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SPLIT HOPKINSON BAR STUDIES OF 350WT STEEL PLATE (U)

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UNUVERSITY of MANITOBA

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Contractor Report

DREA CR 1999-092

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SPLIT HOPKINSON BAR STUDIES OF 350WT STEEL PLATE

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Abstract

This report describes results of tests conducted on 350WT plate steel at high strain rates using a high energy modified Split Hopkinson Bar System (SHB). Compact tension specimens with a thickness of 12.7mm of 350WT steel in both L-T and T-L orientations were fractured. These specimens contained either a fatigued or pressed crack. The results were conducted at –45, -30 and -15° C. Stretch zone width and shear lip measurements were performed. Temperature transition curves for shear lip and stretch zone were obtained for this steel.

Résumé

Ce rapport présente les résultats des essais effectués sur une plaque d'acier 350WT soumise à des vitesses élevées de déformation à l'aide d'un système SHB modifié à haute énergie (Système de barres de Hopkinson). Les éprouvettes de traction compactes, d'une épaisseur de 12,7 mm d'acier 350WT dans les deux orientations L-T et T-L, ont subi une rupture. Ces éprouvettes présentaient une fissure de fatigue ou une fissure de compression. Les essais ont été effectués à -45, -30 et -15 °C. On a mesuré la largeur de la zone d'allongement et les lèvres de la zone de cisaillement. On a aussi tracé les courbes de température de transition pour les lèvres de la zone de cisaillement et la zone d'allongement de cet acier.

Table of Contents

1. Introduction:

This project studies the effect of notch acuity (pressed vs. fatigue crack) on shear lip and its relationship to stretch zone width both as a function of temperature for 350WT plate steel at high strain rates. A custom designed high energy Split Hopkinson Bar (SHB) system with a swing arm mechanism was used in this study. The detailed description of the SHB was described earlier (1). The stretch zone width was measured using a scanning electron microscope (2). Testing was conducted using projectile speeds in excess of 50 m/s and at temperatures of -45° C, -30° C and -15° C.

The compact tension specimens tested contained the following specifications:

(a) saw cut with included angle of 60 degrees per ASTM E604 and pressed to 0.01 inch as per ASTM E604.
(b) saw cut with included angle of 60 degrees per ASTM E604 and fatigue precracked to a/W of 0.55.

Both L-T and T-L orientations were tested in this program.

The project took place from December 98 to June 99. It was carried out by Dr. M. Nabil Bassim as principal investigator. He was assisted by a research associate and a technician.

2. Program:

The major tasks of the project were as follows:

Task 1: measurement of the stretch zone width of specimens tested in the 1998 program (see DREA CR 98/431) II-7, II-8, II-9, II-10.

Task 2: fabrication of specimens with different notch specifications from coupons cut on the T-L and L-T orientations followed by press and/or fatigue precracking of the specimens.

Task 3: conduct high strain rate testing at -45, -30 and -15° C and measuring the shear lip and the stretch zone width (for fatigued specimens).

Task 4: drawing of shear lip and stretch zone temperature transition curves and shear lip and SZW comparison curves.

3. Experimental Procedures:

Task 1: Stretch Zone Measurements

Stretch Zone width measurements were carried out on specimens II-7, II-8, II-9 and II-10 tested in the 1998 contract. A scanning electron microscope was used in this investigation. These tests were conducted at 0 and 15 C using the improved higher energy system.

Task 2: Preparation of New Specimens

Specimen coupons were produced from the 350WT plate supplied by DREA. Compact tension specimens with notches either in the T-L or L-T direction were prepared. Some specimens were pressed while others were fatigue precracked.

Task 3: Fracture Testing Using SHB System

The specimens were tested at –45°C, -30°C and -15°C using the SHB System which was further modified to obtain high energy sufficient to break the specimens. Specimens were photographed after fracture. The shear lip and stretch zone (for fatigued specimens) were measured.

Task 4: Graphs relating stretch zone and shear lip to temperature were obtained and plotted to be included in this report.

4. Results and Discussion:

Table 1 gives results of measurements of the stretch zone width for specimens II-7, II-8, II-9 and II-10. These specimens were tested in 1998 with the increased capacity (modified or fast) Split Hopkinson Bar.

Table 2 lists the results obtained from measurements of the shear lips and stretch zone measurements for the new 350WT specimens tested in either the L-T or T-L orientations. These tests were all with the increased capacity Split Hopkinson Bar.

Table 3 is a reproduction of data obtained with the unmodified Split Hopkinson Bar (slowed) from 1997.

Figures 1-3 show the transition curves obtained in this investigation. Figure 4 shows a graph of the relationship between pressed shear lip and fatigue pre-cracked shear lip for all specimens from both the modified and unmodified Split Hopkinson Bar. Figure 5 shows the relationship between SZW and shear lip for fatigue pre-cracked specimens, for all specimens from the modified and unmodified Split Hopkinson Bar.

Table 1: Stretch Zone Width (SZW) measurements of fatigue precracked specimens from 1998 contract.

ID	Temperature Deg. C	Orientation	Notch	SZW	SZW Value Microns	Shear Lip Mm
II-1	15	L-T	Pressed			6.1
II-2	15	T-L	Pressed			6.0
II-3	0	L-T	Pressed			6.1
II-4	0	T-L	Pressed			6.0
II-5	15	L-T	Fatigue Precracked			6.0
II-6	0	L-T	Fatigue Precracked			6.0
II-7	15	L-T	Fatigue Precracked	Yes	1080[1]	5.5
II-8	15	T-L	Fatigue Precracked	Yes	990[1]	6.0
II-9	0	L-T	Fatigue Precracked	Yes	863[1]	3.0
II-10	0	T-L	Fatigue Precracked	Yes	975[1]	3.8

Table 2: Summary of testing results of 350WT steel (1999)

Temperature Deg. C	Orientation	Notch	SZW	SZW Value Microns	Shear Lip Mm
-45	T-L	Fatigue Precracked	Yes	147	1.5
-45	L-T	Fatigue Precracked	Yes	210	2.0
-45	T-L	Pressed			2.0
-45	T-L	Pressed			2.0
-30	T-L	Fatigue Precracked	Yes	343	2.5
-30	L-T	Fatigue Precracked	Yes	450	2.0
-30	T-L	Pressed			2.0
-30	T-L	Pressed			6.0
-15	T-L	Fatigue Precracked	Yes	812	6.0
-15	L-T	Fatigue Precracked	Yes	1177	6.0
-15	T-L	Pressed			5.5
-15	T-L	Pressed			3.5

Table 3: Shear Lip and Stretch Zone Width (SZW) measurements of fatigue precracked and pressed specimens from 1997 contract (slowed tests).

ID	Temperature Deg. C	Orientation	Notch	SZW	SZW Value Microns	Shear Lip Mm
APA	-45	T-L	Pressed			0.39
APB	-30	T-L	Pressed			0.64
APE	15	T-L	Pressed			2.58
ATE	15	L-T	Pressed			2.8
BPA	-45	T-L	Fatigue Precracked	Yes	56	0.39
BPB	-30	T-L	Fatigue Precracked	Yes	83	0.79
BPC	-15	T-L	Fatigue Precracked	Yes	97	1.31
BPD	15	T-L	Fatigue Precracked	Yes	175	2.21
BPE	0	T-L	Fatigue Precracked	Yes	600	3.08
BTA	-45	L-T	Fatigue Precracked	Yes	46	.24
BTB	-30	L-T	Fatigue Precracked	Yes	55	.3
BTC	-15	L-T	Fatigue Precracked	Yes	69	1.11
BTD	0	L-T	Fatigue Precracked	Yes	140	1.96
BTE	15	L-T	Fatigue Precracked	Yes	500	2.80

Note: all specimens a/W of 0.55

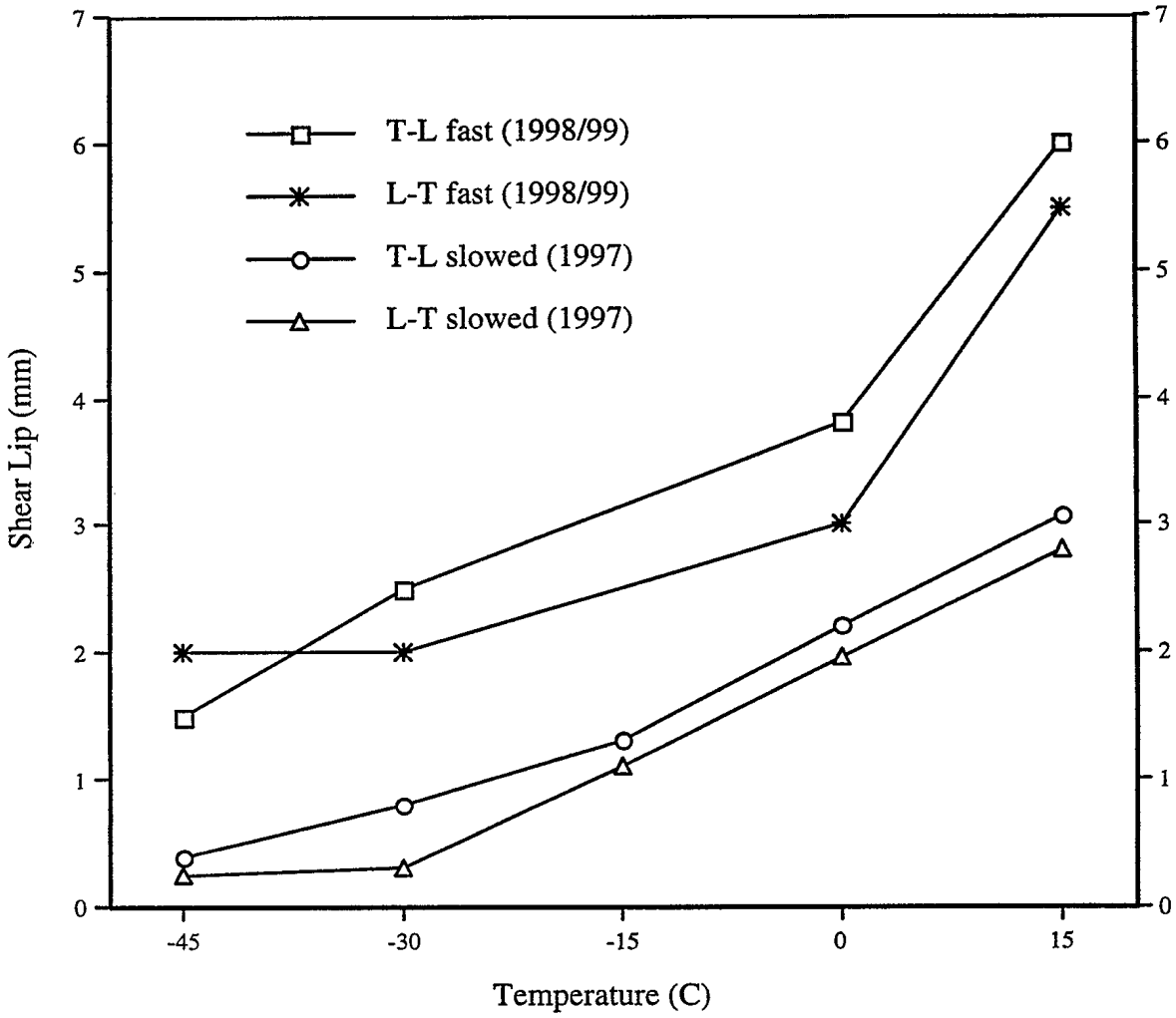

Figure 1: Comparison of the results for the unmodified Splt Hopkinson Bar (1997) which slowed considerably during the test and actually stopped at 0 and 15°C and results with the modified Split Hopkinson Bar (1998 and 1999). Graph shows variation of Shear Lip with Temperature for Fatigue Pre-Cracked Specimens.

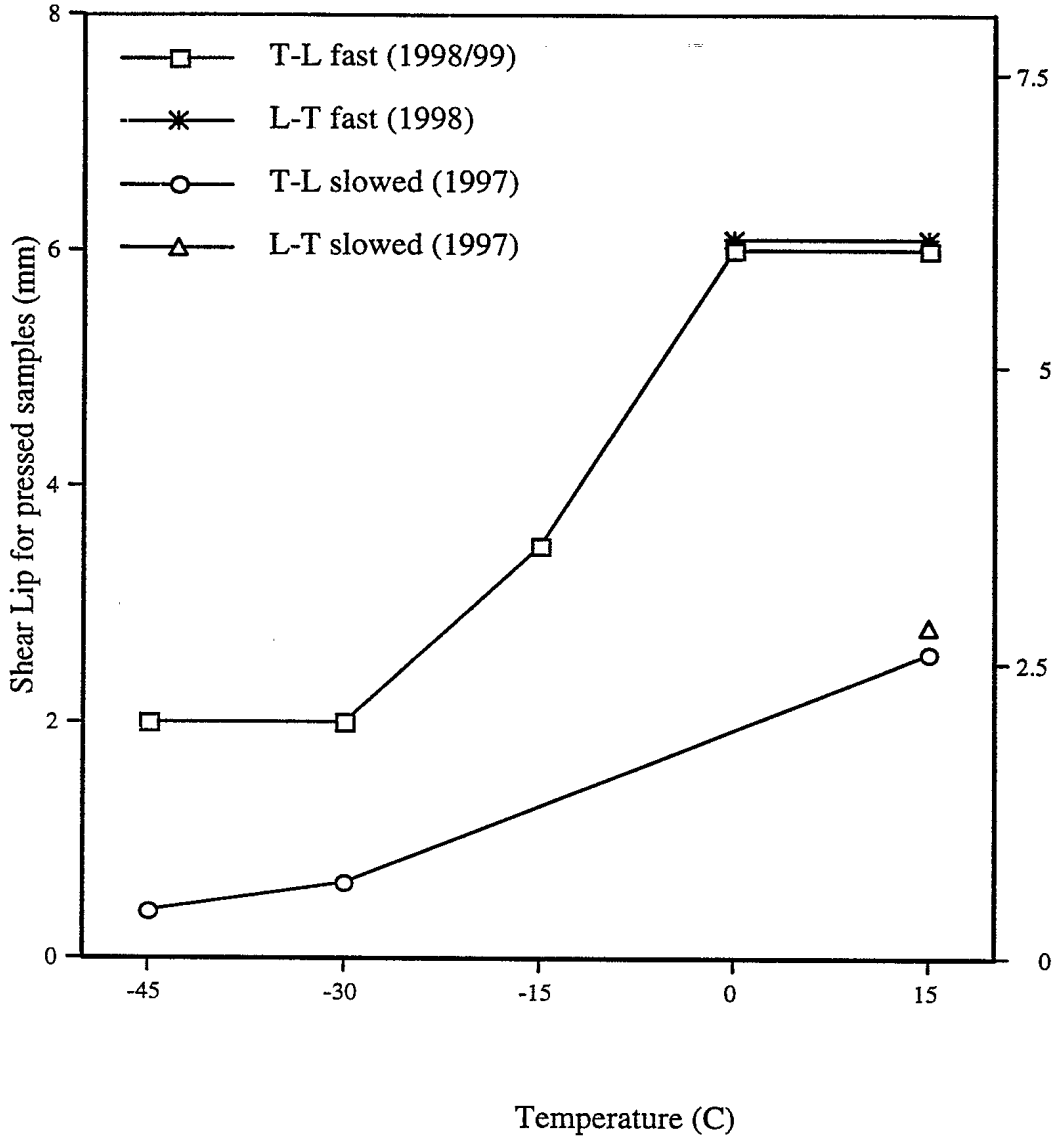

Figure 2: Graph shows variation of Shear Lip with Temperature for Pressed Notched Specimens.

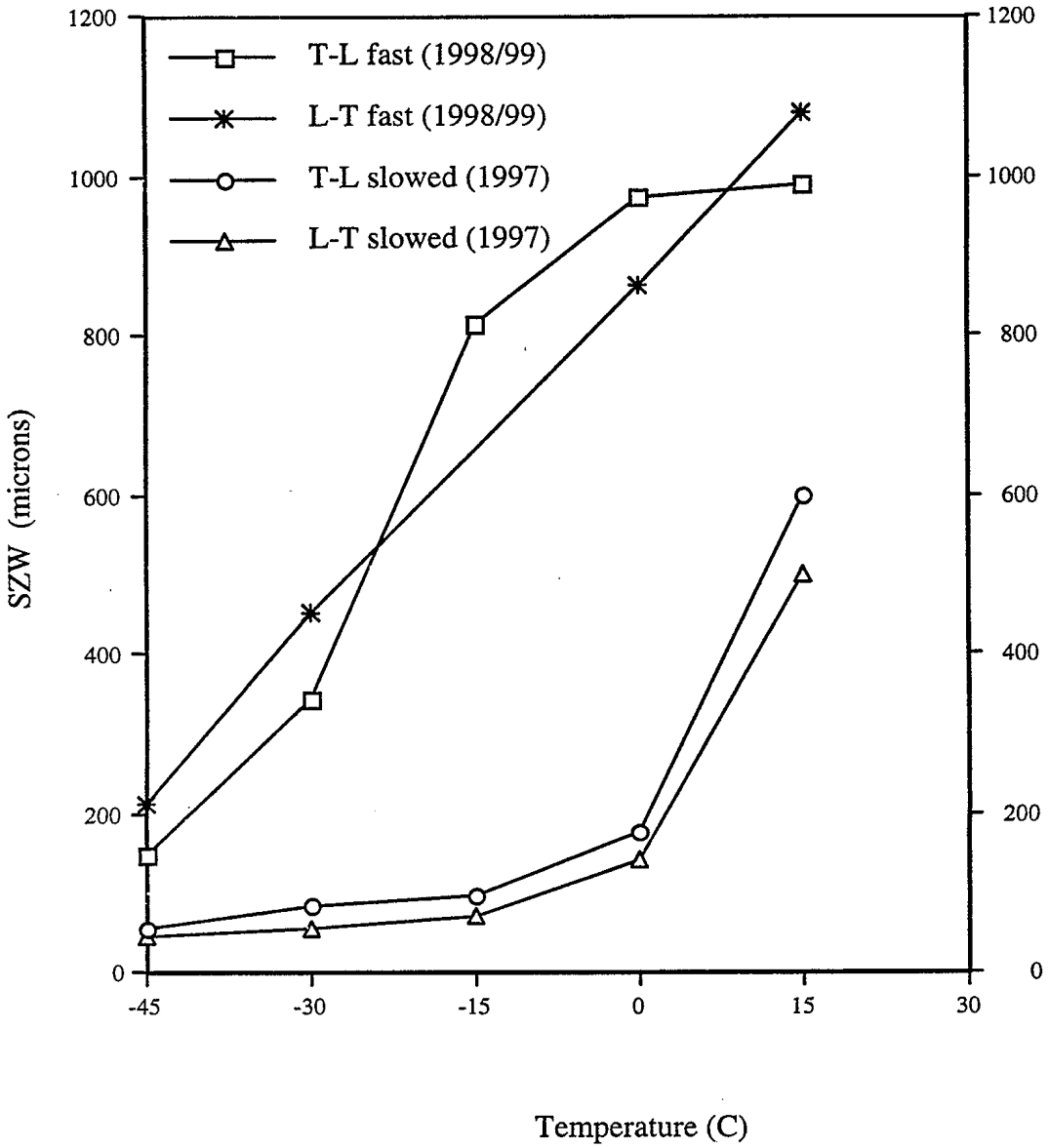

Figure 3: Graph shows variation of SZW with Temperature for fast and slowed.

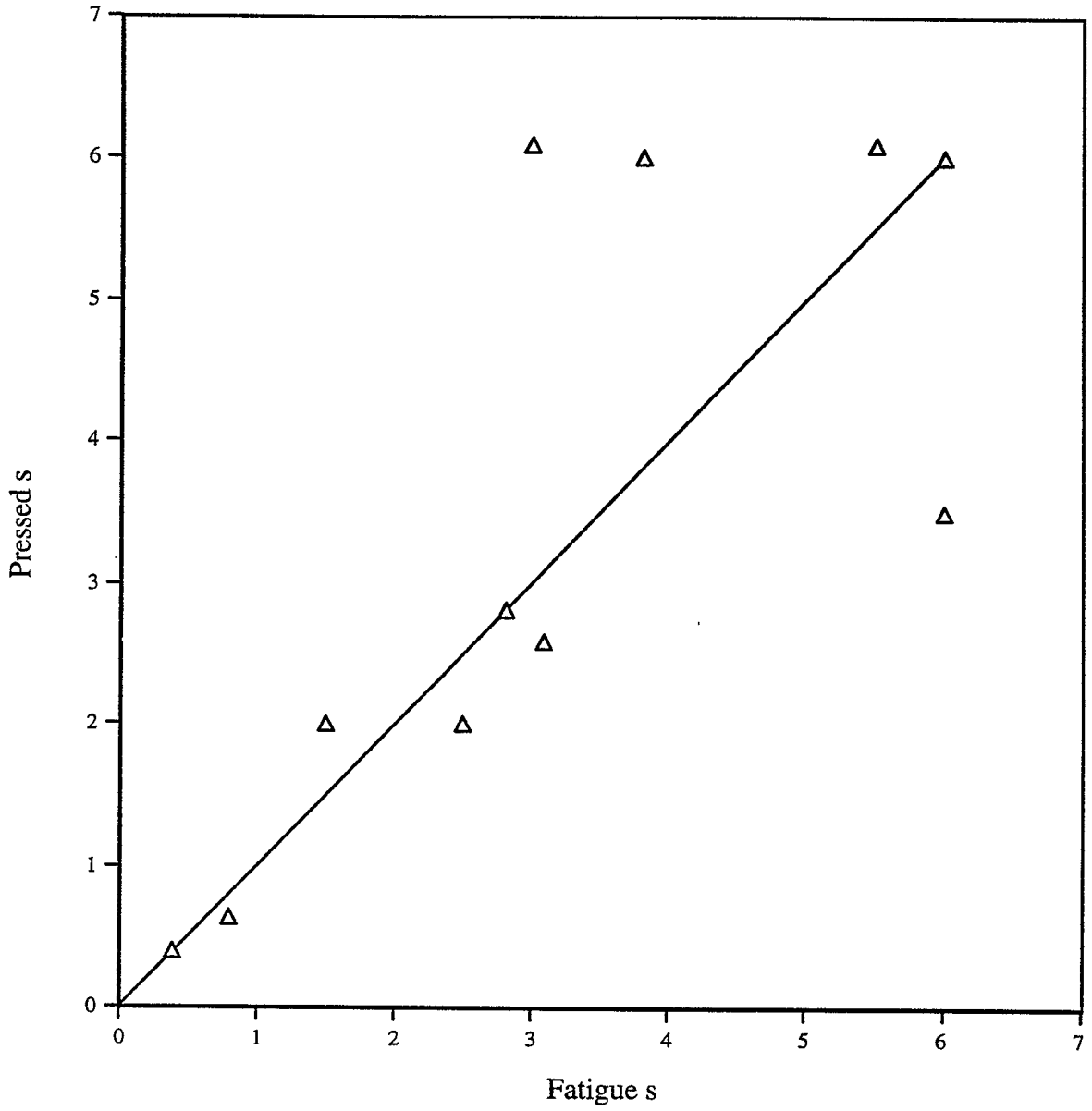

Figure 4: Graph shows relationship between Shear Lip for Pressed Notched Specimens and Fatigue Pre-Cracked Specimens.

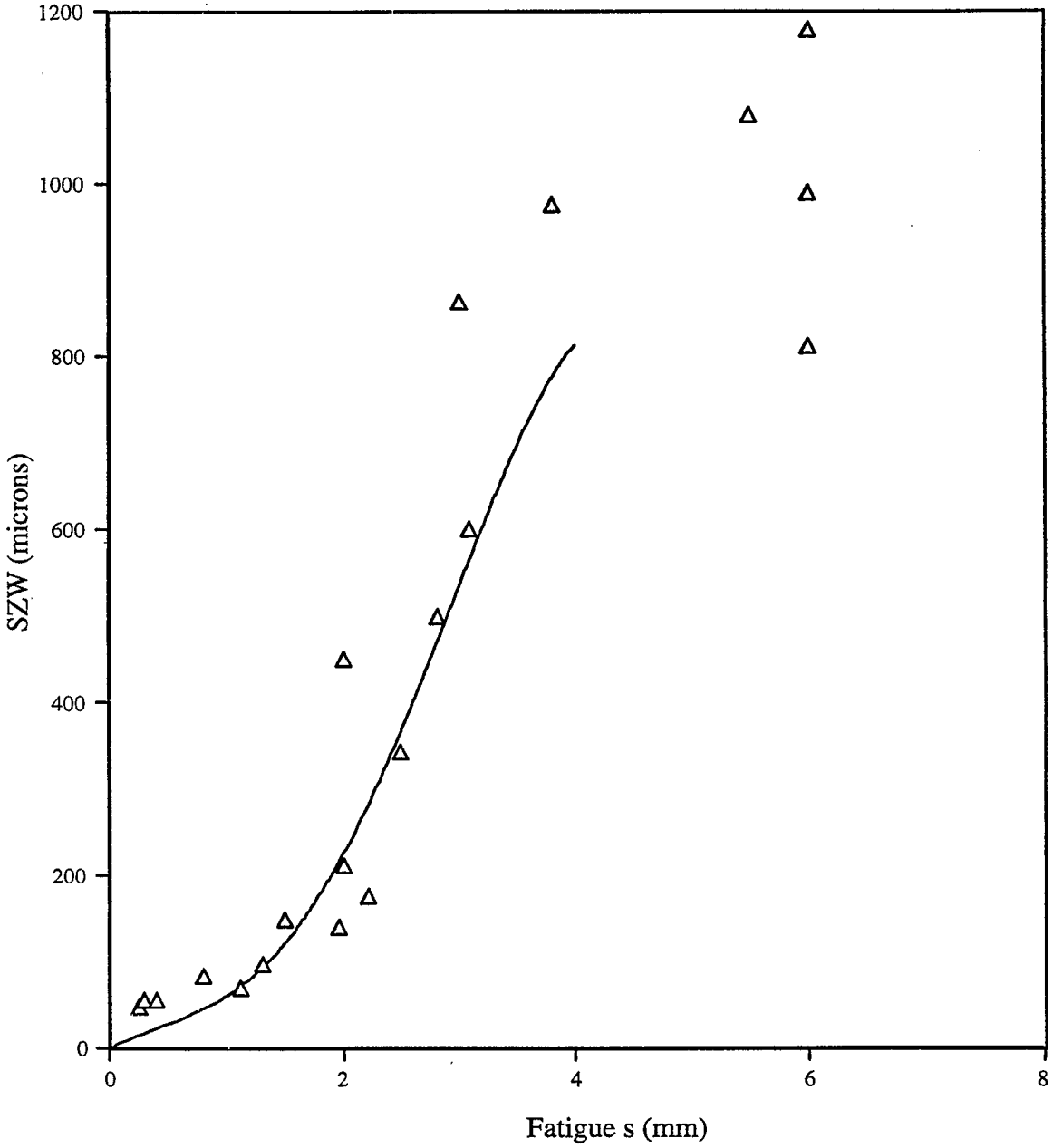

Figure 5: SZW vs shear lip on fatigue pre-cracked specimens.

5. Conclusions:

The objectives of this study have been met to determine the temperature transition curves for shear lip and stretch zone width for 350WT plate steel at very high strain rates.

6. References:

(1) M.N. Bassim, "High Energy Dynamic System for Notch Acuity Studies", DREA CR 98/431.

(2) M.N. Bassim and J.R. Matthews "Ductile Fracture Toughness Evaluation at High Strain Rates Using Stretch Zones and Shear Lips" in Recent Advances in Fracture, Proceedings of TMS Conference, 1997, pp205-212.

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