On the Autonomy of the Crack Tip Region

Talk given at SMD, Swedish Mechanics Days, LiTh, Linköping, Sweden. Orationem Meam.

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- Autonomin för processområdet går förlorad vid samma last som för den plastiska zonen.

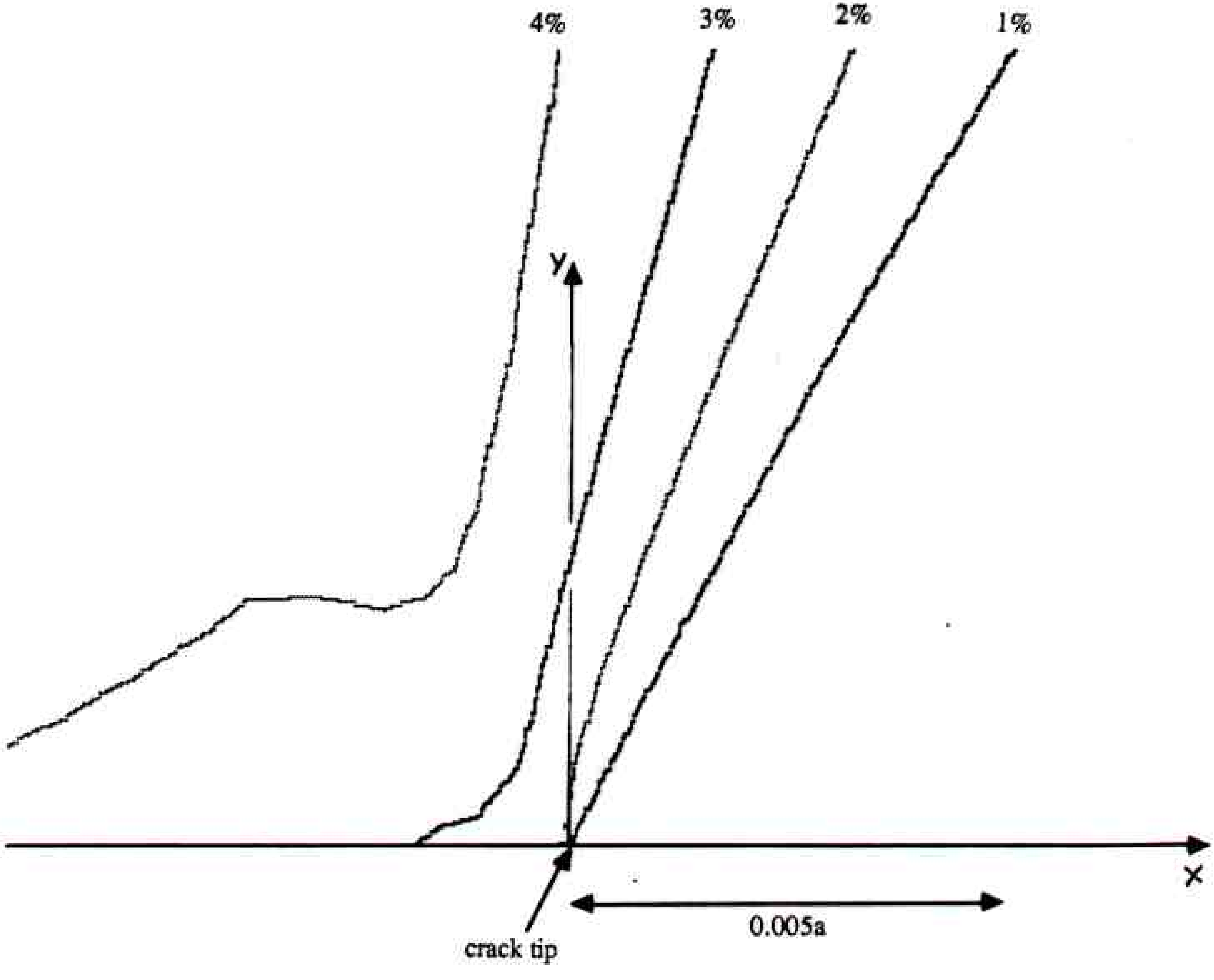
- Beräkning med modell för processområdet kan utföras i två steg:

  (I) Beräkning för kropp med punktformat pr. omr.

  (II) Lokal beräkning för sprickspetsområdet.

Fig. 13a. Displacement deviations for the edge crack calculation when compared with the small scale yielding calculation, both calculations with singular crack tip.

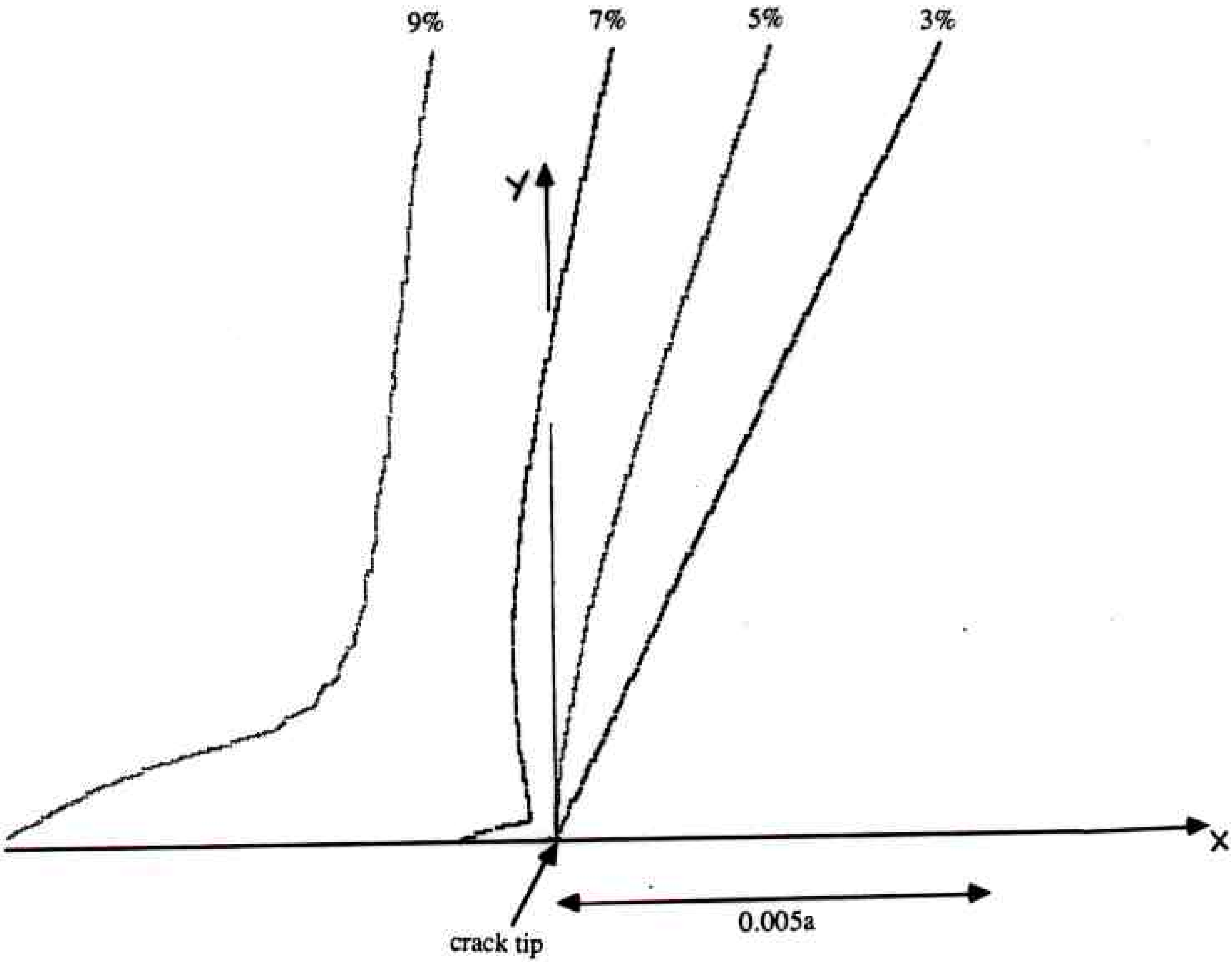
$E_t = 0.05E$; $\sigma_0 = 0.23\sigma_Y$



The maximum extension of the plastic zone is 0.05a.

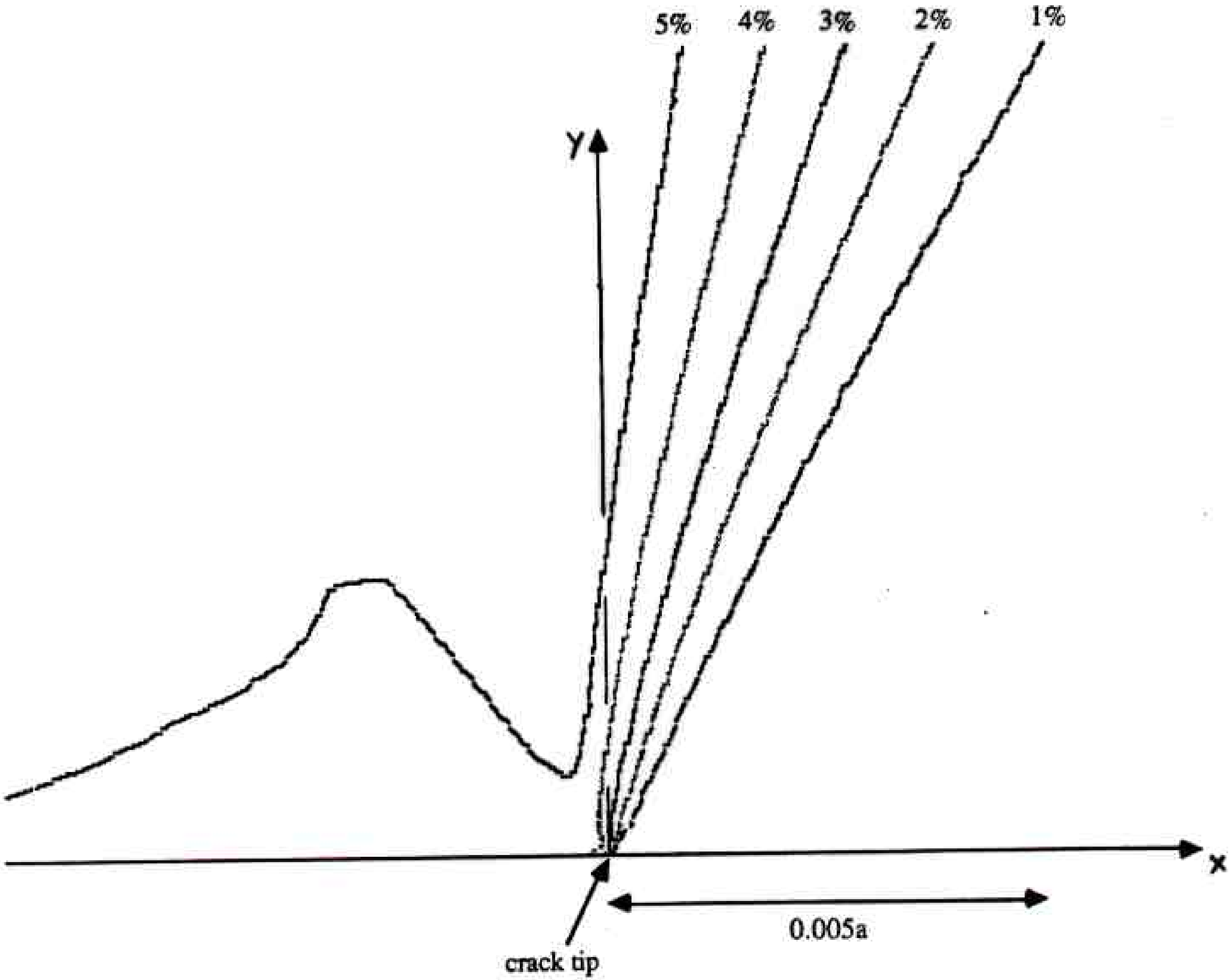
Fig. 14a. Displacement deviations for the edge crack calculation when compared with the small scale yielding calculation, both calculations with singular crack tip.

$E_t = 0.05E$; $\sigma_0 = 0.46\sigma_Y$



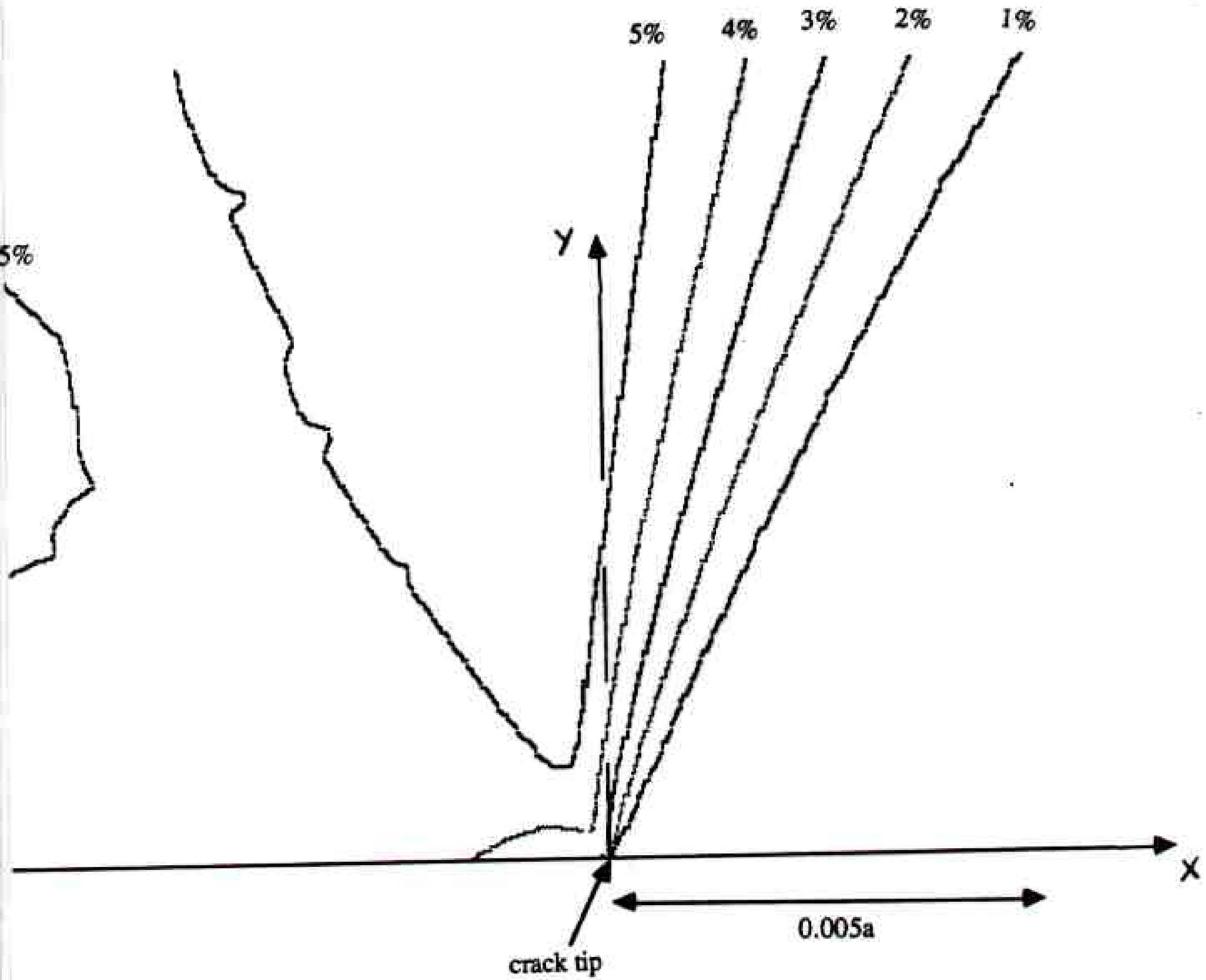
The maximum extension of the plastic zone is 0.19a.

Fig. 18a. Displacement deviations for the edge crack calculation when compared with the small scale yielding calculation, both calculations with cohesive zone: $\sigma_D/\sigma_Y = 8$. $E_t = 0.01E$; $\sigma_0 = 0.23\sigma_Y$

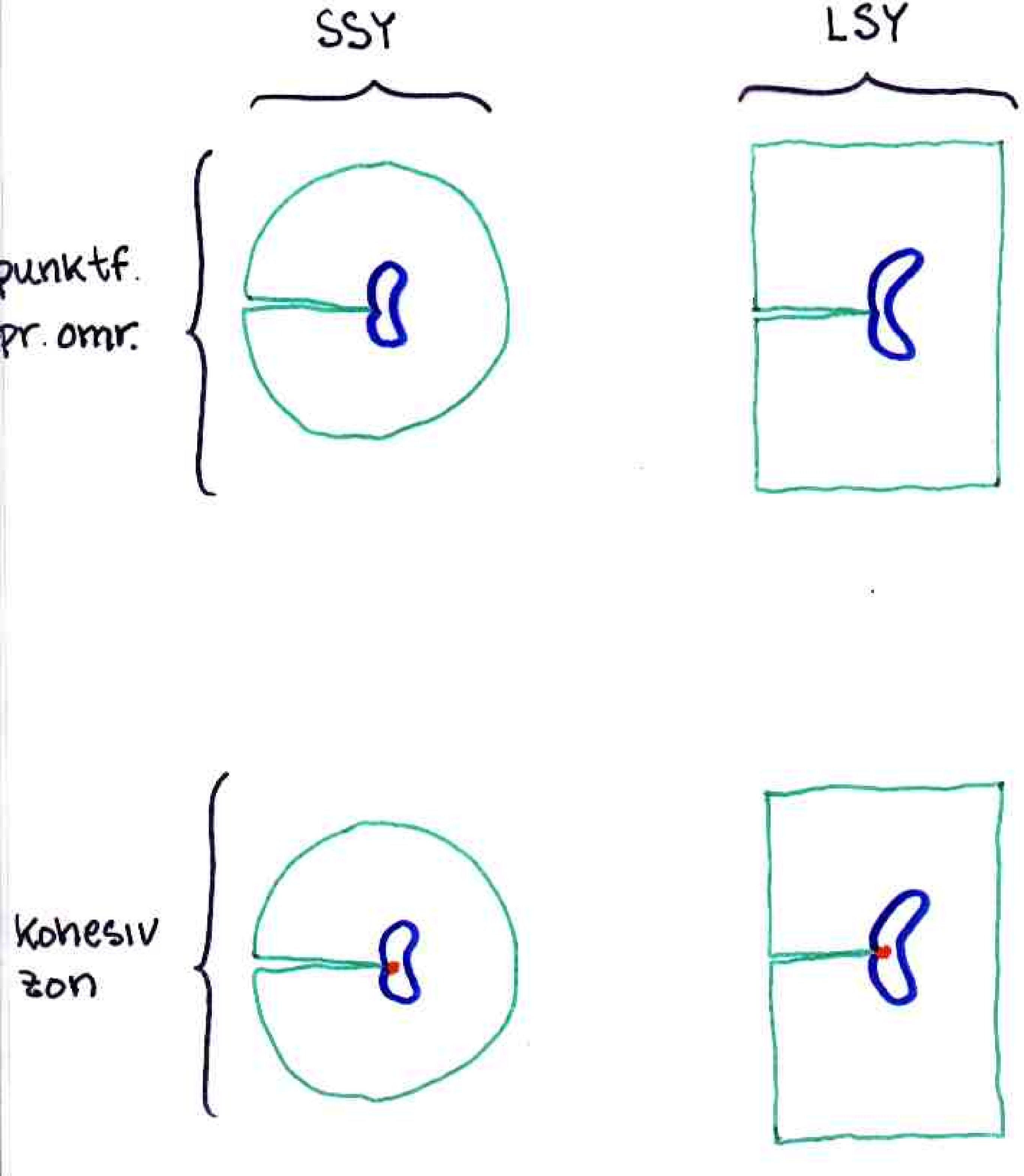


The maximum extension of the plastic zone is 0.05a; the length of the cohesive zone is $5 \cdot 10^{-5}a$

Fig. 15a. Displacement deviations for the edge crack calculation when compared with the small scale yielding calculation, both calculations with singular crack tip.
$E_t = 0.01E$; $\sigma_0 = 0.23\sigma_Y$



The maximum extension of the plastic zone is 0.05a.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σ_0/σ_Y	E_t/E	relative deviations of displacement $10r_p$	r_p	$r_p/10$	$r_p/100$
0.23	1	0.055	0.018	0.0059	0.0022
0.12	0.05	0.041	0.020	0.016	0.0090
0.23	0.05	0.058	0.046	0.031	0.024
0.34	0.05	0.084	0.076	0.058	0.043
0.46	0.05	0.104	0.112	0.091	0.070.
0.12	0.01	0.042	0.023	0.024	0.015
0.23	0.01	0.059	0.061	0.051	0.036
0.34	0.01	0.085	0.099	0.088	0.065
0.46	0.01	0.106	0.124	0.137	0.105

Fig. 22. Dimensionless displacement v $(\sigma_D E)/K_I^2$ as a function of the dimensionless coordinate x $(\sigma_D/K_I)^2$ for the two different geometries. $E_t = 0.01E$; $\sigma_0 = 0.34\sigma_Y$. The cohesive stress is $\sigma_D/\sigma_Y = 8$.

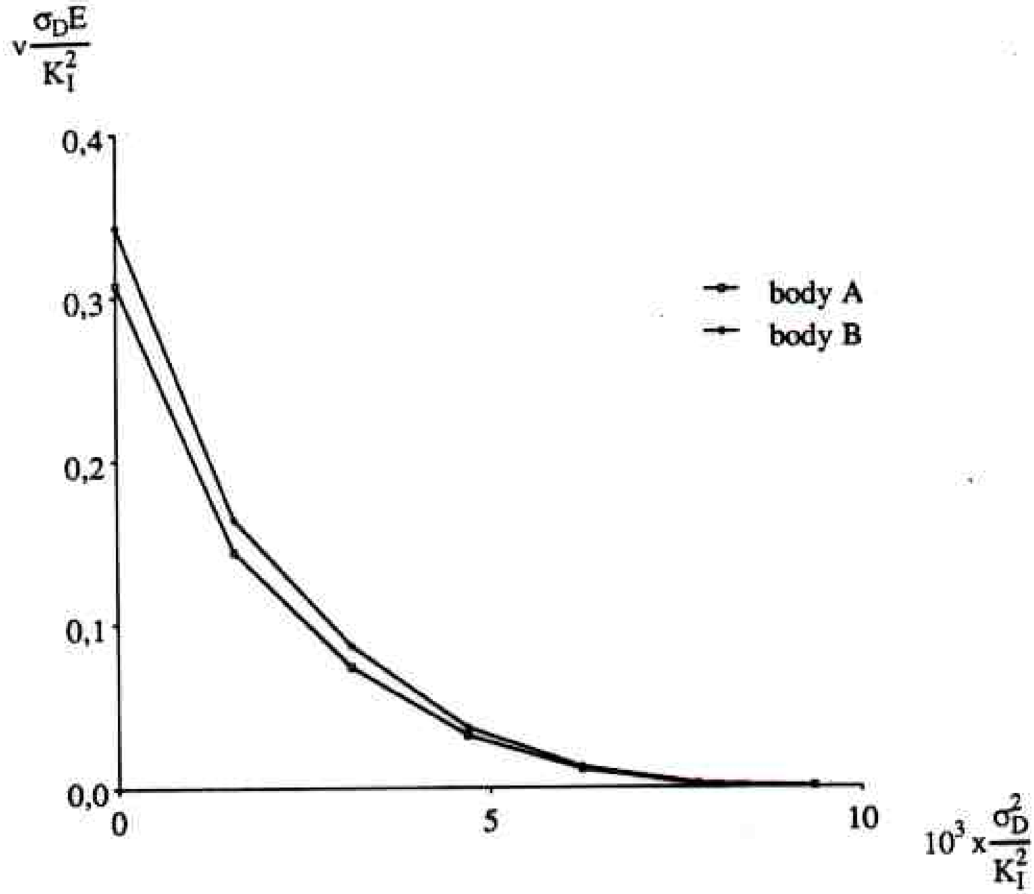


Fig. 21. Dimensionless displacement v $(\sigma_D E)/K_I^2$ as a function of the dimensionless coordinate x $(\sigma_D/K_I)^2$ for the two different geometries. $E_t = 0.01E$; $\sigma_0 = 0.23\sigma_Y$. The cohesive stress is $\sigma_D/\sigma_Y = 8$.

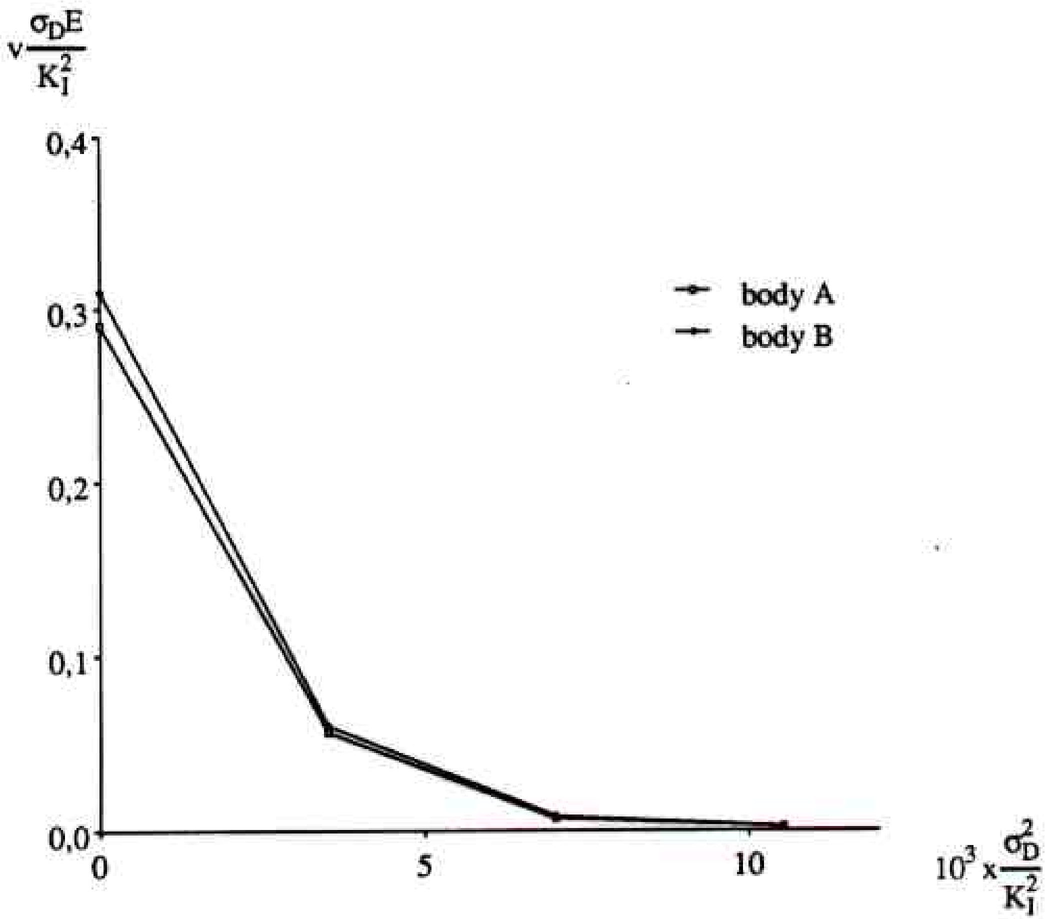


Fig. 20. Dimensionless displacement $v\,(\sigma_D E)/K_I^2$ as a function of the dimensionless coordinate $x\,(\sigma_D/K_I)^2$ for the two different geometries. $E_t = 0.05E$; $\sigma_0 = 0.46\sigma_Y$. The cohesive stress is $\sigma_D/\sigma_Y = 8$.

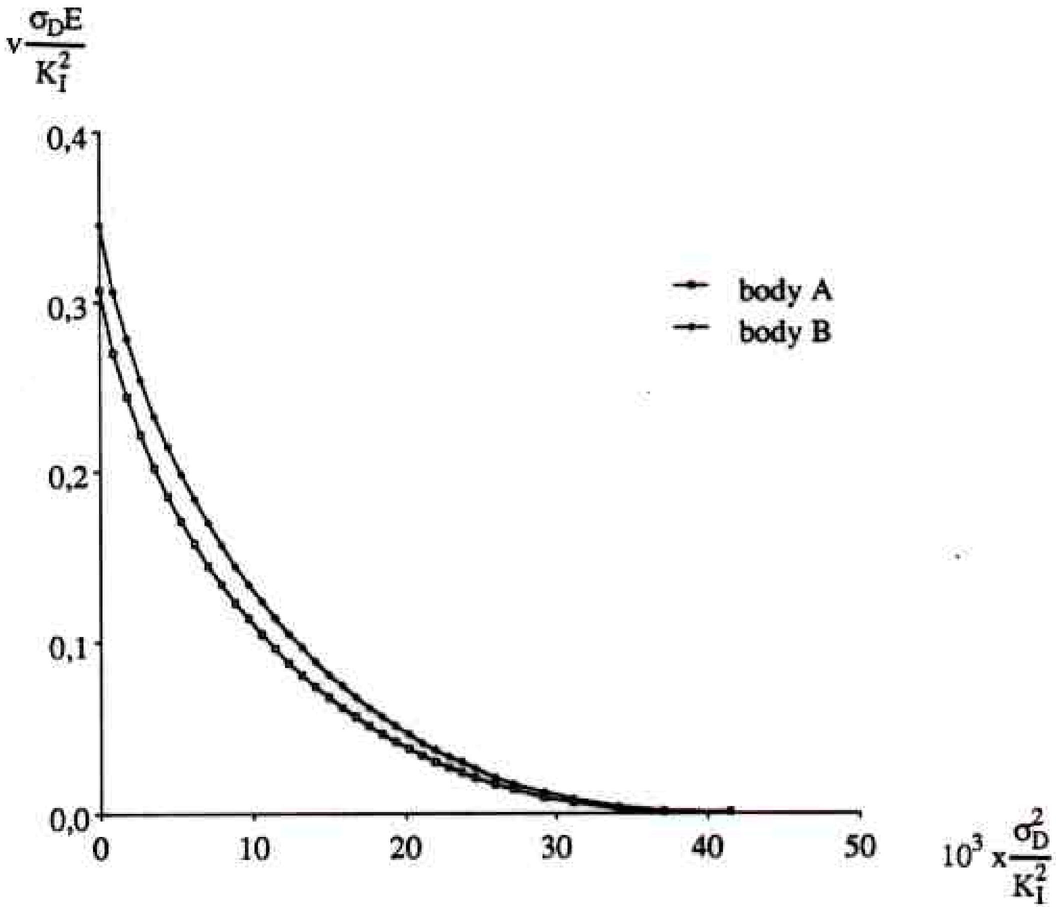


Fig. 19. Dimensionless displacement v $(\sigma_D E)/K_I^2$ as a function of the dimensionless coordinate x $(\sigma_D/K_I)^2$ for the two different geometries. $E_t = 0.05E$; $\sigma_0 = 0.23\sigma_Y$. The cohesive stress is $\sigma_D/\sigma_Y = 8$.

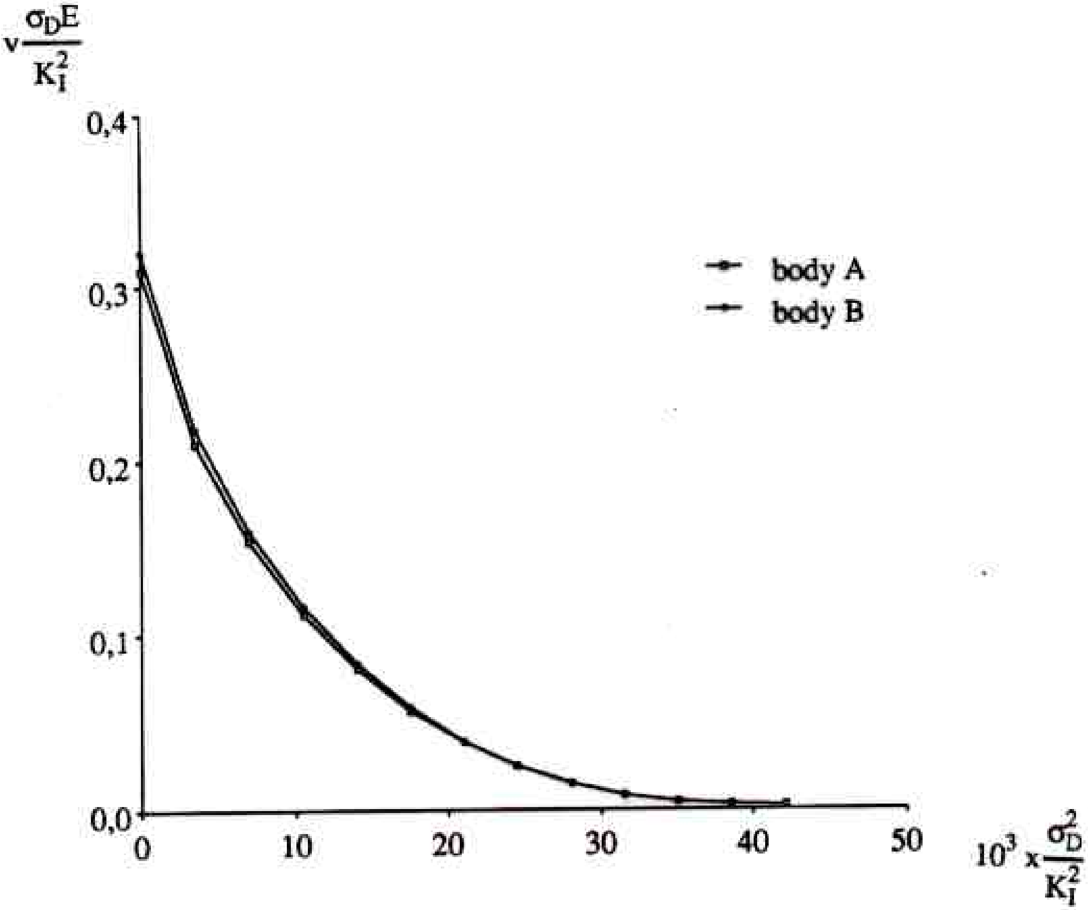
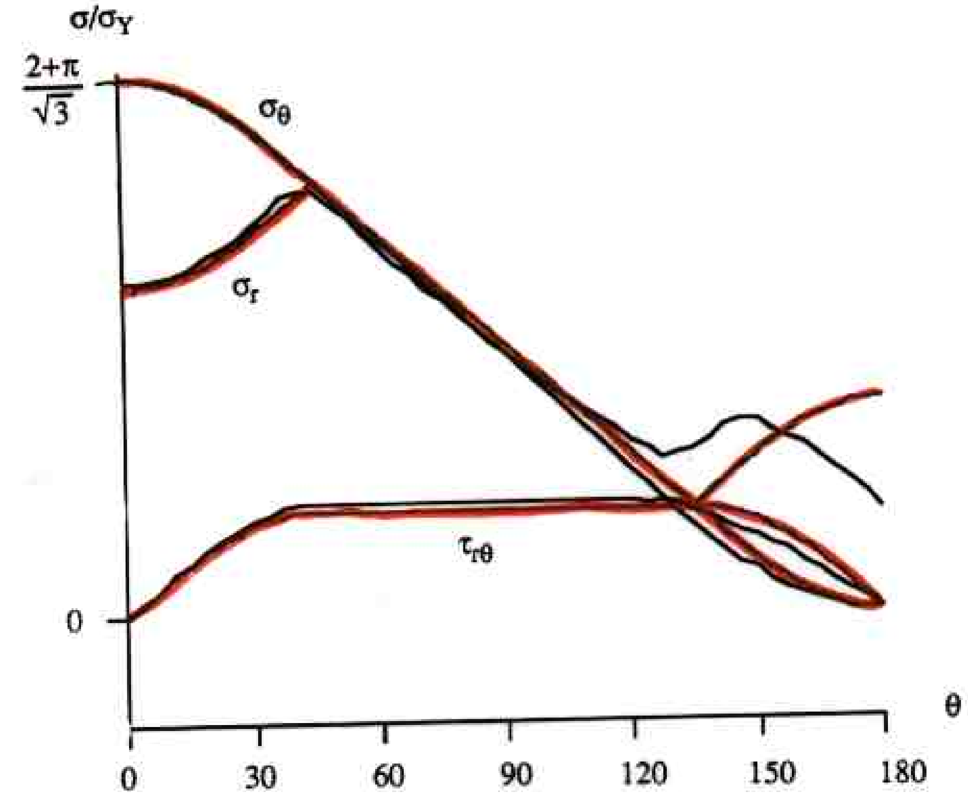


Fig. 7a. Stress components σ_r, σ_θ and $\tau_{r\theta}$ as functions of θ for a constant radius r. The distance from the crack tip is $r_p/100$ where r_p is the extension of the plastic zone in front of the crack tip. The material is perfectly plastic. The Prandtl slip line field stresses are shown in grey.



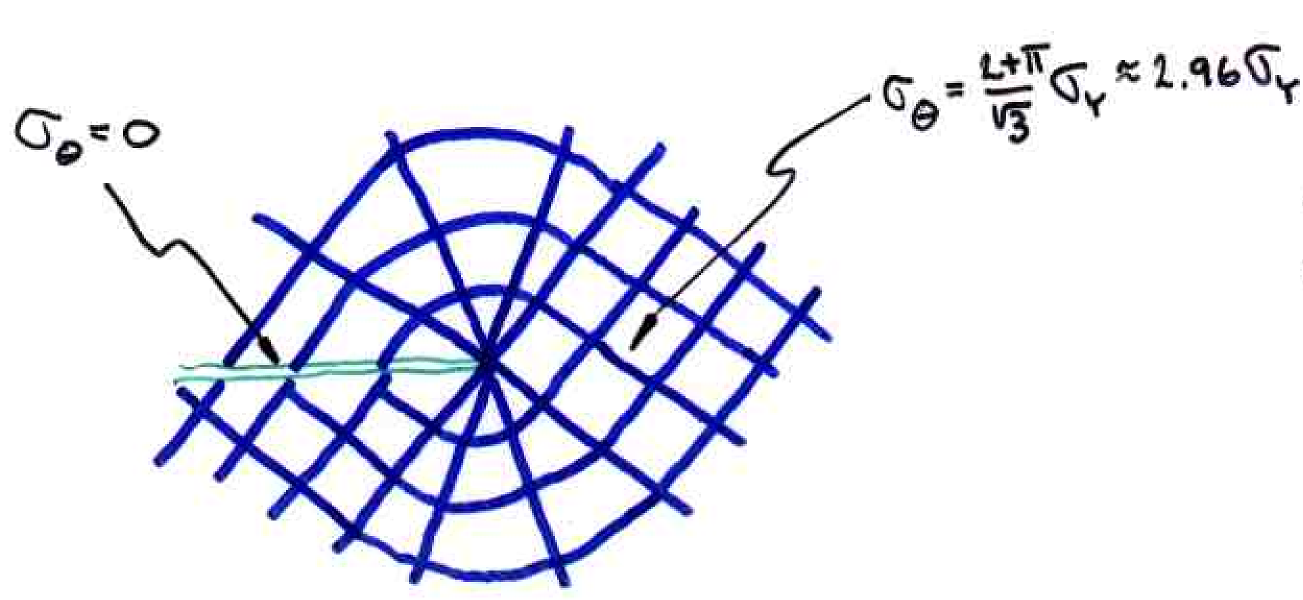
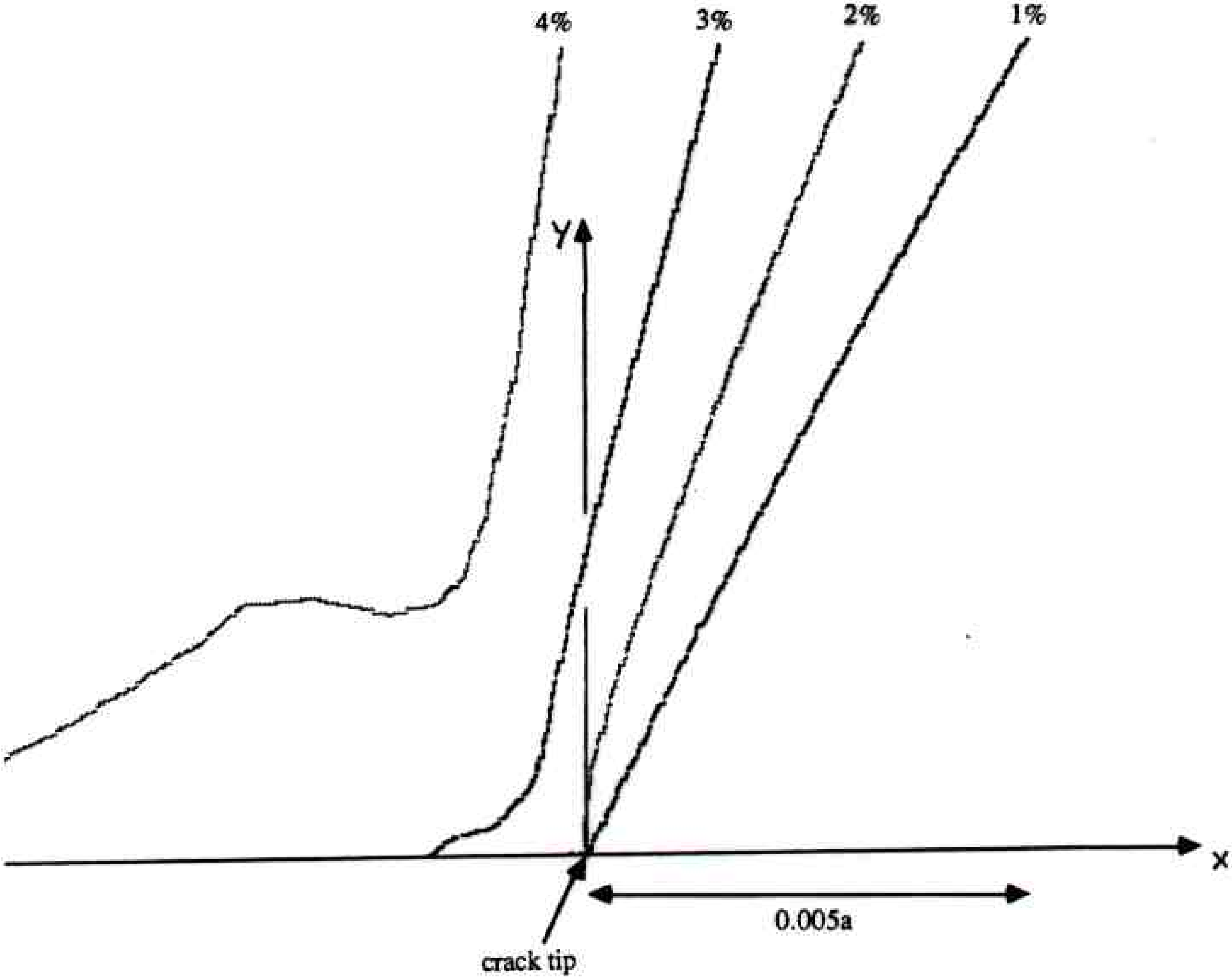
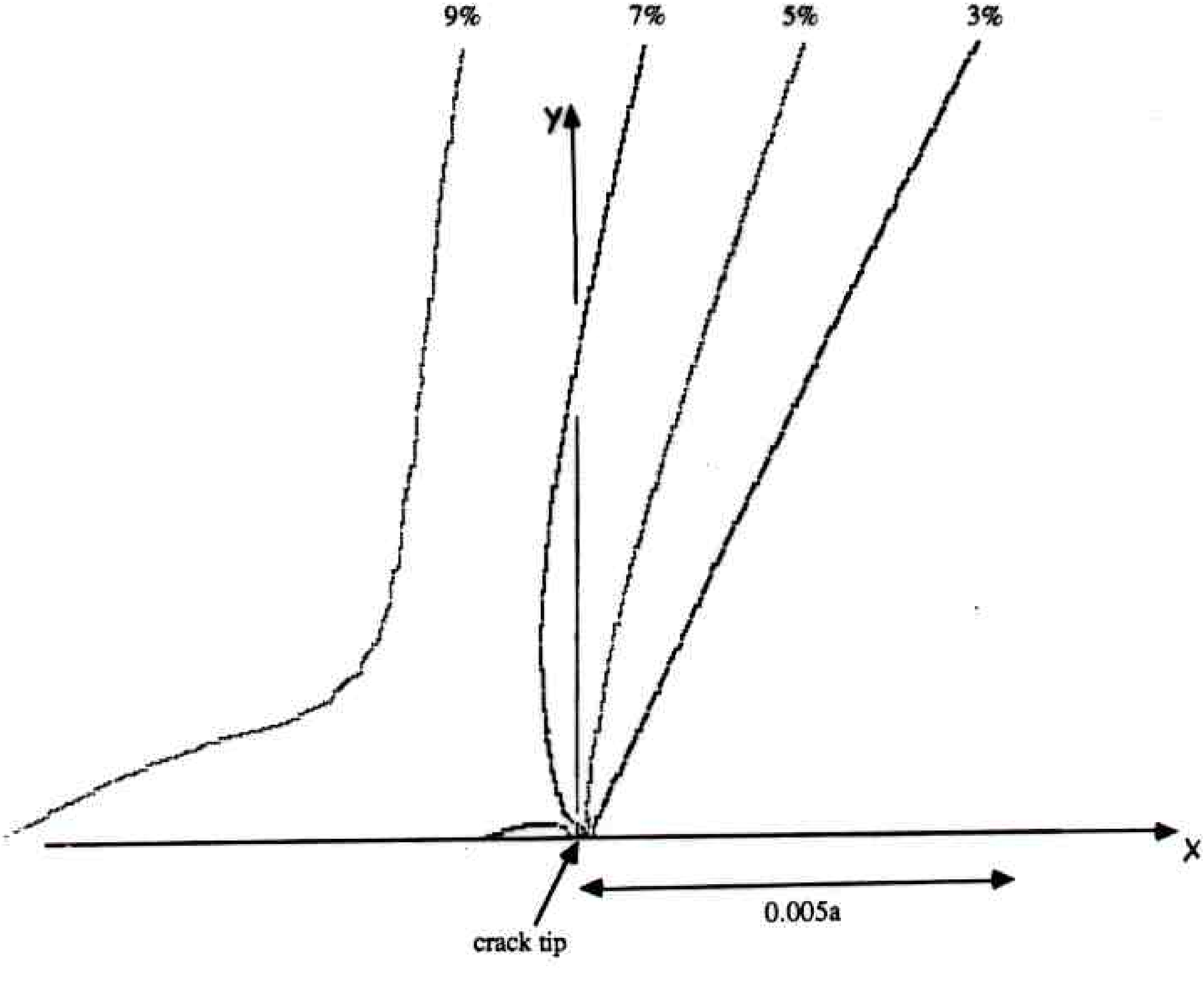


Fig. 16a. Displacement deviations for the edge crack calculation when compared with the small scale yielding calculation, both calculations with cohesive zone: $\sigma_D/\sigma_Y = 8$. $E_t = 0.05E$; $\sigma_0 = 0.23\sigma_Y$



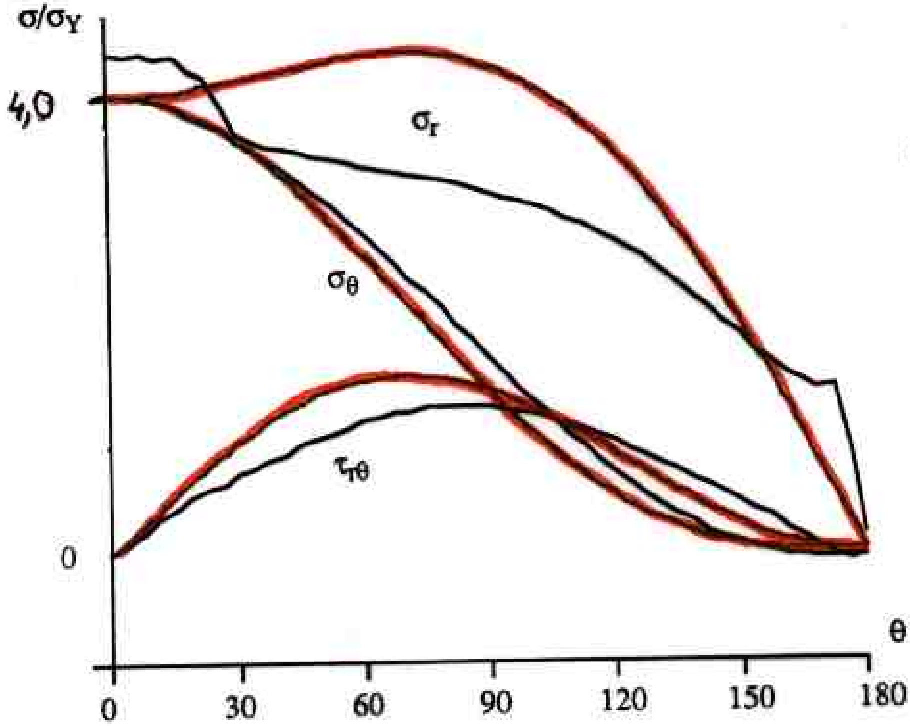
The maximum extension of the plastic zone is 0.05a; the length of the cohesive zone is $2 \cdot 10^{-4}$a

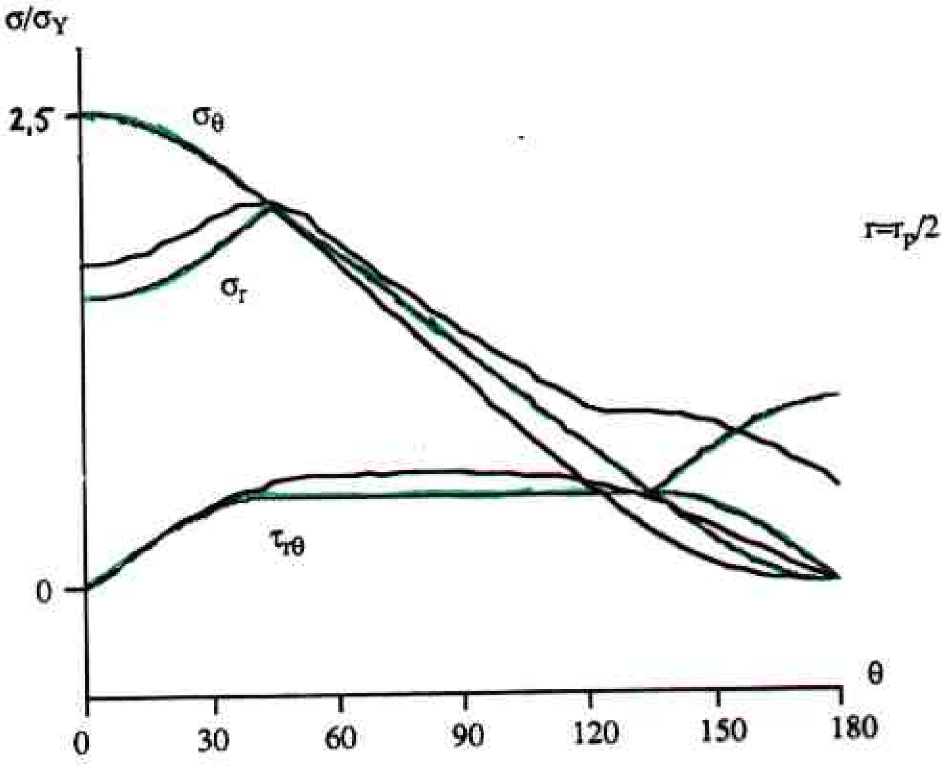
Fig. 17a. Displacement deviations for the edge crack calculation when compared with the small scale yielding calculation, both calculations with cohesive zone: $\sigma_D/\sigma_Y = 8$. $E_t = 0.05E$; $\sigma_0 = 0.46\sigma_Y$



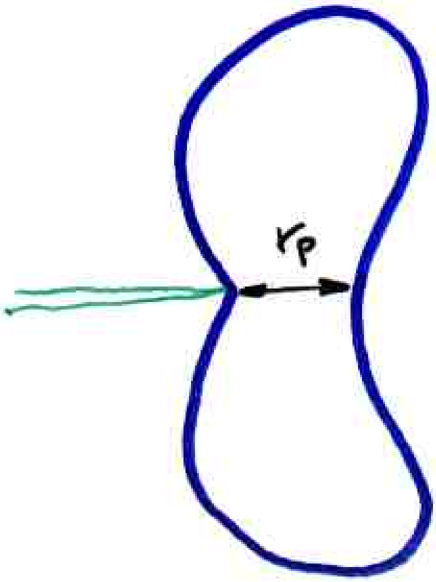
The maximum extension of the plasic zone is 0.19a; the length of the cohesive zone is $7 \cdot 10^{-4}a$

Fig. 7b. Stress components σ_r, σ_θ and $\tau_{r\theta}$ as functions of θ for two different constant radii: $r = r_p/100$ and $r = r_p/2$. r_p is the extension of the plastic zone in front of the crack. The hardening rate in the plastic zone is $E_t = 0.01E$. In the the first diagram the square root singular terms in the Williams expansion are shown in grey; in the second the Prantl slip line field terms. These fields are normalized so that σ_θ has the same value for as the FEM results for $\theta = 0$.





σ_D/σ_Y	E_t/E	$r(\sigma_Y/K_I)^2 \cdot 10^3$ for $\sigma_e/\sigma_Y \geq 2$	$\sigma_e/\sigma_Y \geq 3$	$\sigma_e/\sigma_Y \geq 4$	$\sigma_e/\sigma_Y \geq 5$
3	0.05	0	-	-	-
4	0.05	2.76	-	-	-
8	0.05	3.70	1.25	0.49	0.05
no cohesive zone	0.05	3.70	1.32	0.658	0.38
3	0.01	0	-	-	-
4	0.01	0.69	-	-	-
8	0.01	0.82	0.27	0.11	0
no cohesive zone	0.01	0.82	0.27	0.11	0.05



$$r_p(\sigma_Y/K_I)^2 \cdot 10^3 \approx 40$$

Fig. 8.Dimensionless length $d(\sigma_D/K_I)^2$ of the cohesive zone for different cohesive stresses σ_D/σ_Y and different hardening rates E_t/E

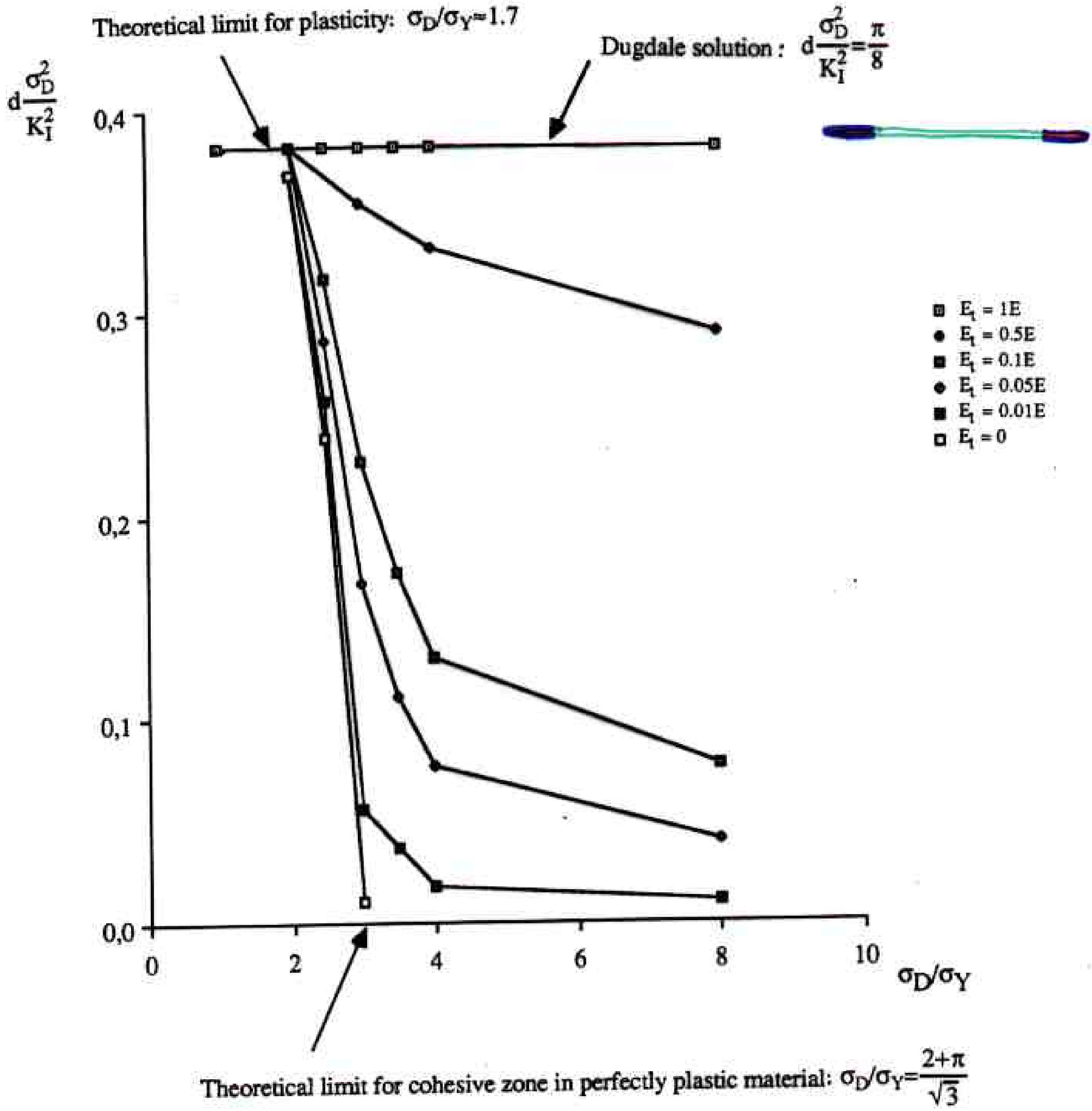


Fig. 9. Dimensionless displacement v $(\sigma_D E)/K_I^2$ as a function of the dimensionless coordinate x $(\sigma_D/K_I)^2$ for different hardening rates in the plastic zone. The cohesive stress is $\sigma_D/\sigma_Y = 4$

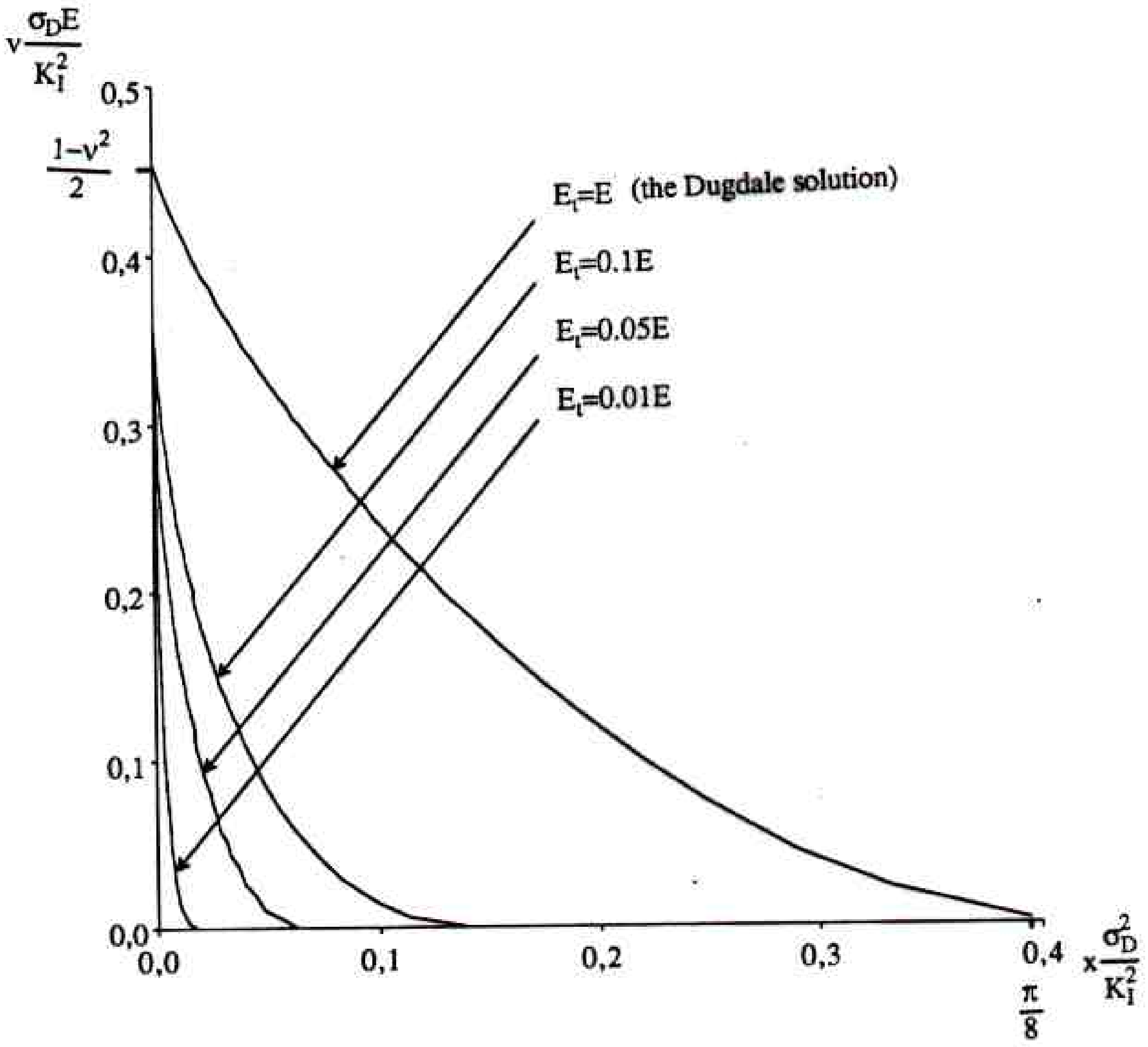
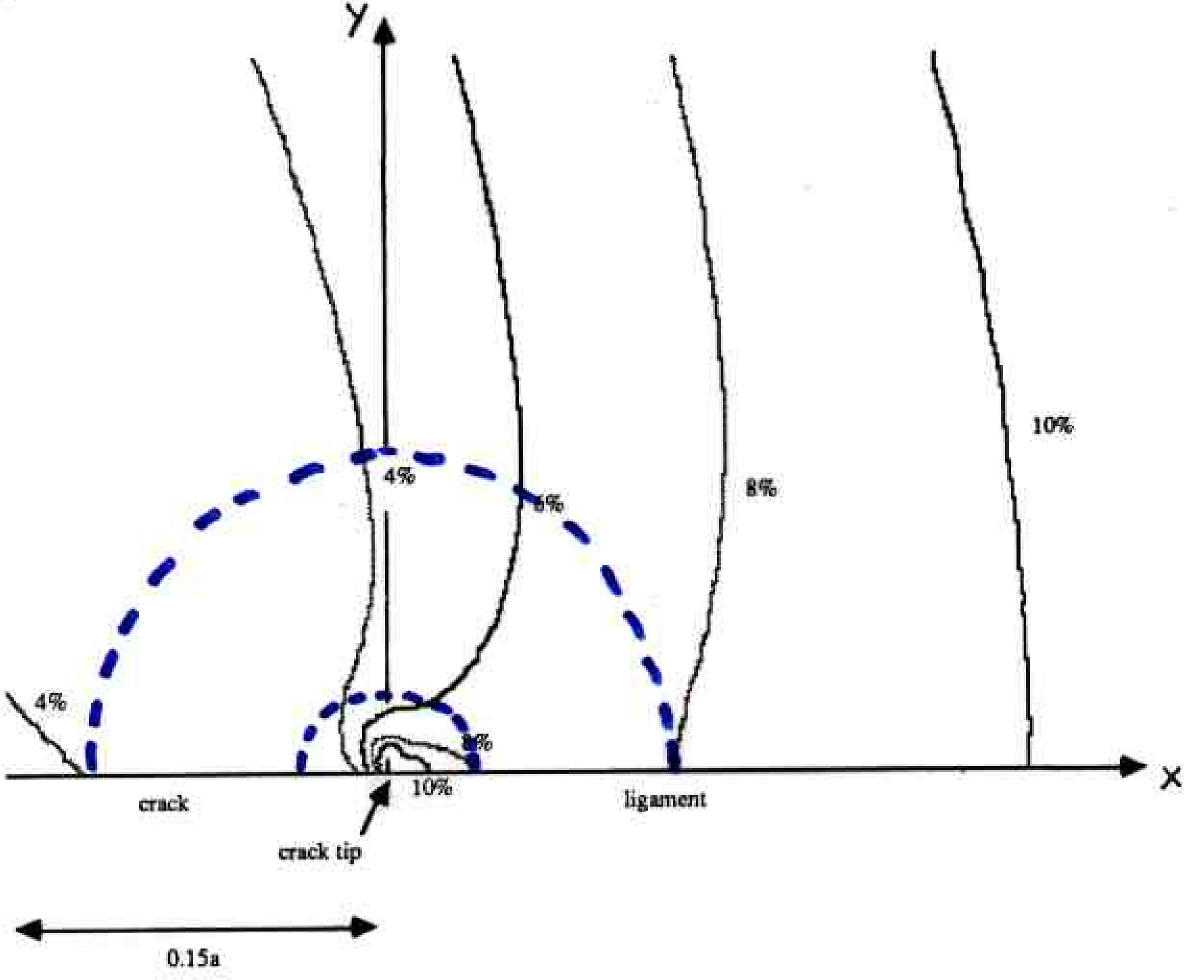
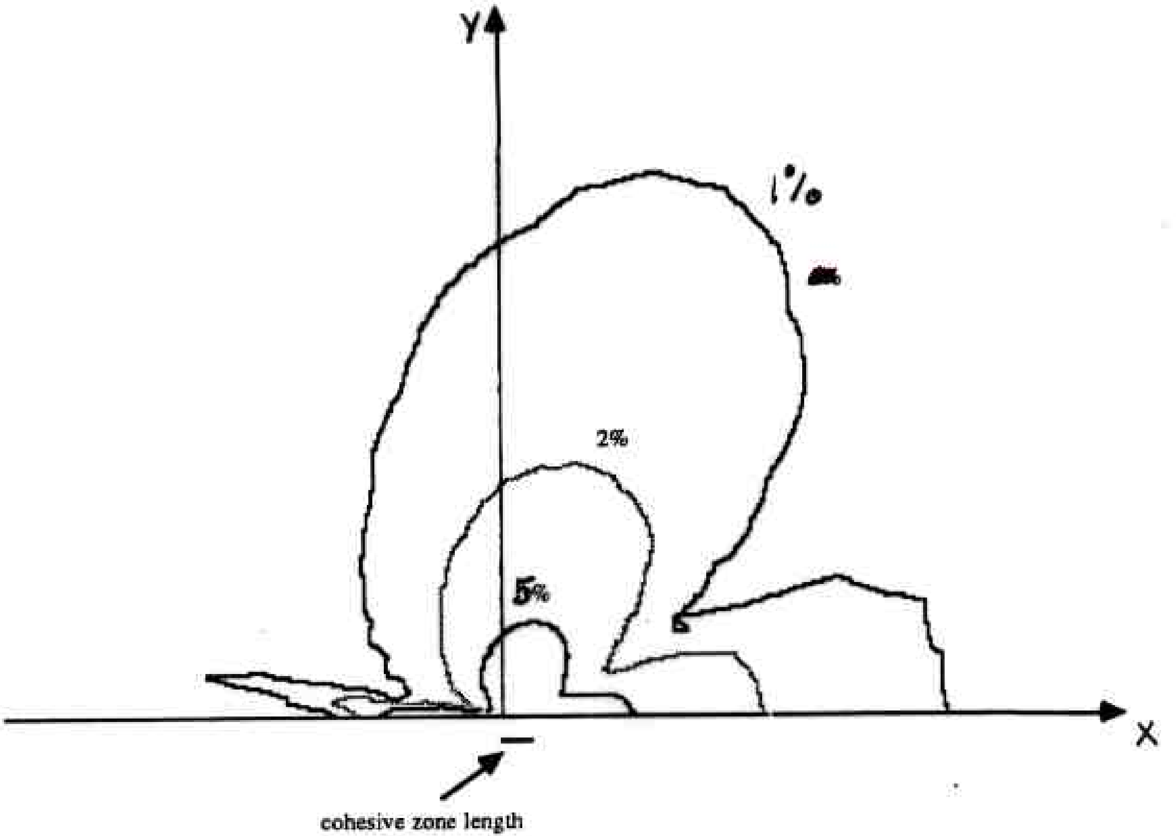


Fig. 12. Deviations from the square root singular displacement field for an edgecrack with plastic zone, $E_t = 0.01E$ The load is half the load at the ASTM-limit. The deviations in front of the crack has a minimum of 7.6%.



The maximum extension of the plastic zone 0.01a

Fig 11. Stress deviations from singular crack tip solution due to a cohesive zone with $\sigma_D/\sigma_Y = 8$; $E_t = 0.05E$.



The extension of the plastic zone in front of the crack is 73 times the length of the cohesive zc

σ_D/σ_Y	E_t/E	r_p/d	r/d for relative deviations of stress		
			1%	2%	5%
-	1	-	24.7	11.1	4.23
4	0.05	10.1	11.0	5.99	1.95
8	0.05	72.6	14.6	6.58	3.52
4	0.01	42.0	14.8	7.15	2.49
8	0.01	290	15.8	7.66	4.33

σ_D/σ_Y	E_t/E	r/d for relative deviations of displacement		
		1%	2%	5%
-	1	16.5	7.45	3.34
4	0.05	8.86	4.07	1.38
8	0.05	10.4	4.36	1.50
4	0.01	8.37	3.76	1.29
8	0.01	7.33	3.33	1.0