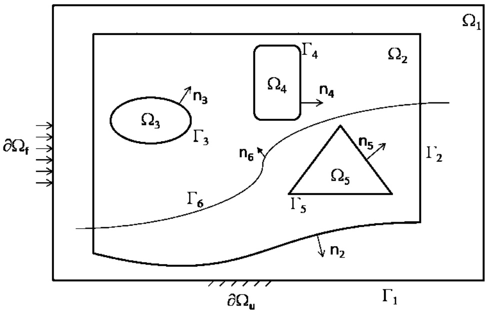
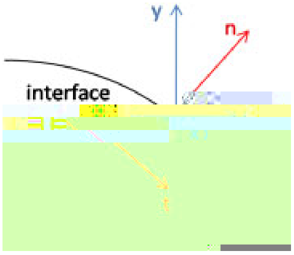


Figure 1. General [illegible] of the nano-structured [illegible].



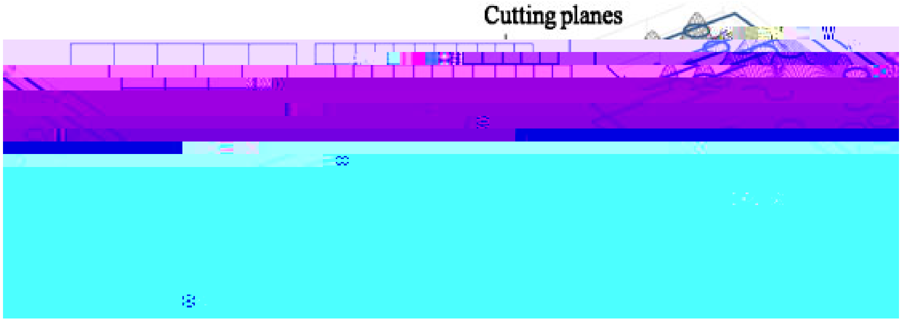


Figure 3. (a) Enriched nodes [illegible] surface ([illegible]); (b) [illegible] enriched nodes and [illegible] enriched [illegible] surface; and (c) [illegible] function [illegible] and [illegible].

where

$$
{}_{I}(\ )=\begin{bmatrix} N_I(\ ) & 0 \\ 0 & N_I(\ ) \end{bmatrix} \tag{17}
$$

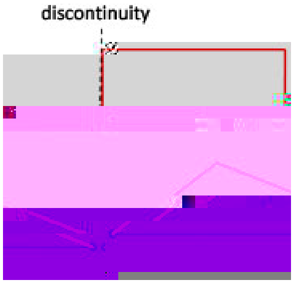
where [illegible] functions $N_I(\ )$ are [illegible] shape functions associated with node I. $N_J(\ )$ are [illegible] shape functions associated with [illegible] the [illegible] nodes [illegible] surface (Figure 3(b)) and $H(\ )$ and $\chi(\ )$ are [illegible] functions [illegible] ([illegible] function and Heaviside function, [illegible] [32, 33]). In Equation (16), n [illegible] number of [illegible], whereas m [illegible] number of enriched nodes ($m\leqslant n$). [illegible], a enriched node [illegible] surface and [illegible] Figure 3. The [illegible] surface [illegible], [illegible] function $\phi(\ )$ [illegible] surface [illegible] Figure 3(c). [illegible], [illegible] ϕ [illegible]. A [illegible] surface [illegible] function $\phi(x)$ as follows:

$$
(\ )=\frac{\nabla\phi(x)}{\|\nabla\phi(x)\|} \tag{18}
$$

Let [illegible] Heaviside and [illegible] function [illegible] (16). Referring to Figure 4, the Heaviside function [illegible]; [illegible] function [illegible] surface [illegible]. We [illegible] Heaviside and [illegible] function are defined by ([illegible]):

$$
H(\phi)=\begin{cases} 1 & \phi\geqslant 0 \\ 0 & \phi<0 \end{cases} \quad \text{and} \quad \chi_j(\ )=|\phi(\ )|-|\phi(\ _j)| \tag{19}
$$

The [illegible] (16) [illegible] (14) and (15). [illegible] [27].



F[illegible] 4. A [illegible] (a) [illegible] and (b) [illegible]

Bulk energy

S[illegible] $\delta\tilde{W}_b^e$ [illegible] δW_b^e [illegible]:

$$\delta\tilde{W}_b^e = \int_\Omega \delta\epsilon^e : [illegible]^e : \epsilon^e \, d\Omega = \delta [illegible]^{eT} \cdot \left(\int_\Omega [illegible]^{eT} \{ [illegible]^e \} [illegible]^e \, d\Omega \right) \cdot [illegible]^e \qquad (20)$$

[illegible] ^{e} and $\{ {}^e \}$ [illegible]. I[illegible] add[illegible]

External energy

F a , a a f a a c a d a d d a f c , a d b :

$$\delta\tilde{W}^{e} = \delta \; {}^{e\mathrm{T}} \cdot \int_{\Omega} {}^{e\mathrm{T}} \, \mathrm{d}\Omega + \int_{\partial\Omega_F} {}^{e\mathrm{T}} \, \mathrm{d}\Gamma \qquad (30)$$

Final XFEM equation

U E a (20), (22), (28), a d (30), a d a f (14) a d (15), XFEM a f a a f :

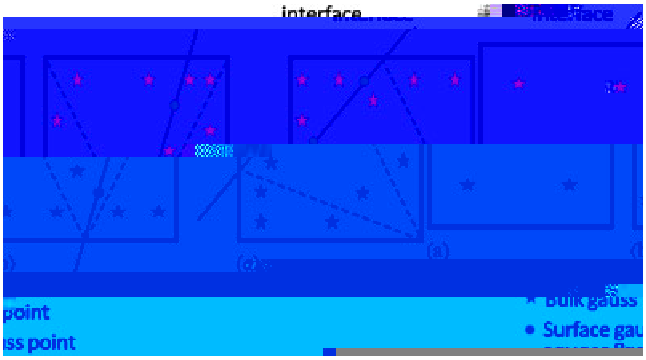
$$({}^{e}_{b} + {}^{e}_{d} + {}^{e}_{s}) \cdot {}^{e} = {}^{e} - {}^{e}_{s} \qquad (31)$$

da d ac ^{e} c d f c b f c , a d c , a d d c d :

$${}^{e} = [\; {}^{-}\{ \nabla \; \rangle \; \in$$

d

$\mathrm{d}\Omega$



F[illegible] 5. T[illegible] : (a) [illegible]; (b) a[illegible]d (c) [illegible].

[illegible] Ω_2 [illegible]

[illegible] Ga[illegible]

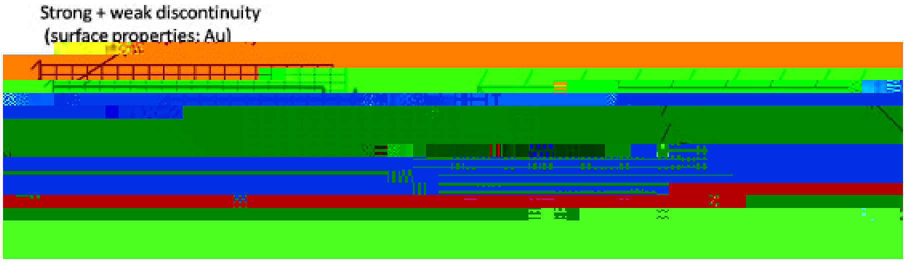


FIGURE 6. Sc[illegible] XFEM d[illegible].

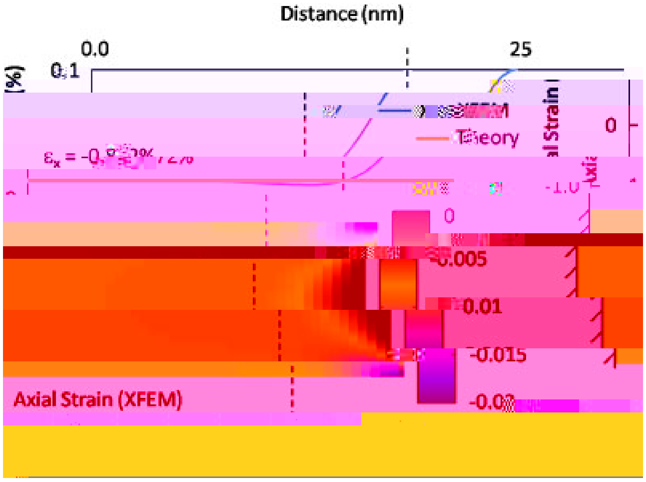


FIGURE 7. A c[illegible] (40) a d XFEM a[illegible].

[illegible] (40) a d [illegible] XFEM [illegible]. W[illegible] (40), [illegible] P[illegible], [illegible]; [illegible] P[illegible] XFEM [illegible].

B•ca • $\gg t$, •ca • •c t • $\blacktriangleright + t$ • (41) a d • a:

$$\frac{F}{\blacktriangleright} = \sigma t + 2\tau \tag{42}$$

If E a d S_{1111} a • •b Y ' d a d a a fac• •a c c a , • •c • , • ca • a:

$$_1 = \frac{\sigma}{E} \quad \text{a d} \quad _2 = \frac{\tau}{S_{1111}} \tag{43}$$

• $_1$ a d $_2$ a • •a a a •b a d fac•, • •c • . C b E a (42) a d (43) a d a $_1 = {}_2 = \delta L \blacktriangleleft L$, • b a :

$$\frac{E\blacktriangleleft\blacktriangleright}{\delta L} = \frac{Et}{L} + \frac{2S_{1111}}{L} = K_b + K_s \tag{44}$$

• K_b a d K_s a • •b a d fac• a a ff • , • •c • . F (44), • • a f a a f d a Tab • I a •c d •d, b•ca • •b Y ' d E c •a a S_{1111}, • • •c a • fac• ff • K_s b• • b •f a • a • , •b•c c •a a f a a a •. F •, E a (44) d• a • a •a •c a f • a •$t\blacktriangleleft L$ a •a ca •ff•c •b , a d a ff • f • a a •. F • 9 •c a • a a ff • a af c f • a a • • , • • a a •a •c a $t\blacktriangleleft L$ a c a a 10. A ca b• •• F 9, a •c• • a • • f d b• •• • • • ca E a (44)

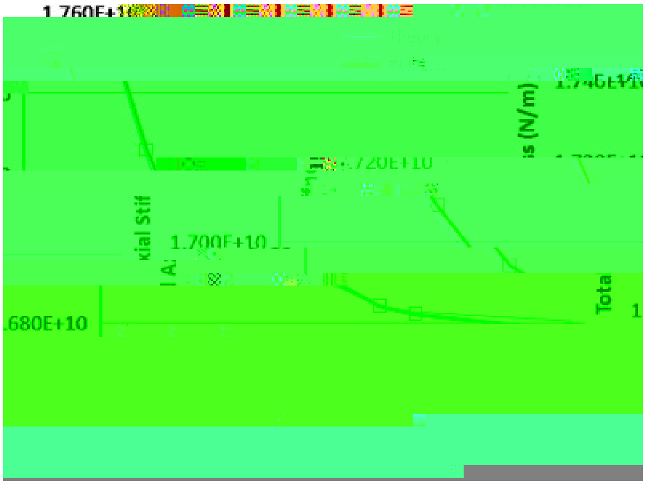


Figure 9. Surface effects [illegible] -d [illegible] d [illegible] a a [illegible] ff [illegible] f a [illegible] d a [illegible] a [illegible] a c [illegible] a a [illegible] c [illegible] a [illegible] f 10.

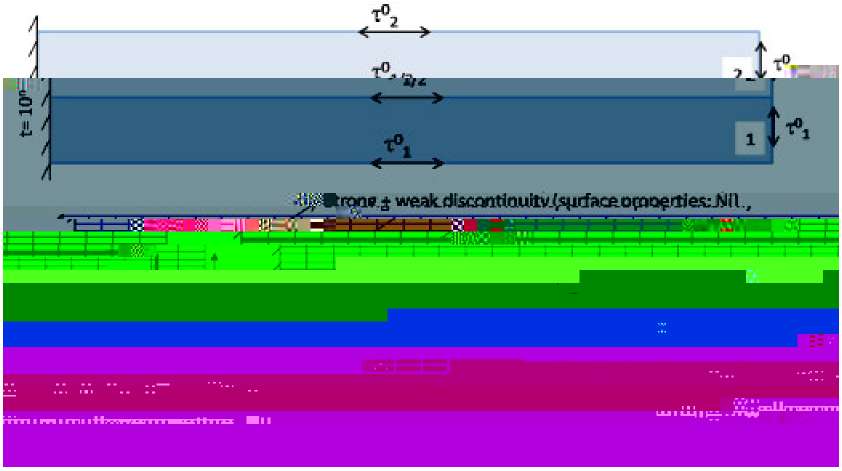
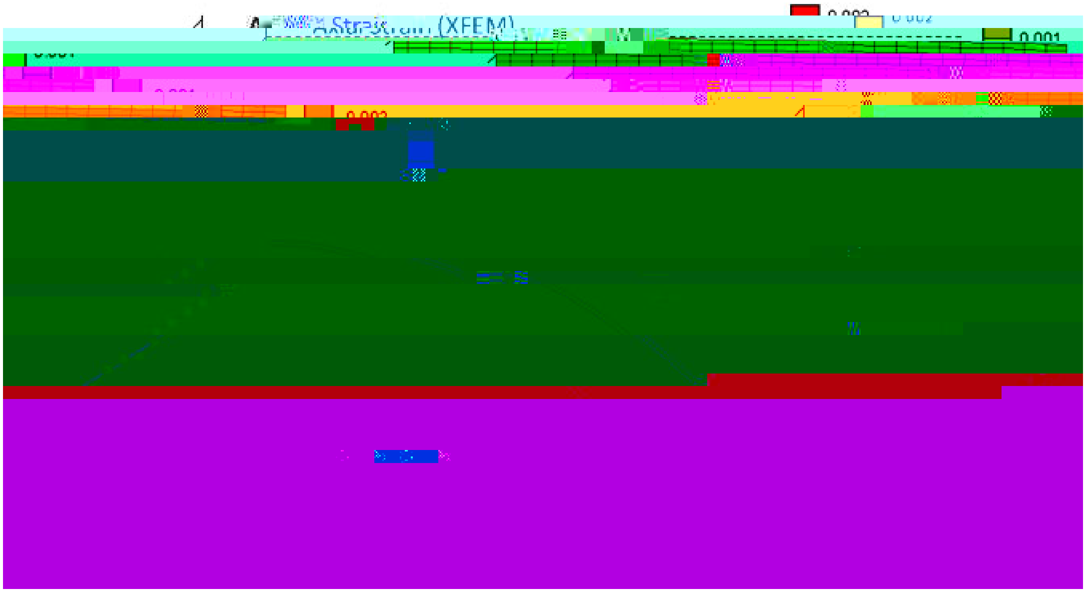


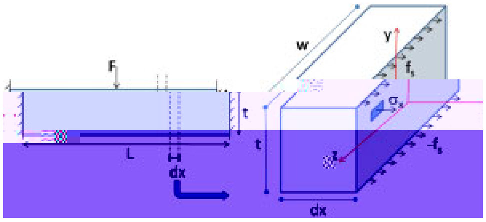
Figure 10. Ge [illegible] a [illegible] f [illegible] d f [illegible] b- a [illegible] d a -b a [illegible] c d [illegible] b [illegible] surface a d [illegible] surface effec [illegible].

If [illegible] de [illegible] τ_1^0, τ_2^0, a d τ_{12}^0 a [illegible] surface [illegible] (f [illegible] c [illegible]) [illegible] a [illegible] a 1, 2 a d [illegible] surface f a [illegible] a 1 a d 2, [illegible] c [illegible], [illegible] ca ca [illegible] a [illegible] d c d [illegible] (M) [illegible] c [illegible] a [illegible] f [illegible] a [illegible] a a d surface [illegible] a c [illegible] d ff [illegible] c b [illegible] a [illegible] a 1 a d 2 a :

$$M=(\tau_1^0)(t-x)-(\tau_2^0)x+(\tau_{12}^0)\left(\frac{t}{2}-x\right) \tag{47}$$



F ı ı ç 11. (a) A a ç a c a b XFEM a d ç (E ı a (49) (51)) d b ı ç fac a d fac ç f ç a b - a d P N a a , (b) ç a d c c a a ı a b - a d P N a a b XFEM a d ç (E ı a (52)) d b ı ç fac a d fac ç .



F ı ı ç 12. Sc a c f a d d a b a b b a a d f ç c F.

a ç ca ı c a XFEM ç ı . T b d ı ı b ı f c - c F ı ı ç 12 ca b ç a

$$\int_A \sigma_x y\,\mathrm{d}A+2\int f_s \frac{t}{2}\,\mathrm{d}z=-M \tag{53}$$

σ_x a a ç f c - c a d f_s f ç c d c d b a ı ç fac d ı ç fac a c c a S_{1111}; $f_s=S_{1111}$ a , a a ı a a ç a a cc ç a d b ı ç fac . B a ı a da d ç a $\sigma_x=E$ a d

$=(y\;y\;{}_a)$ a a d b (53) d a:

$$\frac{2E}{t}\;{}_a\int_A y^2\,\mathrm{d}A+S_{1111}t\;{}_a=-M \tag{54}$$

K a $I=\int y^2\,\mathrm{d}A$, I c f a a d a z, ca :

$$_a=\frac{-M}{\dfrac{2EI}{t}+S_{1111}t} \tag{55}$$

F c a a c F 12, $I=\frac{1}{12}t^3$; f , ca f E a- (55) :

$$_a=\frac{-M}{t(\frac{1}{6}Et+S_{1111})} \tag{56}$$

f ca :

$$=\frac{-2My}{t^2(\frac{1}{6}Et+S_{1111})} \tag{57}$$

If c d F a d d

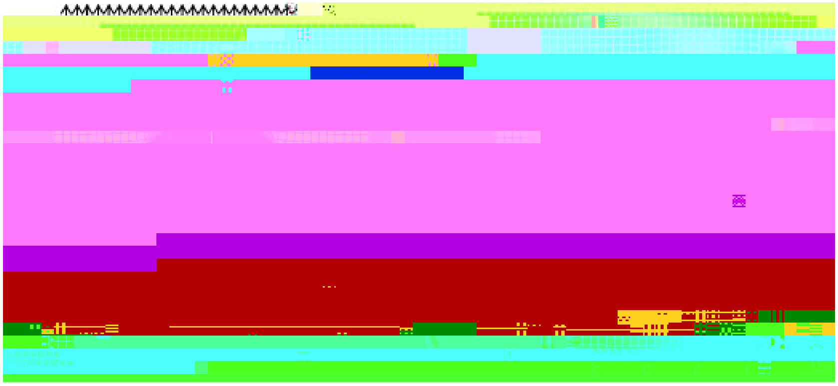
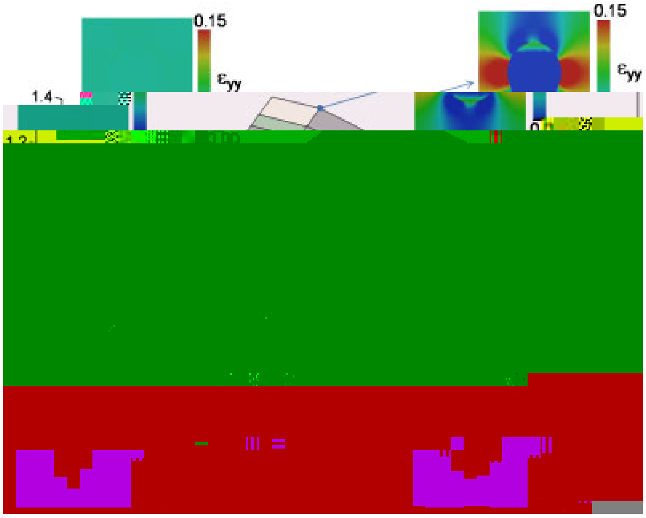


Figure 14. Ge[illegible]a [illegible] d[illegible]d: (a) [illegible] deformed and (b) deformed ([illegible] surface c[illegible]). Sub-[illegible] c[illegible] surface a[illegible]d [illegible].



- T d ab d c b c a a b a a -c c a a c da a . I a fi f d fac a d fac ff c d f a a d ac f a -c c .

T d d d a d a f ca a fac- -d a a f a a a a d a - a a b-a a a , fac ff c a a ff f a a a , a d fac ff c b d ff f a a b a . I a ca , XFEM ca c a d d a a ca . F , a da ca f fac- -d a a f d a a a f d a b c a a c a d ca SCB ca a . F a , a a , a c b a f a a d d c a d ca ac b fac d c a d fac a c a a a c . T c f fac , a d d c a ca f c a c d b a d. S c fac a c a a c a d c , b d a d d c a a a c b c a d a a c d d. H , ff c b d fac c a d.

F f c a ff c f a c a d fac d c d f a [38 40], a a d a d a fac ff c ac c a ca f a a .

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9.0454259999 0 .9968(d c H1) 68(d c H1) 0 Tc383.9(L)9.8 L 2(a 103.2 c)( )0(a 9.8) a ,P ca R c ; fB