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MEMORANDUM FOR PRS (In-House /Contractor Publication)

FROM: PROI (TI) (STINFO) 21 October 1999

SUBJECT: Authorization for Release of Technical Information, Control Number: **AFRL-PR-ED-TP-1999-0196**
Smith, C.W.; Gloss, K.T., Liu, C.T, "Test Geometries for Bondline Cracked Photoelastic Models; Preliminary Results" (VuGraphs)

ASME 1999 Mechanical Engineering Congress and Exposition **(Statement A)**

Item, (Liu

TEST GEOMETRIES FOR BONDLINE CRACKED PHOTOELASTIC MODELS: PRELIMINARY RESULTS

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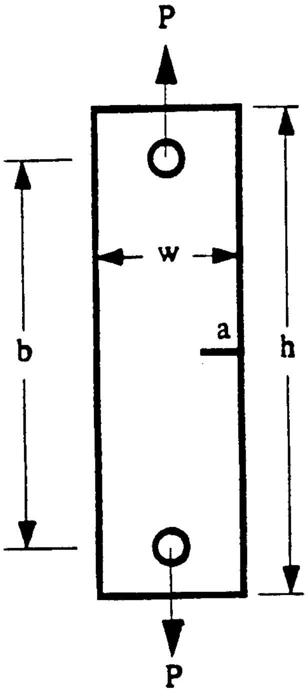
$w = 38.1$ mm
$t = 12.7$ mm
$h = 127$ mm
$b = 102$ mm
$P = 2.74$ kgs



		(MPa $\sqrt{m}$)		
a (mm)	**a/w**	**K_{exp}**	**K_{th}^{*}**	**% difference**
7.54	0.20	12.76	11.84	7.80

* Srawley and Brown, 1967

Fig. 1 Single Edge Crack Results for Artificial Cracks

(Mode I Algorithm)

Beginning with the Griffith-Irwin Equations, we may write, for Mode I, for the homogeneous case,

$$\sigma_{ij} = \frac{K_1}{(2\pi r)^{\frac{1}{2}}} f_{ij}(\theta) + \sigma^{\circ}_{ij} \qquad (i.j. = n, z) \qquad (1)$$

where:

σ_{ij} are components of stress,

K_1 is SIF,

r, θ are measured from crack tip(Fig. A-1),

σ°_{ij} are nonsingular stress components.

Then, along $\theta = \pi/2$ the direction of greatest local fringe spreading, after truncating σ_{ij}

$$(\tau_{nz})_{\max} = \frac{K_1}{(8\pi r)^{\frac{1}{2}}} + \tau^{\circ} = \frac{K_{AP}}{(8\pi r)^{\frac{1}{2}}} \qquad (2)$$

where $\tau^{\circ} = f(\sigma^{\circ}_{ij})$ and is constant over the data range, K_{AP} = apparent SIF, $(\tau_{nz})_{max}$ = maximum shear stress in nz plane

$$\therefore \frac{K_{AP}}{\bar{\sigma}(\pi a)^{\frac{1}{2}}} = \frac{K_1}{\bar{\sigma}(\pi a)^{\frac{1}{2}}} + \frac{\sqrt{8}\tau^{\circ}}{\bar{\sigma}} \left(\frac{r}{a}\right)^{\frac{1}{2}} \qquad (3)$$

where (Fig. A-1) a = crack length, and $\bar{\sigma}$ = remote normal stress

$$i.e. \frac{K_{AP}}{\bar{\sigma}(\pi a)^{\frac{1}{2}}} \text{ vs. } \sqrt{\frac{r}{a}} \text{ is linear.}$$

Since from the Stress-Optic Law:

$$(\tau_{nz})_{\max} = \frac{nf}{2t} \text{ where}$$

n = stress fringe order

f = material fringe value

t = specimen thickness

and from Eq. 2

$$K_{AP} = \tau^{max}_{nz}(8\pi r)^{\frac{1}{2}} = \frac{nf}{2t}(8\pi r)^{\frac{1}{2}},$$

then K_{AP} (through a measure of n) and r becomes the measured quantity from the stress fringe pattern at different points in the pattern.

A typical plot of normalized K_{AP} vs. $\sqrt{r/a}$ for a cracked, bonded specimen is shown in Fig. A-2.

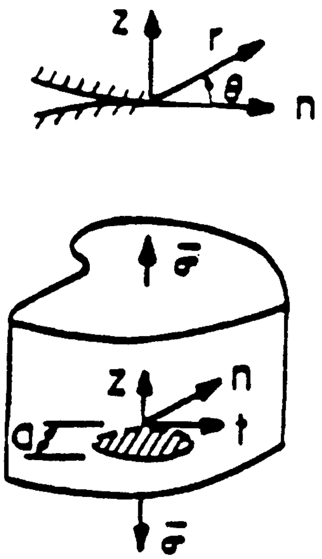


Fig. A-1 Mode I Notation

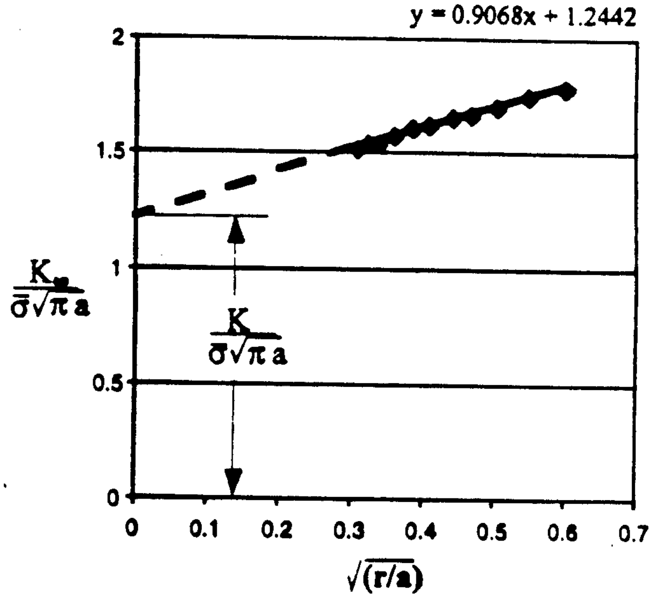


Fig. A-2: Determination of K_I from Test Data for DS4.

Mixed mode algorithm

The mixed mode algorithm was developed (see Fig. 12(a) and (b)) by requiring that

$$\lim_{\substack{r_m \to 0 \\ \Theta_m \to \Theta^\circ_m}} \left\{ (8\pi r_m)^{1/2} \frac{\delta(\tau)^{\max}_{nz}}{\delta\Theta} (K_1, K_2, r_m, \Theta_m, \tau_{ij}) \right\} = 0 \tag{4}$$

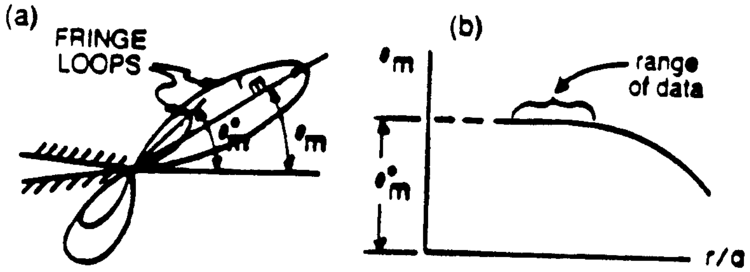


Fig. 12. (a) and (b). Determination of $\theta^\circ{}_m$.

which leads to

$$\left(\frac{K_2}{K_1}\right)^2 - \frac{4}{3}\left(\frac{K_2}{K_1}\right)\cot 2\Theta^\circ_m - \frac{1}{3} = 0 - - - . \tag{5}$$

By measuring $\Theta^\circ{}_m$ which is approximately in the direction of the applied load, K_2/K_1 can be determined.

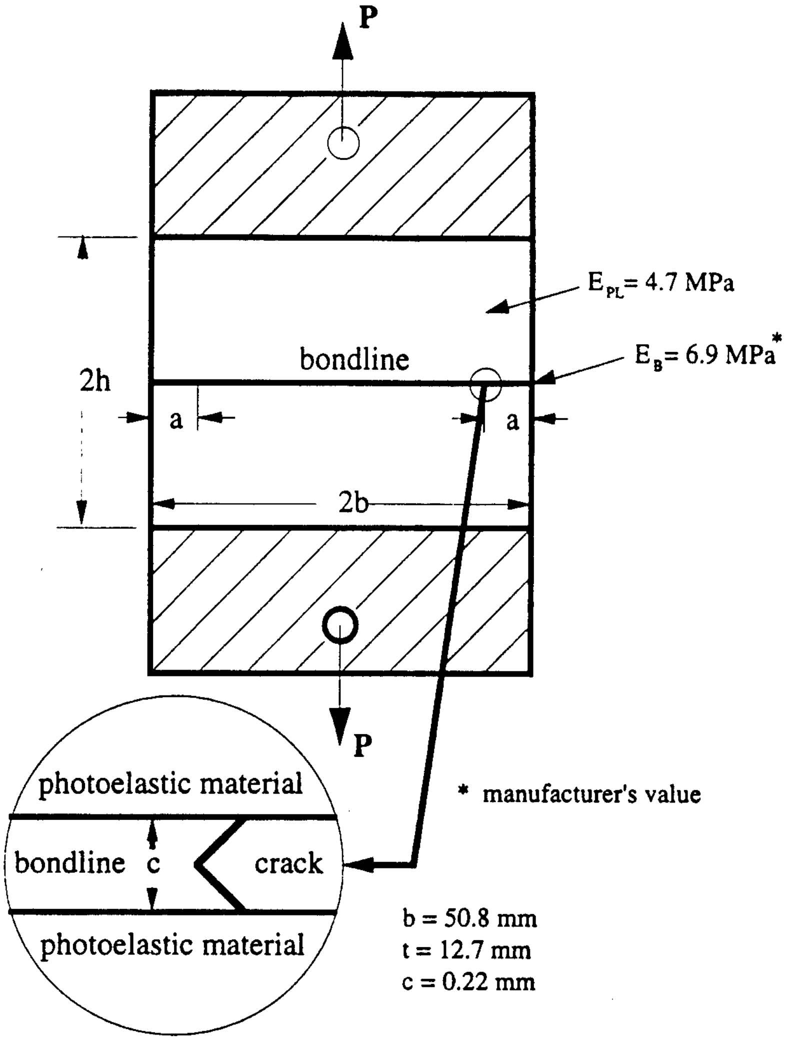
Then writing the stress optic law as

$$\tau^{\max}_{nz} = \frac{fn}{2t} = \frac{K^*_{AP}}{(8\pi r)^{\frac{1}{2}}},$$

one may plot $K^*_{AP}/\bar{\sigma}(\pi a)^{1/2}$ vs $\sqrt{r/a}$ as before; locate a linear zone and extrapolate to $r = 0$ to obtain K^*. Knowing, K^*, K_2/K_1 and $\Theta^\circ{}_{,m}$ values of K_1 and K_2 may be determined since

$$K^* = \left[\left(K_1 \sin\Theta^\circ_m + 2K_2 \cos\Theta^\circ_m \right)^2 + \left(K_2 \sin\Theta^\circ_m \right)^2 \right]^{\frac{1}{2}} - - - . \tag{6}$$

Knowing K^* and $\Theta^\circ{}_m$, K_1 and K_2 can be determined from Eqs. (5) and (6). Details are found in Ref. [3].



* manufacturer's value

b = 50.8 mm
t = 12.7 mm
c = 0.22 mm

test	a (mm)	h (mm)	a/b	P (kg)
DS2	7.94	50.8	0.16	7.64
DS3	12.7	50.8	0.25	7.64
DS4	17.4	50.8	0.34	7.64
DS5	20.6	50.8	0.41	7.64
DS6	25.4	50.8	0.50	7.64
DS7	27.9	50.8	0.55	7.64
DS8	7.94	25.4	0.16	7.64
DS9	12.7	25.4	0.25	7.64
DS10	17.4	25.4	0.34	5.37
DS11	20.6	25.4	0.41	5.17
DS12	25.4	25.4	0.50	5.17
DS13	27.9	25.4	0.55	5.20

Fig. 2 Bonded Specimens with Double Edge Bondline Cracks

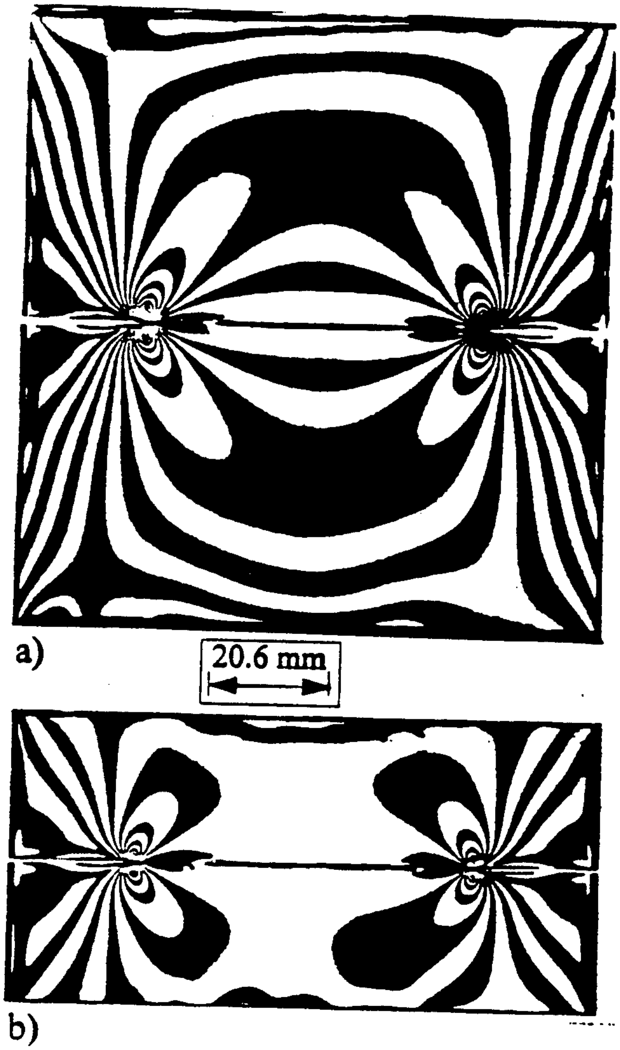


Fig. 3[+]: Global Stress Fringe Patterns for a) Square Specimen, b) Short Specimen.

[+] All fringe patterns have a bright background, (i.e. integral fringes are white, half fringes are black).

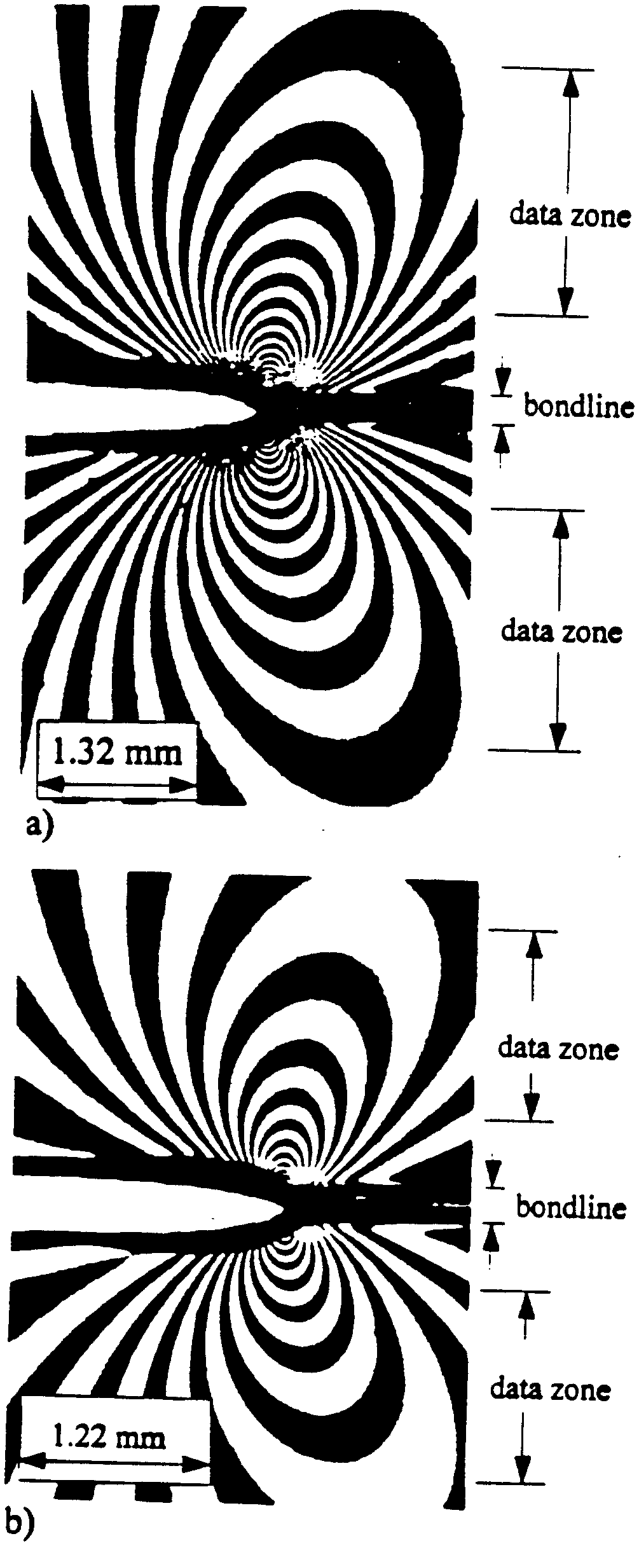


Fig. 4⁺: Local Stress Fringe Patterns for a) Square Specimen, b) Short Specimen.