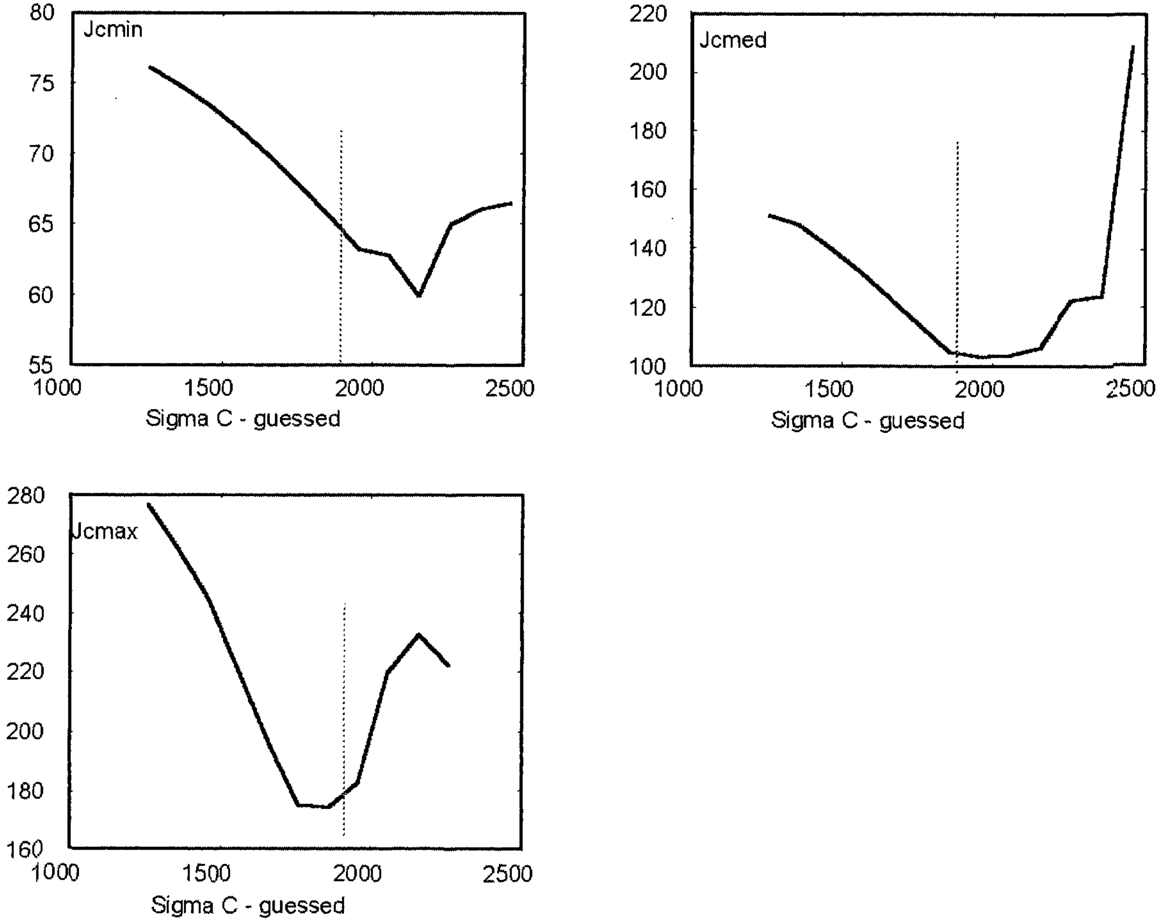
σ_c prediction for the **20MnMoNi55** Steel - T1=-90 °C, T2=-60 °C



σ_c prediction for the **1CrMoV** Steel - T1=100 °C, T2=80 °C



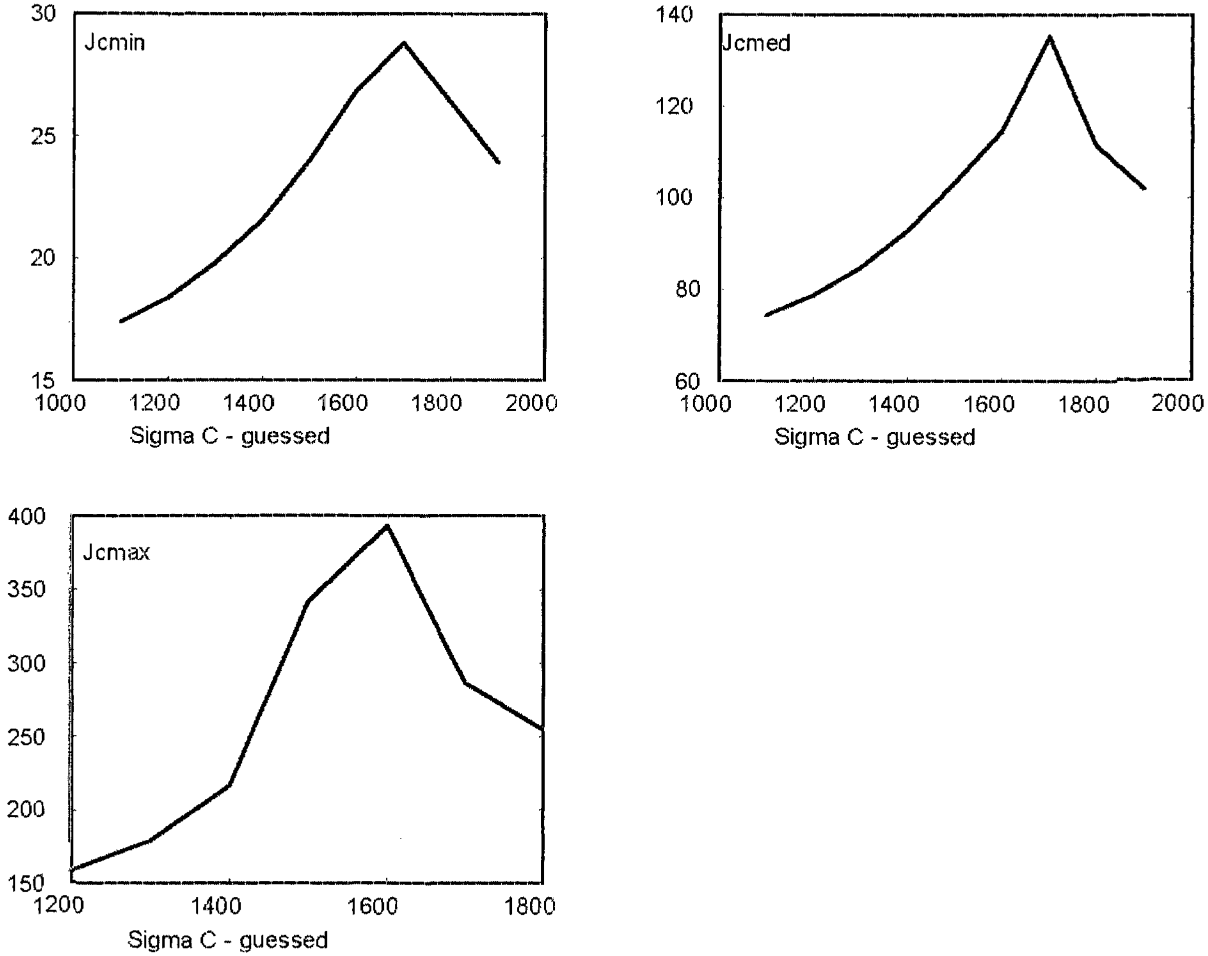
σ_c prediction for the **1CrMoV** Steel - T1=80 °C, T2=100 °C



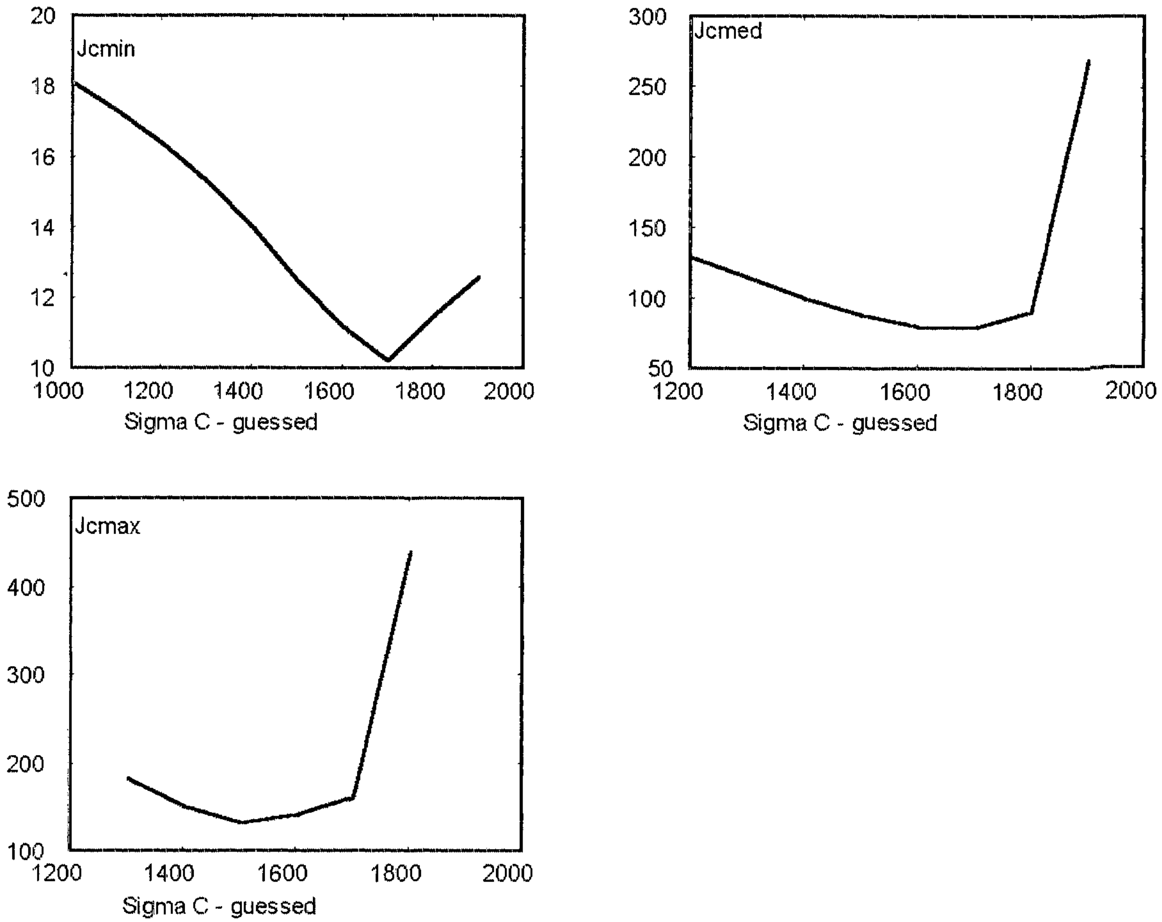
σc prediction for the **1CrMoV** Steel - T1=100 °C, T2=20 °C

Application for Other Nuclear Materials

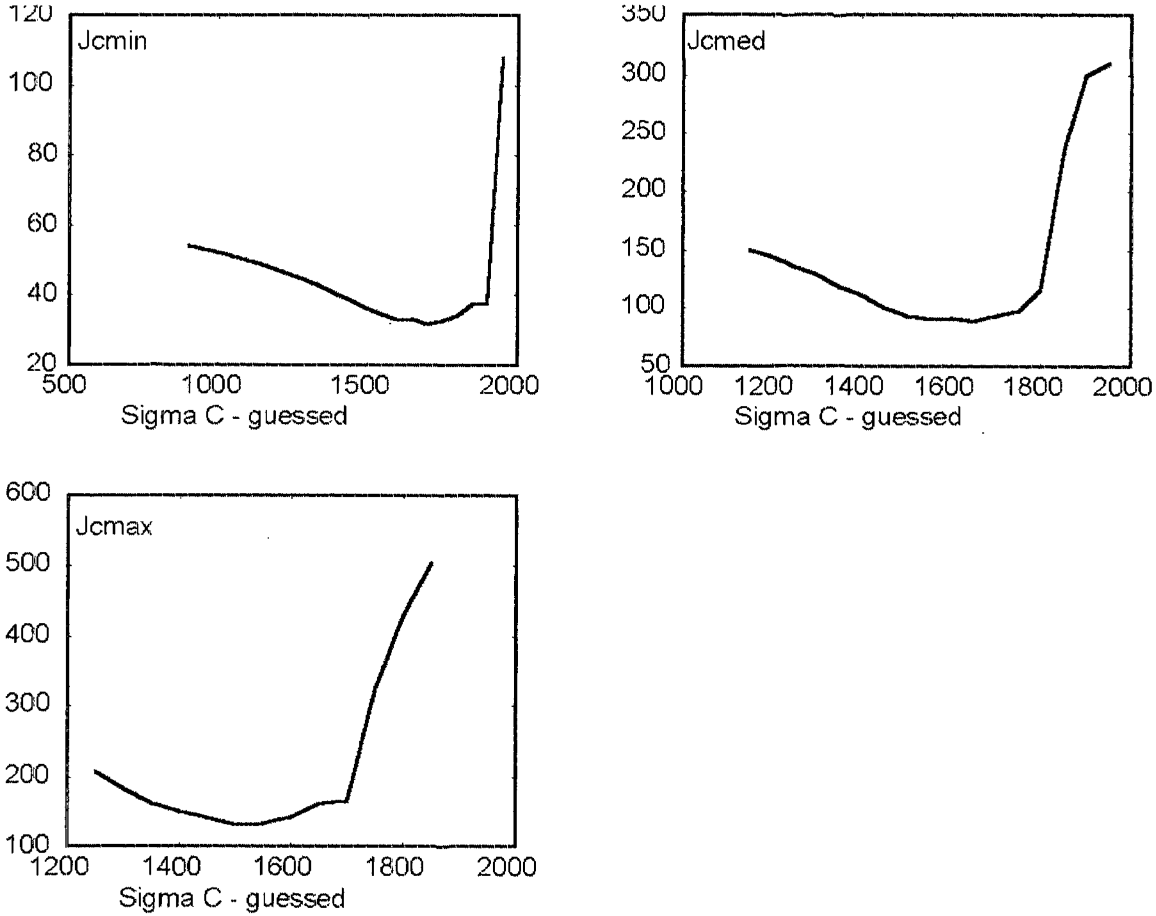
		Cleavage Stress σ_c (MPa) from			
T1 (°C)	T2 (°C)	convergence	min / max	σ_c average	material
-50	-100	1540.	1640.	1600. (MPa)	**A508**
-100	-50	1530.	1665.		
-75	-50	1530.	1580.		
-75	-100	1650.	1665.		
-18	-75	1540	1600	1580 (MPa)	**A533B**
-75	-18	1580	1610		



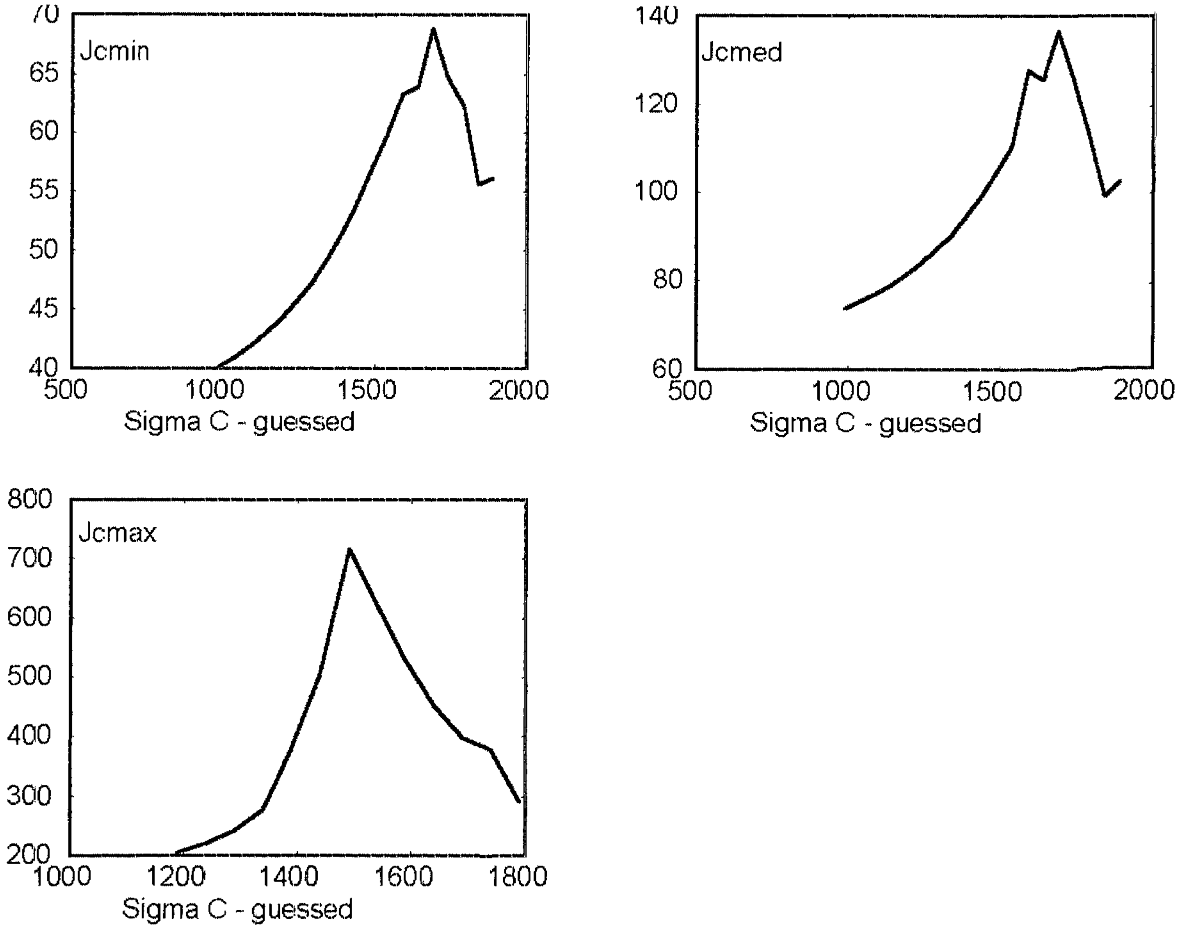
σ_c prediction for the **A508** Steel - T1 = -100 °C, T2 = -50 °C



σ_c prediction for the **A508** Steel - T1 = -50 °C, T2 = -100 °C



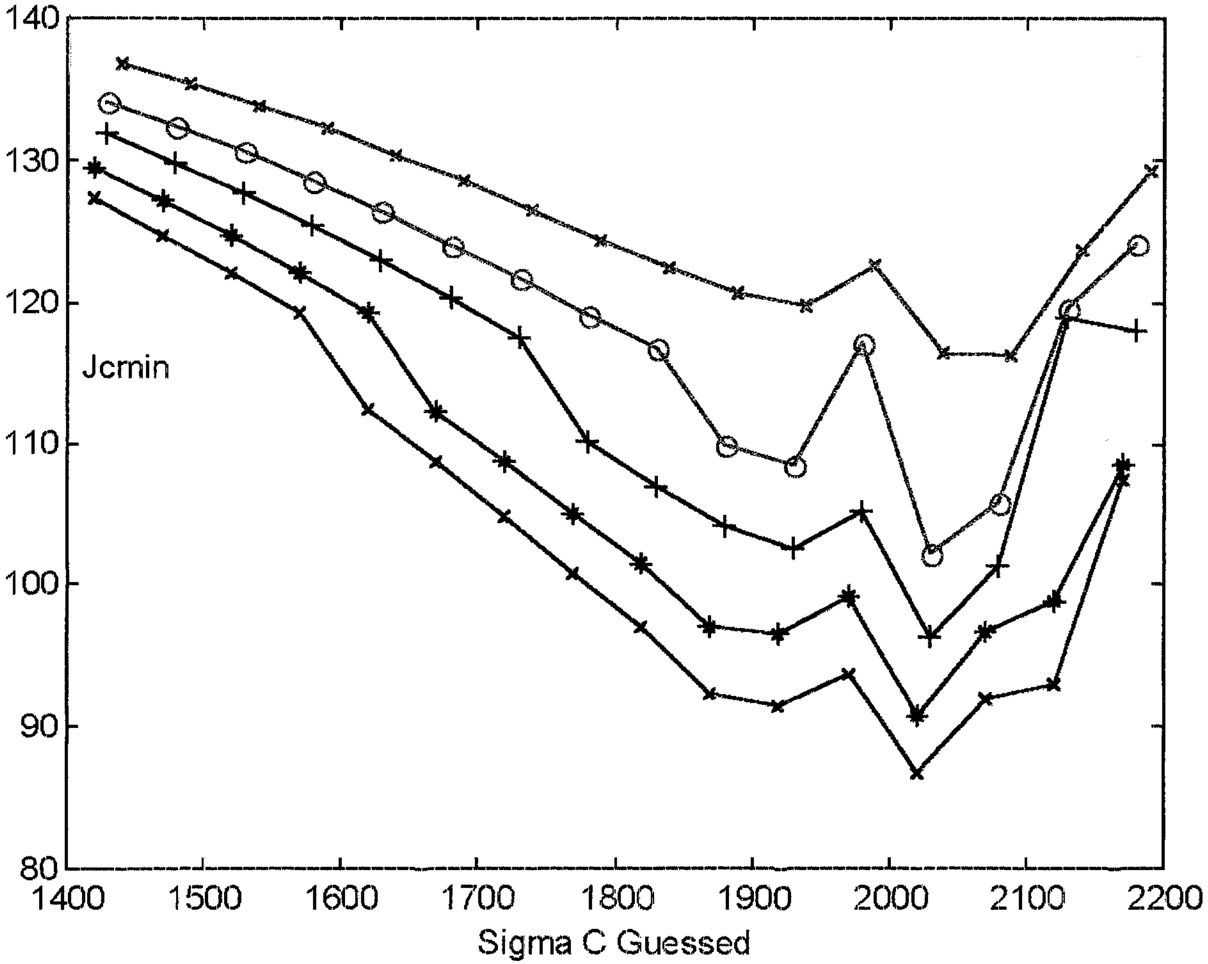
σ_c prediction for the **A533B** Steel - T1 = -18 °C, T2 = -75 °C



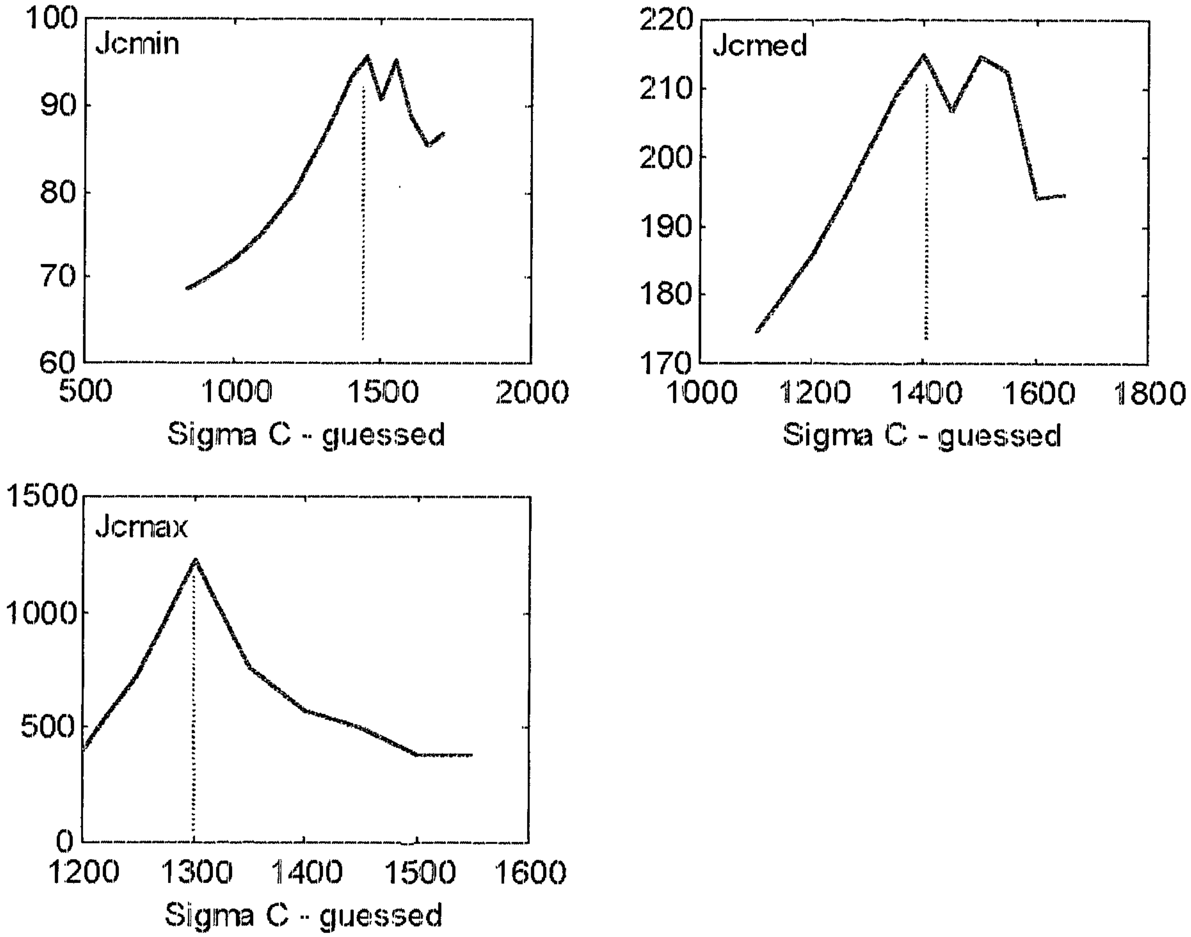
σ_c prediction for the **A533B** Steel - T1 = -75 °C, T2 = -18 °C

Application for a Non-Nuclear Materials

T_1 (°C)	$\sigma_{ys}(T_1)$ (MPa)	T_2 (°C)	$\sigma_{ys}(T_2)$ (MPa)	Average Cleavage Stress σ_c (MPa) from the min / max behavior			material
-40	From 610 to 629	-60	From 632 to 650	Jminimum 2000.	Jmedian 1860	Jmaximum 1700	**HSLA 80**
		Average σ_c 1850 MPa					
-80	478	-60	451	Jminimum 1500.	Jmedian 1400	Jmaximum 1500	**A 131** **EH36**
		Average σ_c 1500 MPa					



Cleavage Stress Prediction Using Jc minimum - T. Anderson's Material (**HSLA 80 Steel**)



Cleavage Stress Prediction - T. Anderson's Material (**A131 EH36 Steel**)

CONCLUSIONS

1. For both Steels with the Cleavage Stress already measured (**20MnMoNi55** and **1CrMoV1**) the proposed method gave an average value very near (error < 10 %) that measured one

2. The same behavior in the curve "Jc versus σ_c guessed" was found for all cases, with the min/max of the curve near the measured σ_c value

3. For the **A508** and **A533B** steels, with composition near the 20MnMoNi55 steel, the proposed method gave average σ_c values near that one for the 20MnMoNi55 steel

4. The max/min behavior of the curve "Jc versus σ_c guessed" was found, also, for the non-nuclear materials: **HSLA 80** steel and **A131 EH36** steel

Material	1CrMoV	20MnMoNi55	A508	A533B	HSLA 80	A131 EH36
σc (MPa)	2000	1600	1600	1580	1850	1500

M.H.

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NSWC/USNA Workshop on Fracture in the Ductile-Brittle Fracture Region

Viewgraphs

July 14-15, 1998

US Naval Academy
Annapolis, MD

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Workshop on Fracture in the Ductile-Brittle Fracture Region
PRELIMINARY AGENDA

TUESDAY, JULY 14, 1998

8:00 **Opening Remarks**
8:05 **Empirical Validation of E1921 Constraint Limits and Justification of RT-To as an Alternative to RT-NDT**, Kirk, Lott, Server, Hardies, Rosinski
8:35 **Technical Basis for Application of the Master Curve Approach to Reactor Pressure Vessel Integrity Assessment**, Server, Rosinski
9:05 **Application of Master Curve Within the ASME Boiler and Pressure Vessel Code**, Tregoning
9:35 **Discussion**
10:00 **Break**
10:15 **Effects of Residual Stresses and Strength Mismatch on Cleavage Fracture in Piping and Pressure Vessels**, Dong
10:45 **Application of Master Curve to Irradiated Reactor Pressure Vessel Steels**, Sokolov
11:15 **Results of Crack Arrest Testing of Irradiated Pressure Vessel Steels**, Iskander, Nanstad, McCabe and Swain
11:45 **Discussion**
12:15 **Lunch**
1:30 **Constraint and Statistical Effects on Fracture in the Transition Region: Some Preliminary Observations**, Odette
2:00 **A New Procedure for Calibration of Weibull Models for Cleavage Fracture in the Ductile-to-Brittle Transition Region**, Dodds, Gao, Ruggieri
2:30 **Evaluation of the Weakest-Link Size Adjustment Procedure**, Sokolov
3:00 **Discussion**
3:30 **Break**
3:45 **Constraint Effects of Biaxial Loading on the Shallow Flaw Fracture Toughness of RPV Steels, Experimental Investigation**, McAfee
4:15 **Constraint Effects of Biaxial Loading on the Shallow Flaw Fracture Toughness of RPV Steels, Evaluation of Dual Parameter Fracture Toughness Correlations**, Bass
4:45 **Application of Master Curve Technology to Biaxial and Shallow Crack Fracture Data for A533B Steel**, Joyce, Tregoning, Zhang
5:15 **Discussion**
5:45 **Adjourn**

WEDNESDAY, JULY 15, 1998

8:00 **The Impact of Microstructural Non-uniformities on the Fracture Behavior of Heavy-Section A533B Plate**, Zhang
8:30 **A Micromechanical Evaluation of the Master Curve**, Natishan, Kirk
9:00 **Estimating Cleavage Stress for Ferritic Steels From Measured Jc Values in the Transition Region**, Landes, Miranda
9:30 **Discussion**
10:00 **Break**
10:15 **Evaluation of Variability in Charpy and Fracture Toughness for Irradiated Midland Reactor Welds**, Nanstad
10:45 **Transition Temperature Determination Using Notched Round Bars**, Wilson
11:15 **Outstanding Issues for Future Research Activities in Ductile-Brittle Fracture**, McCabe
11:45 **Discussion and Concluding Remarks**
12:30 **Adjourn**

Naval Surface Warfare Center
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August 26, 1998

Dear Workshop Participant:

The viewgraphs from the **NSWC/USNA Workshop on Fracture Performance within the Ductile to Brittle Transition Regime** are enclosed. I want to again thank you for participating in this workshop. The presentations were informative and the discussion sessions were lively and identified several areas for ongoing and future study.

Best wishes,
Rob Tregoning
Fatigue and Fracture Branch