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TITLE

EVALUATION OF FRACTURE TOUGHNESS OF HIGH STRENGTH STEEL FROM STRETCH ZONES

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Evaluation of Fracture Toughness of High Strength Steels from Stretch Zones

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ABSTRACT

High strength steels exhibit elastic-plastic fracture behavior at the crack tip even at low temperature and/or high strain rates. Characterization of their fracture toughness under these conditions by means of standardized J_{IC} tests is extremely difficult. This is particularly the case at very high strain rates such as those obtained using Split Hopkinson Bar devices. Alternatively, measurements of the stretch zone ahead of the crack on the fracture surface allows evaluation of the fracture toughness. It was found, however, that the stretch zone, which is indicative of the plasticity at the crack tip is affected by several factors such as the level of loading during fatigue precracking, the extent of strain hardening which occurs at the crack tip, the length of the crack and the corresponding a/w ratio and the occurrence of transverse and compressive strains ahead of the crack.

In this study, the effect of these factors of the measured stretch zone width and the corresponding J_{IC} is evaluated systematically. Factors examined are a/w values, $\Delta K_{fatigue}$, temperature and strains ahead of the crack. The results emphasize the importance of using stretch zone measurements for fracture toughness evaluation.

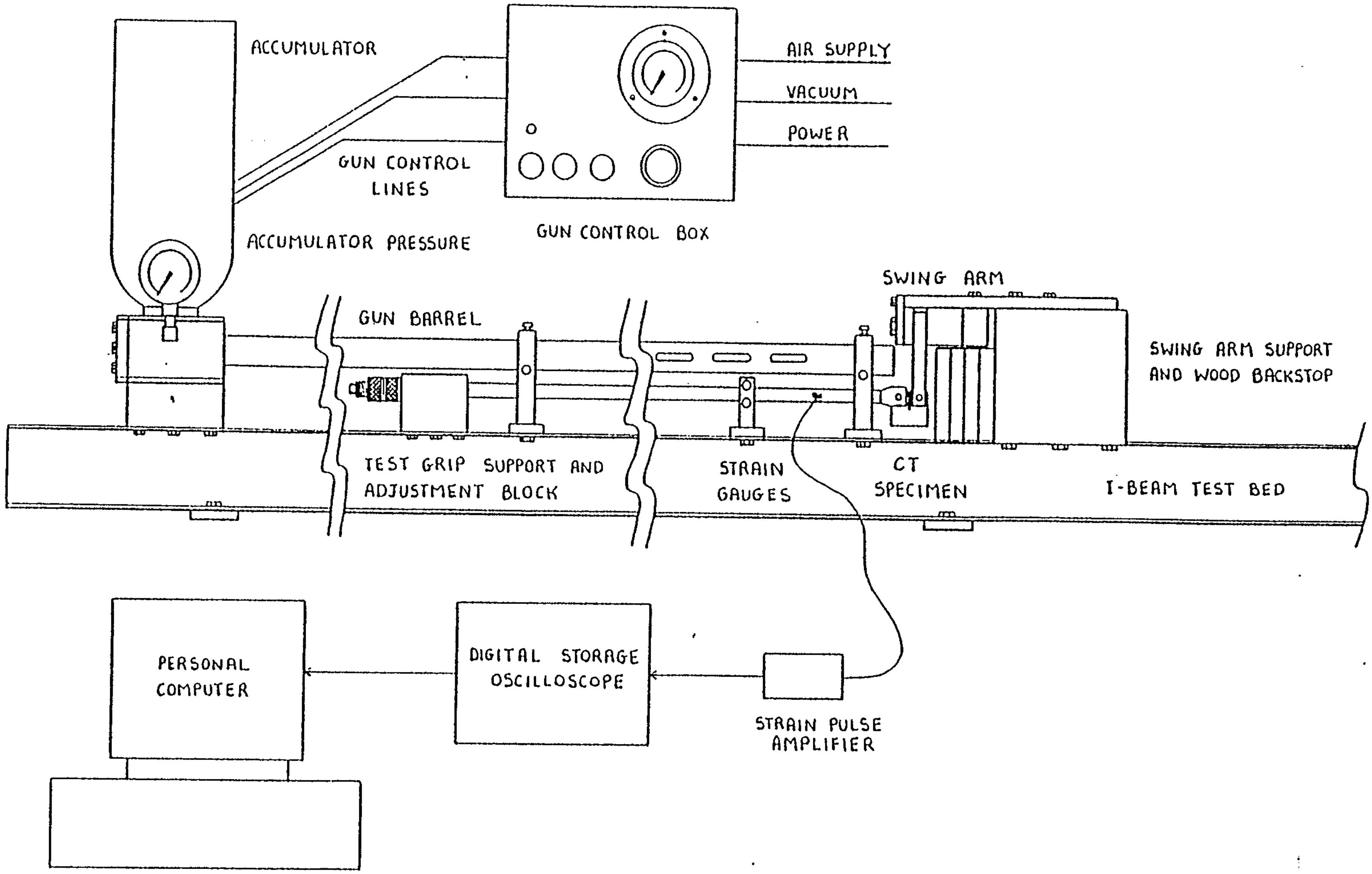


FIG. SPLIT HOPKINSON BAR ASSEMBLY FOR CT SPECIMEN TESTING

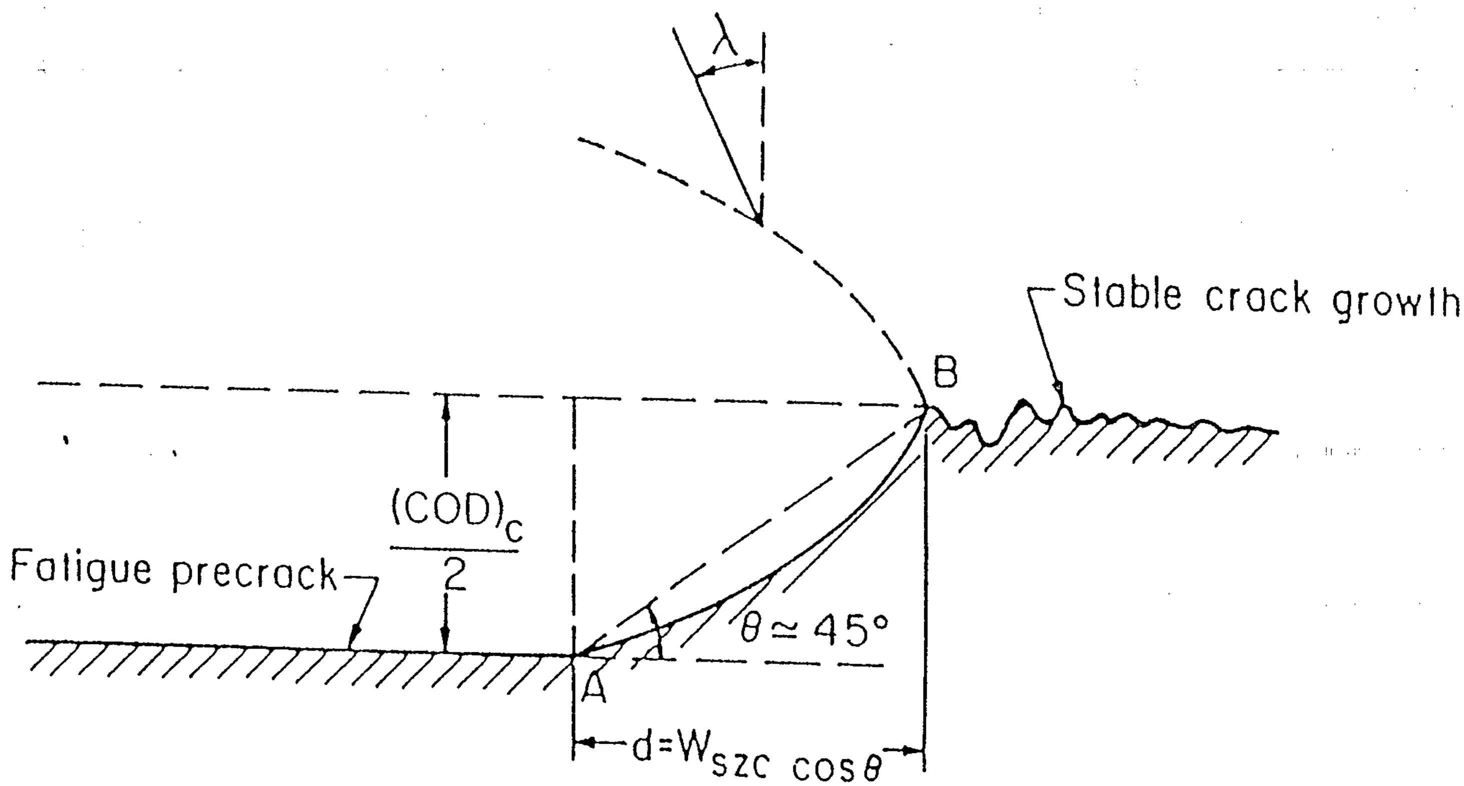
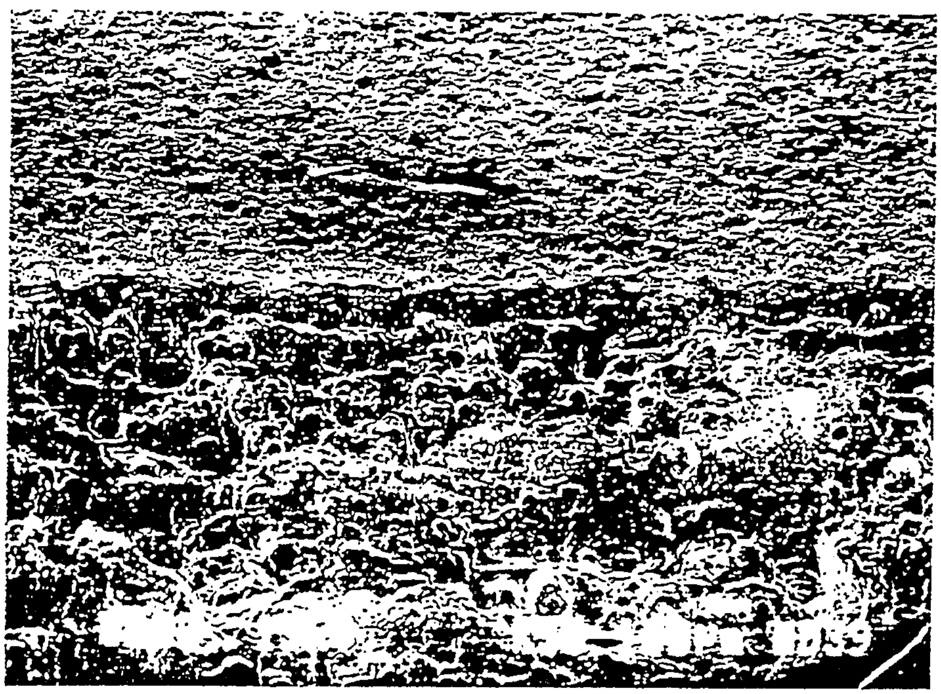


FIG CONCEPT OF THE STRETCH ZONE ANALYSIS



No.	Temp °C	Load Speed m/S	Stretched Zone width 10^{-6} m									
			1	2	3	4	5	6	7	8	9	Average
2	24	10^{-5}	100	200	142	186	88	100	140	136	100	132.4
3	24	10^{-3}	225	110	140	138	65	124	138	144	70	128.2
4	24	10^{-1}	176	180	166	174	140	110	128	110	132	145.7
7	24	19.5	190	216	180	168	150	148	190	240	144	180.7
1	24	26.7	208	580	352	200	392	134	225	260	200	258.4
6	24	32.0	185.7	190	300	325	282.5	356	162.5	154	222.2	242.3
11	-20	10^{-5}	140	89	149.3	149.3	105.5	128.9	185	81.4	155	131.5
8	-20	10^{-3}	178	178.5	128.9	138.7	83	157.1	154.7	67	70	128.2
9	-20	10^{-1}	136.5	130	96.7	178.5	105.5	149.3	224	58	118	132.9
14	-30	19.5	131.7	61	165.7	172.3	146.3	58	84	137.6	207.3	129.3
12	-30	26.7	127.8	97	95	118	134.1	154.7	162.9	129	117.9	126.3
13	-30	32.0	116	176.9	136.4	116	178.5	136.5	178.5	203.6	128.9	152.4

Table 1: Stretch zone measurements of HY100 Specimens Tested at Different Loading Rates and Temperatures.

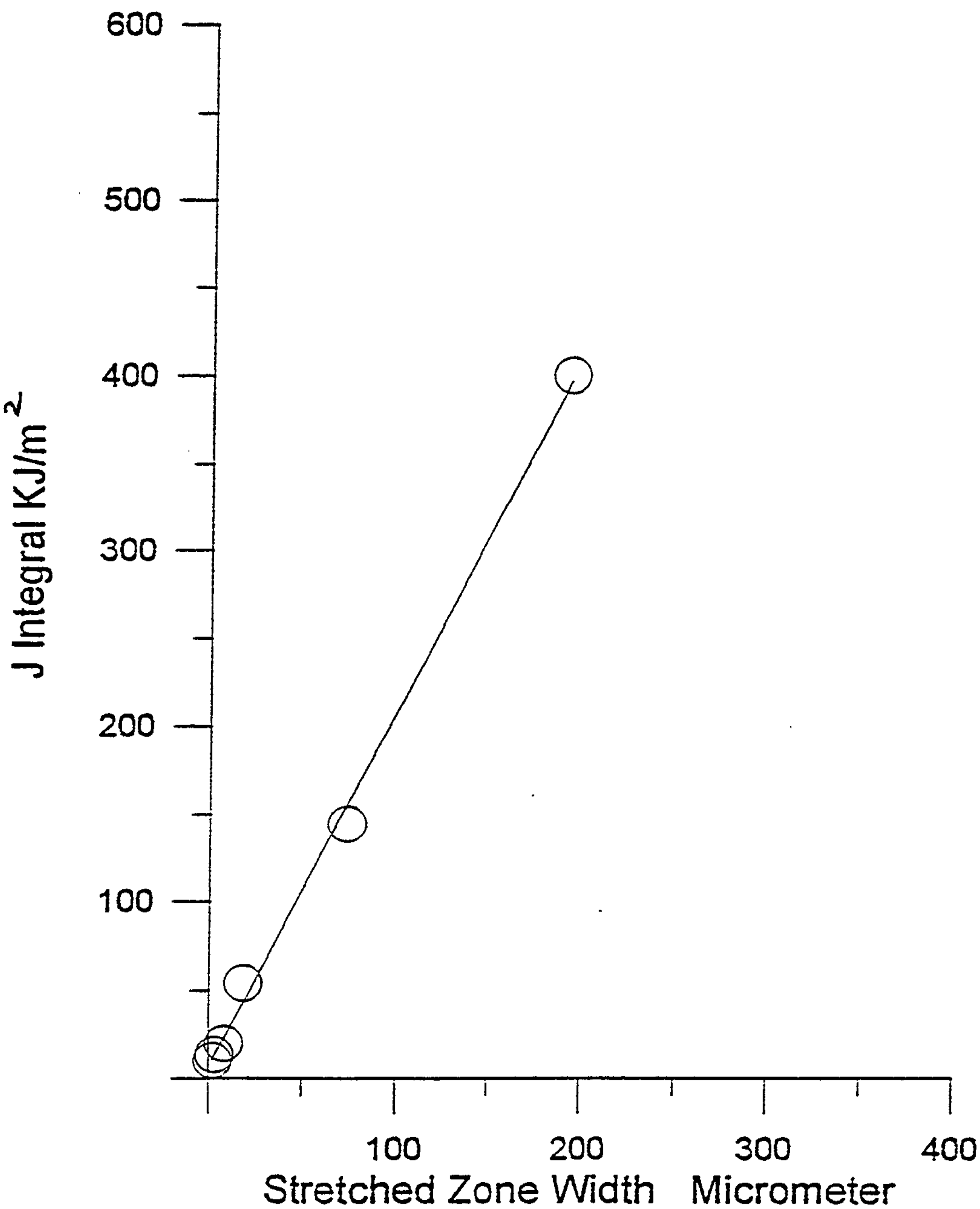


FIG. J-integral vs stretch zone for HY100 steel.

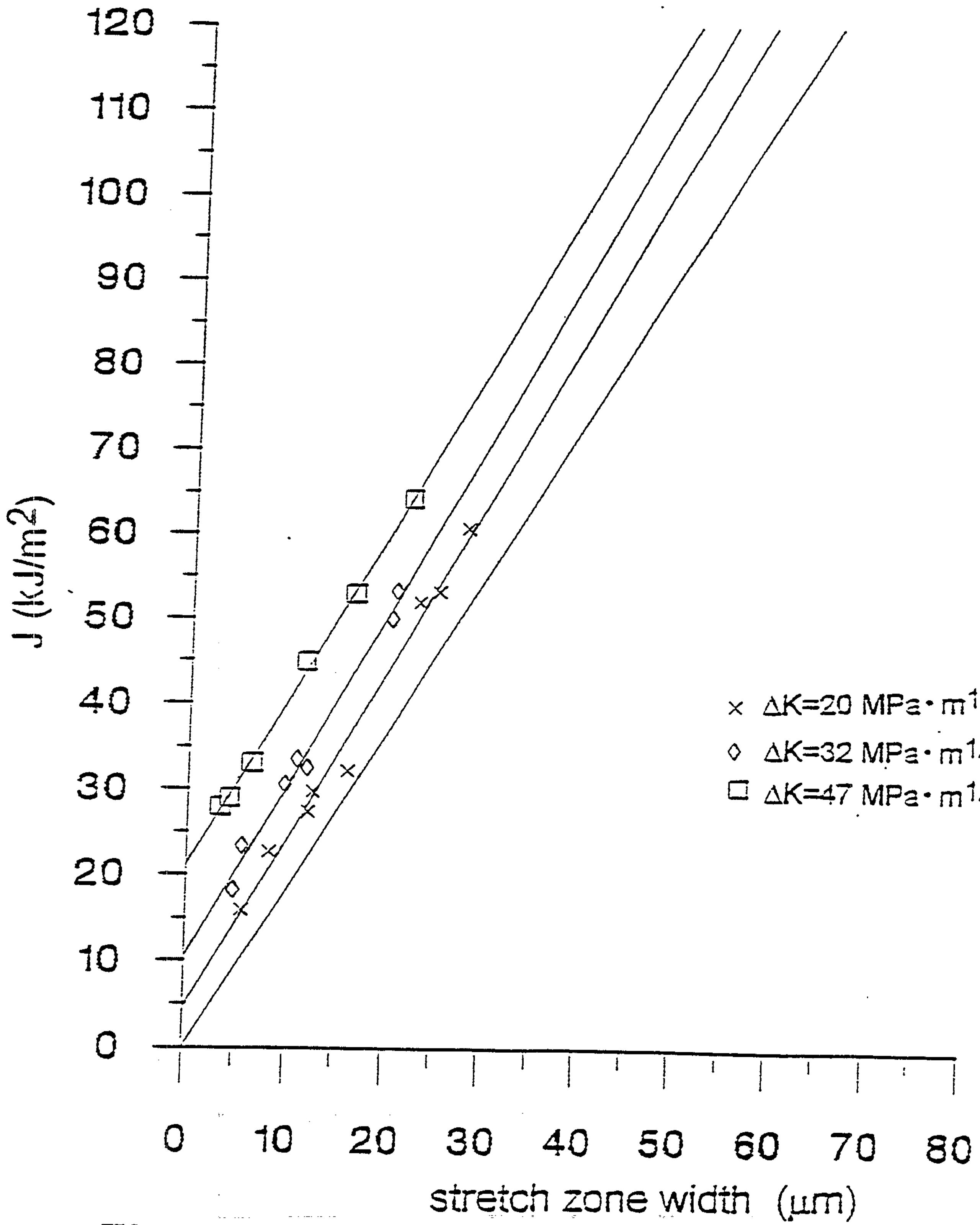


FIG. Effect of fatigue precracking on fracture toughness of 4340 steel.

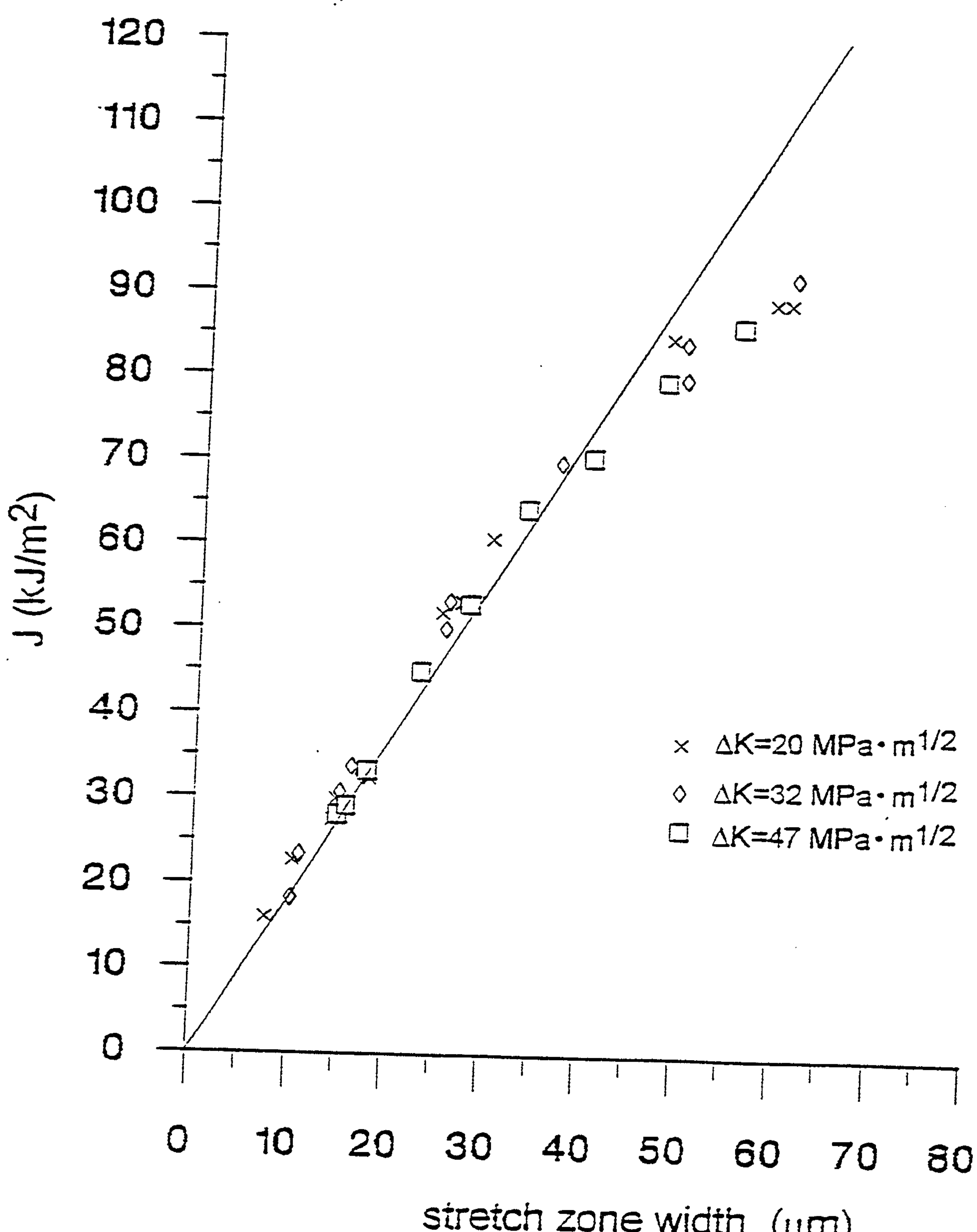


FIG. Corrected effect of fatigue precracking on fracture toughness.

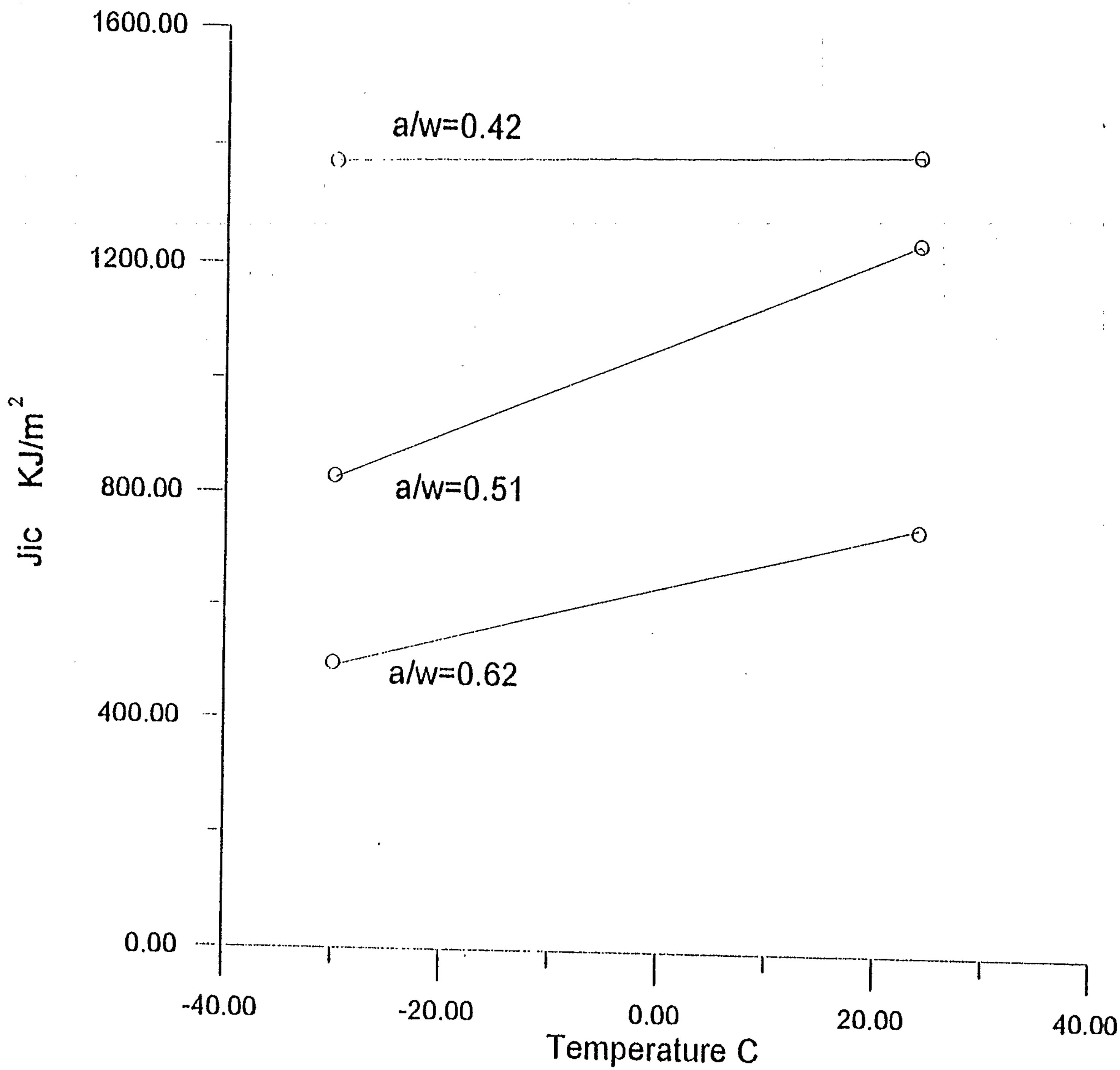


FIG. Effect of temperature and crack length on J-integral.

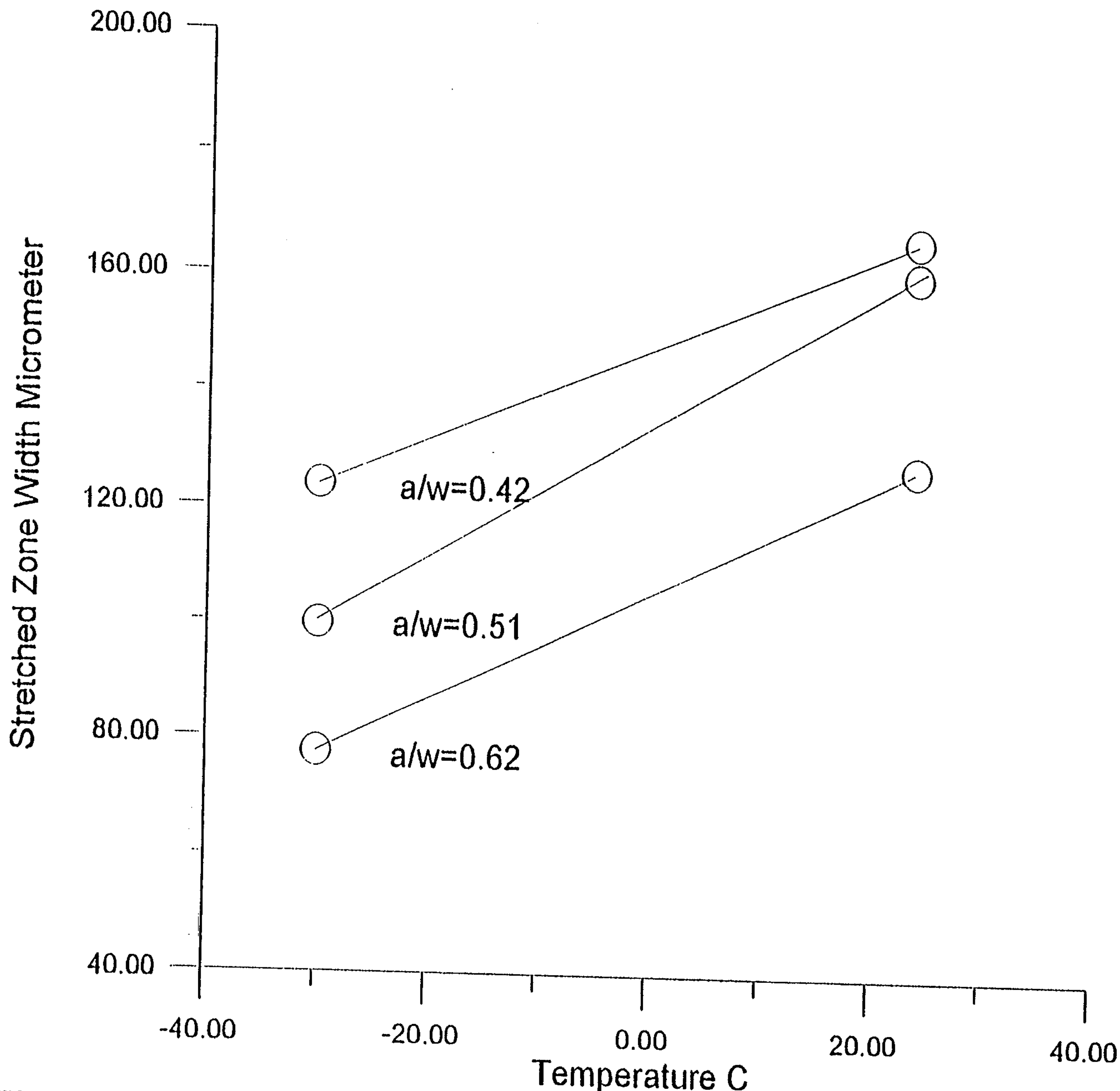


FIG. Effect of temperature and crack length on SZW.

B = 12.7mm (0.5")
Bn = 10.7mm (0.4213")
a_o = 17.70mm (0.7")
b_o = 33.0mm (1.3")
W = 51mm (2")
2H = 63.5mm (2.5")

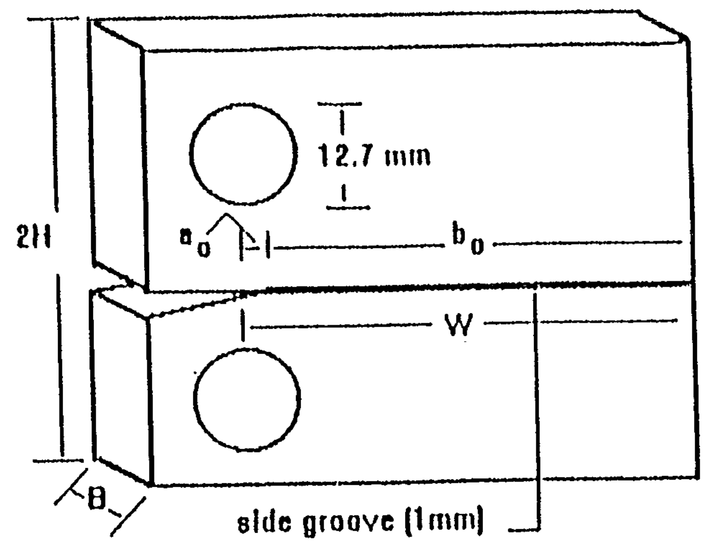


FIG. Large CT specimen dimensions.

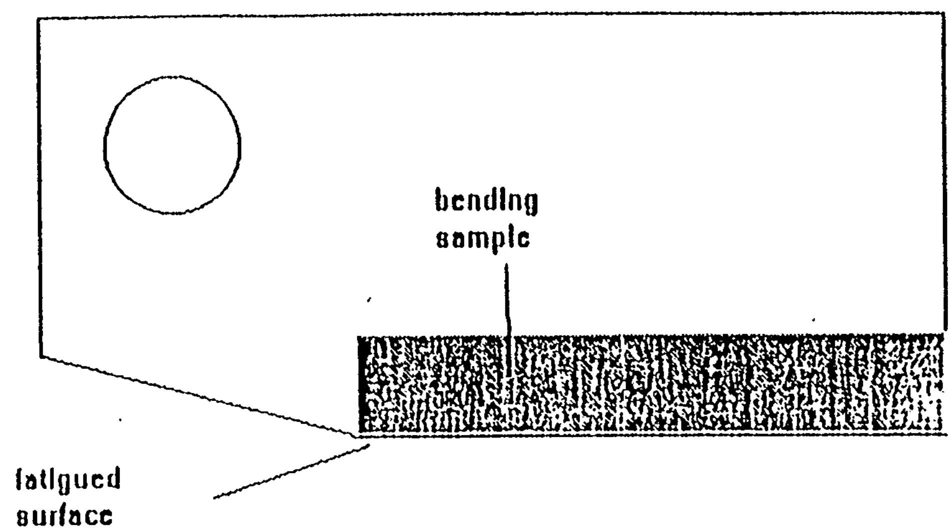


FIG. .. Configuration of bending specimen from large CT specimen.

L = 25.4mm (1.0")
H = 5.08mm (0.2")
D = 0.64mm (0.025")
B = 10.44mm (0.411")
L_0 = 36.93mm (1.455")

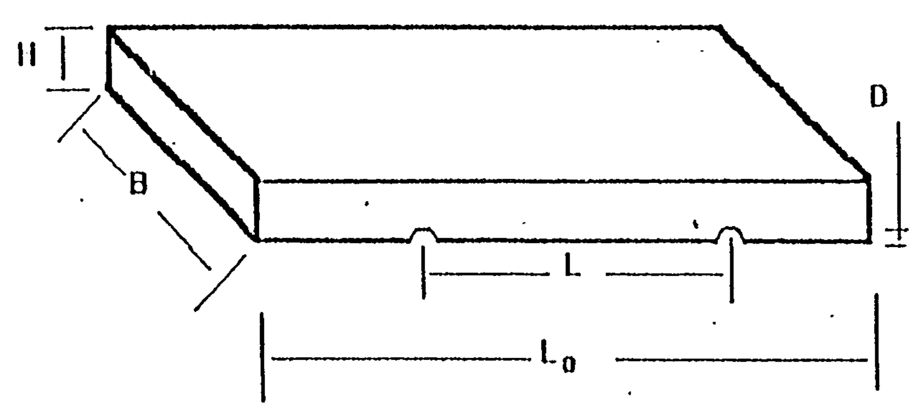


FIG. Dimensions of bending specimen used in strain measurements.

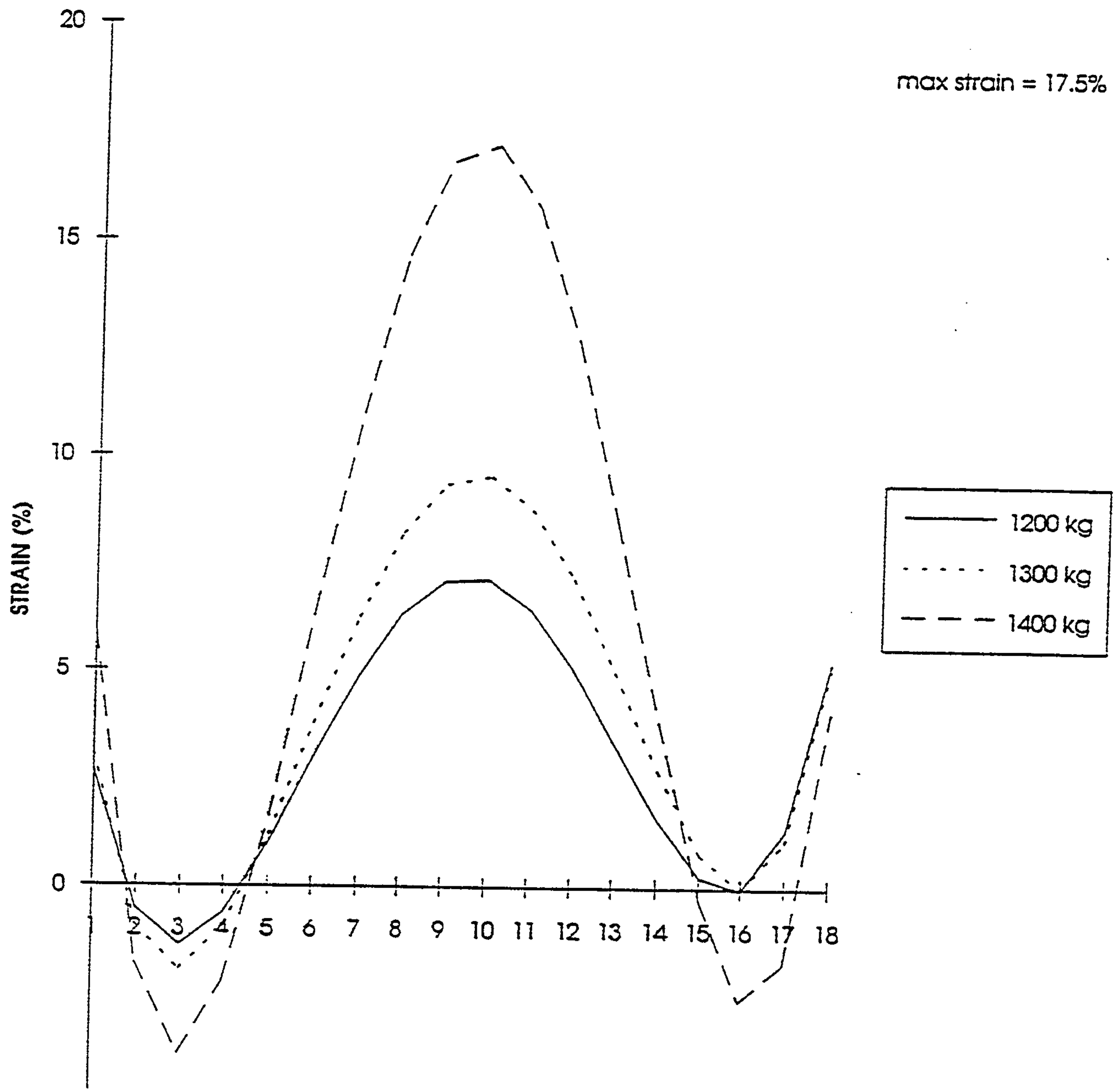


FIG. Strain distribution on polished bending specimen.

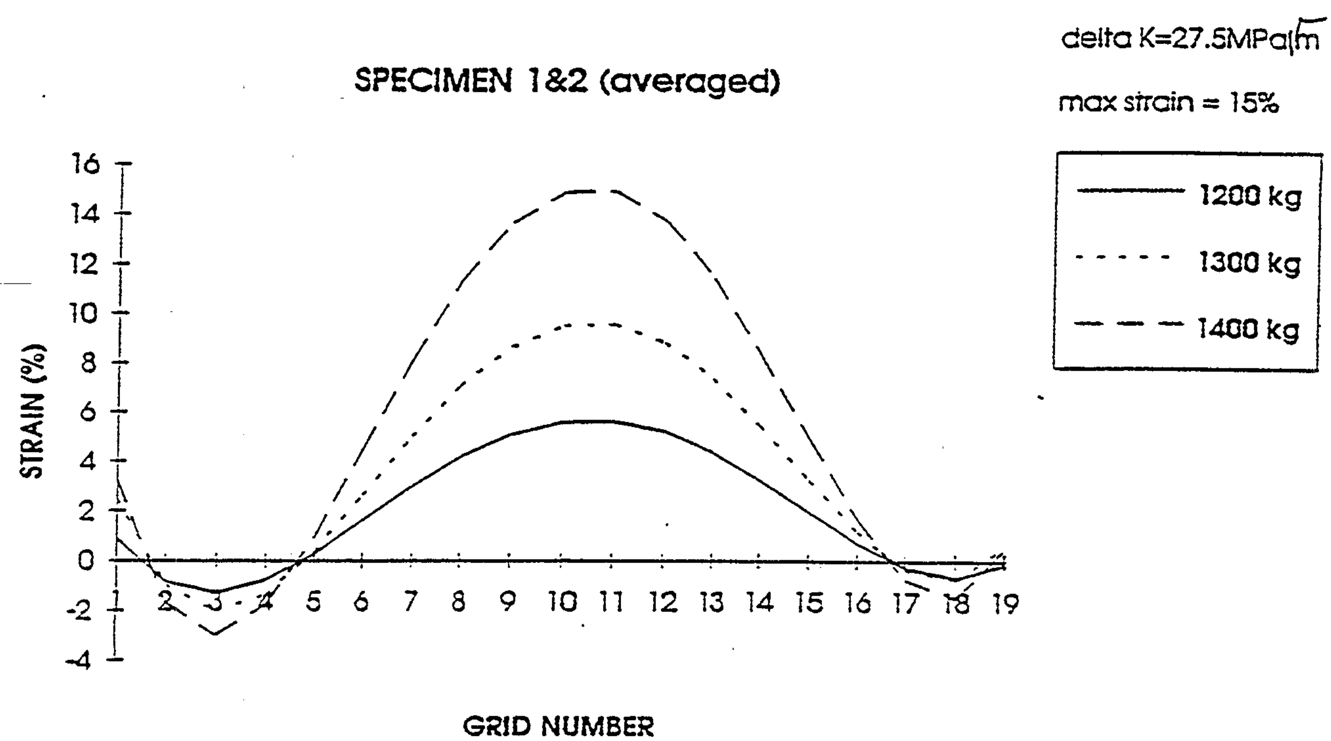


FIG. Strain distribution on fatigued bending specimen. (delta K = 27.5MPa$\sqrt{m}$)

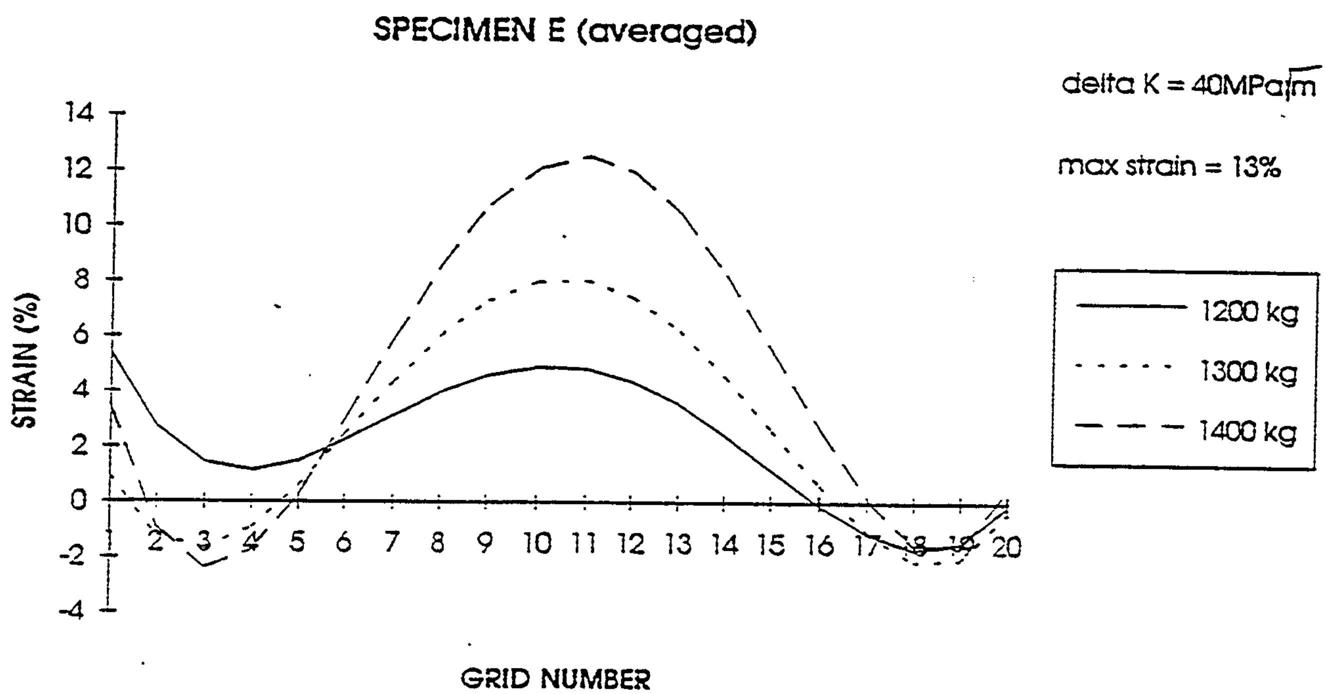


FIG. Strain distribution on fatigued bending specimen. (delta K = 40MPa$\sqrt{m}$)

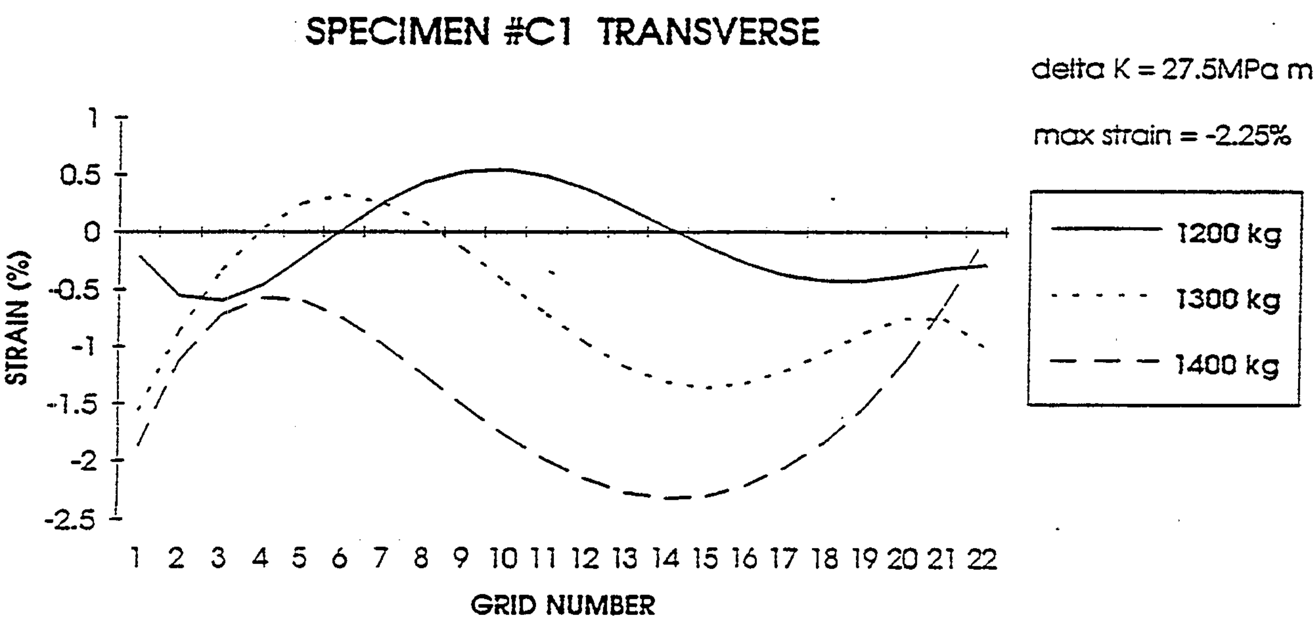


FIG. Strain distribution in transverse direction.

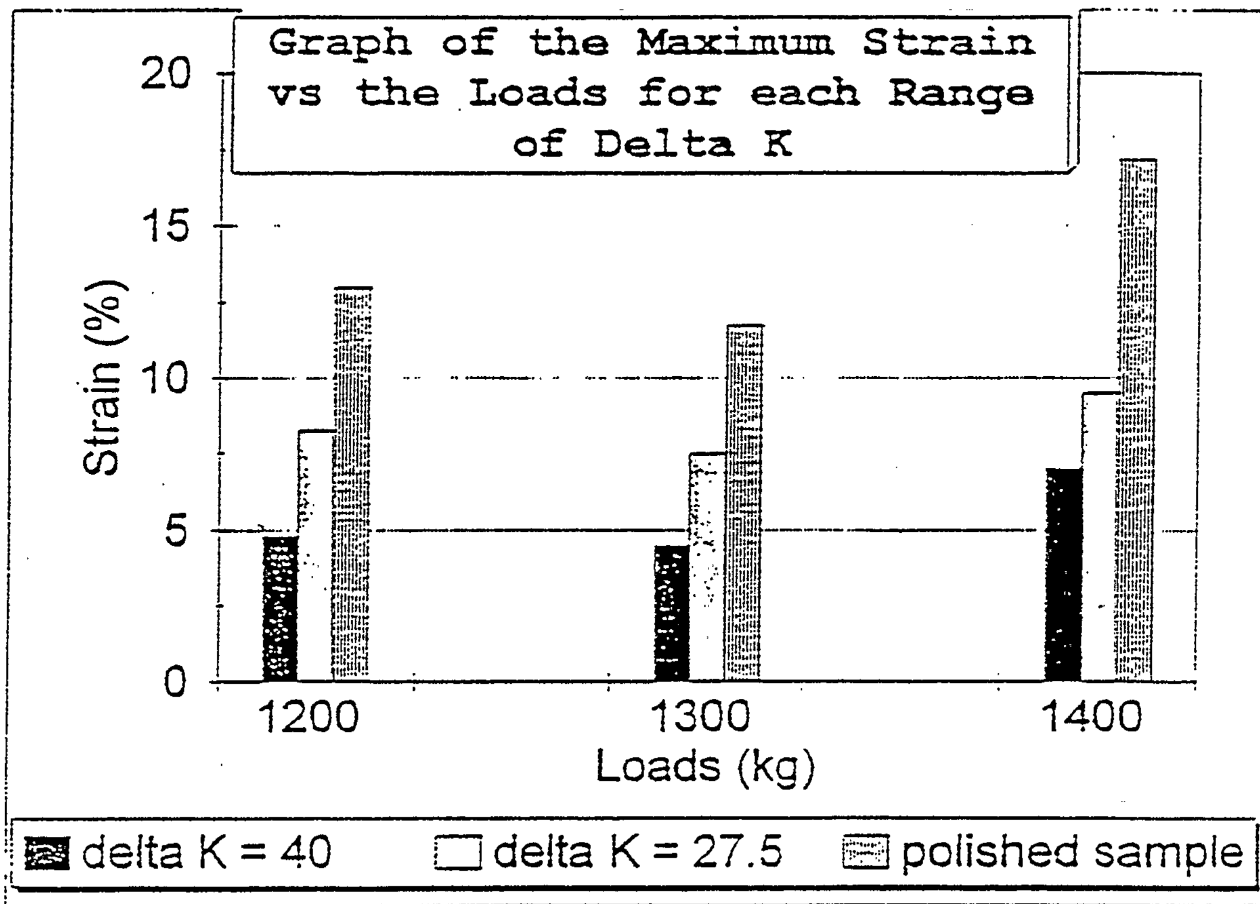


FIG. Summary of strain distribution results.

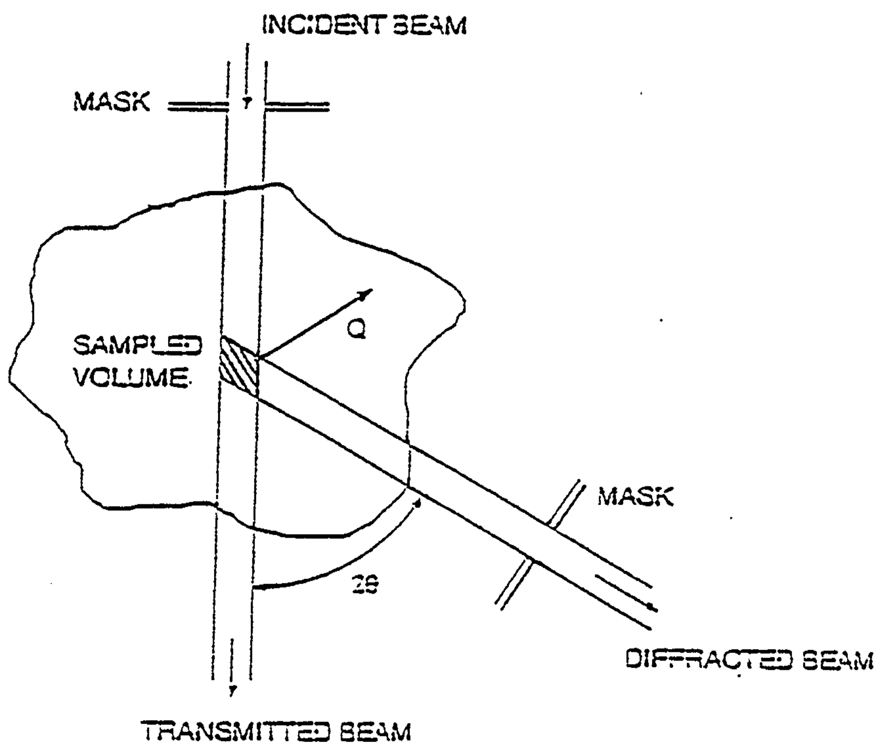


FIG. Configuration of neutron diffraction testing.

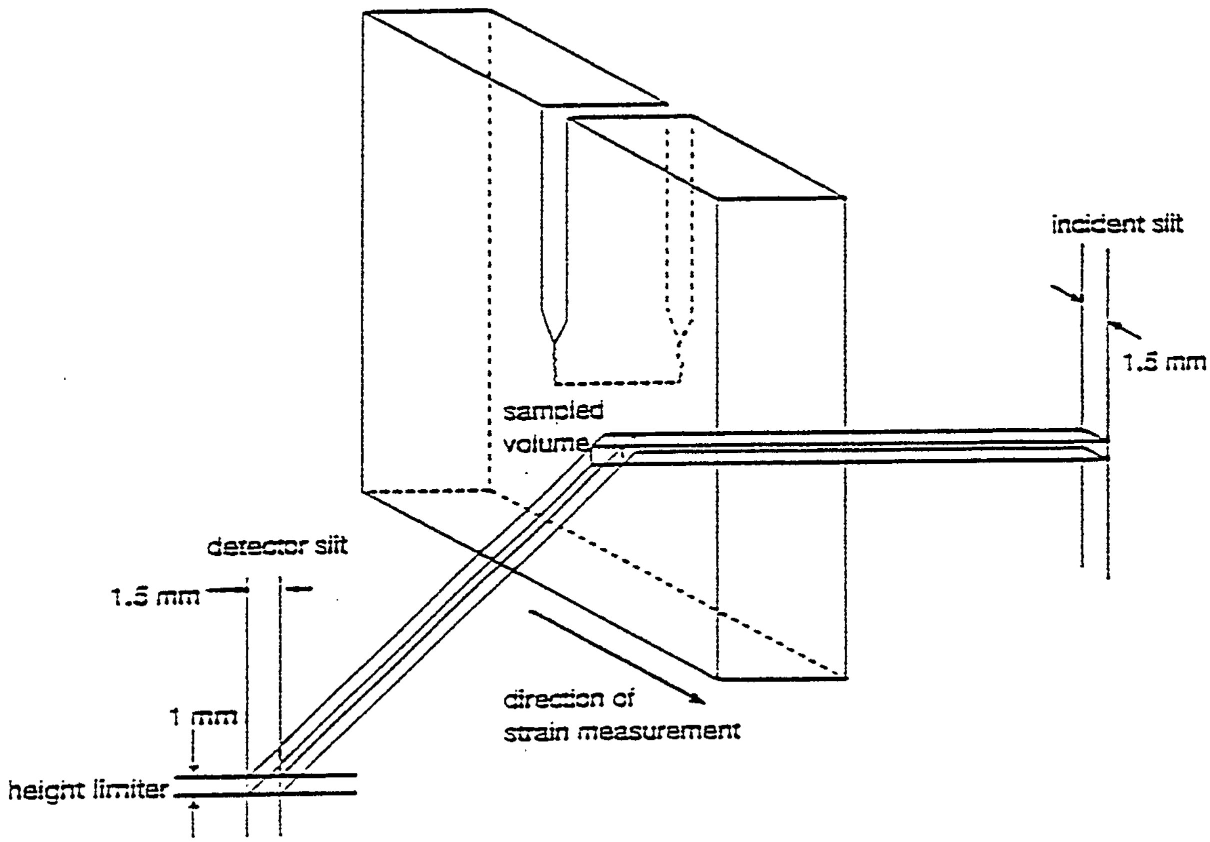


FIG. Neutron diffraction arrangement for CT specimen.

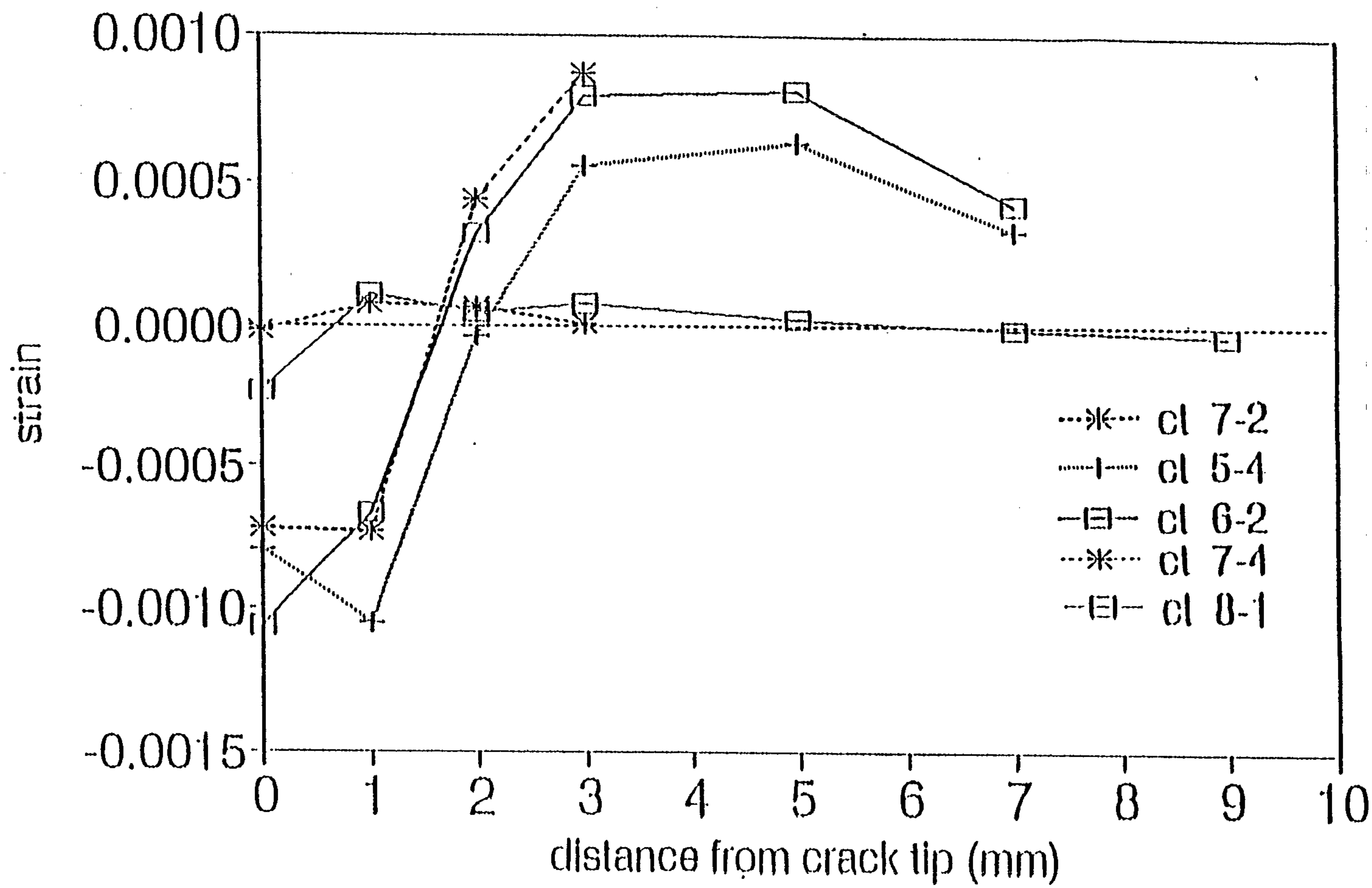


FIG. Residual elastic strains.

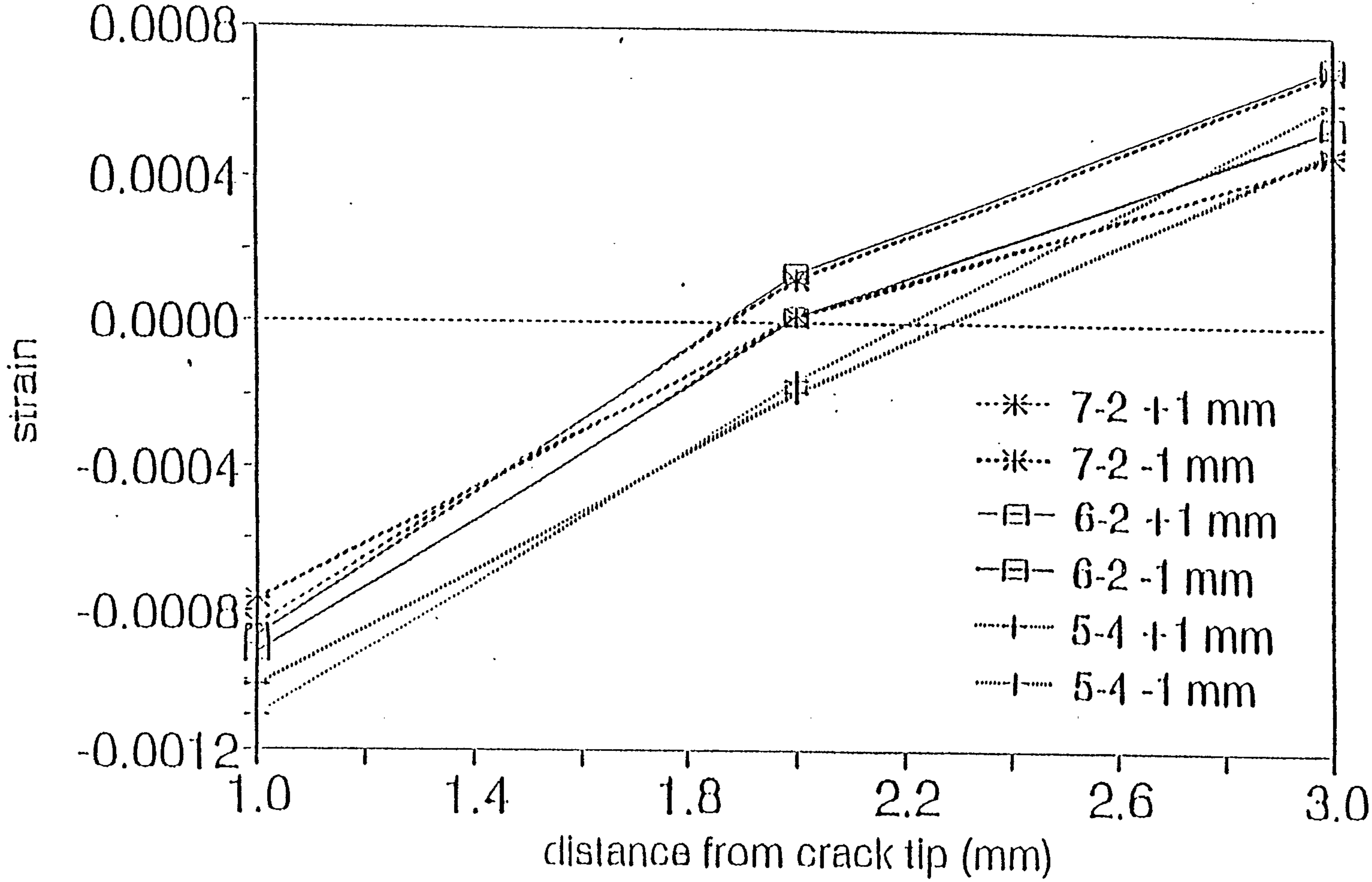


FIG. Residual elastic strains offset $\pm$ 1 mm from the crack plane.

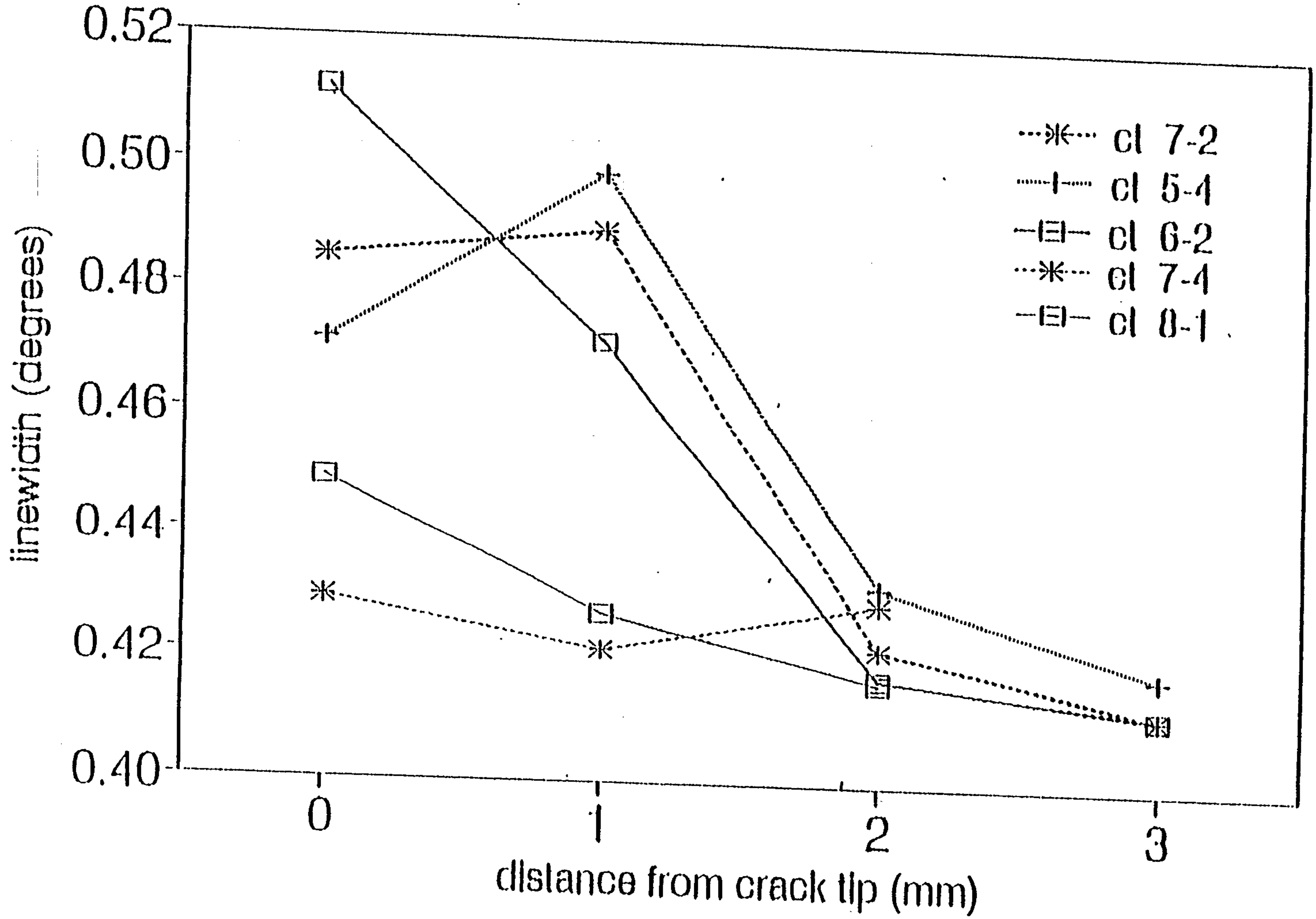


FIG. Linewidths arising from plastic deformation.

CONCLUSIONS

The research described deals with consideration of the effects which may influence the stretch zone with measurements and hence the determination of the fracture toughness of the high strength low alloy steels. Among these factors are the effect of crack size, temperature, loading rates as well as other factors related to the pre cracking process such as prestraining and strain hardening of the crack surface. The results obtained provide an in-depth understanding of these factors. Equations for compensation of these factors were also developed.