ACOUSTIC EMISSION GENERATED BY THE CRACK PROPAGATION

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FORMULATION OF THE MODEL

In this article we describe material cracking and corresponding acoustic emission (AE) by a twodimensional lattice model. The lattice cells are composed of four masses connected by six ligaments as shown in Fig.1. One ligament includes a nonlinear spring and a dashpot. The inelastic deformation is taken into account by changing the equilibrium lengths of the springs. We assume that the spring rupture takes place when the comparative tension in the Mises 's criterion gets an arbitrarily chosen critical value.(1)

The equation describing the lattice dynamics of our model is represented by:

$$\mathbf{M}u'' = S + D + V + F \qquad (1)$$

where $\mathbf{M}$ is a diagonal mass matrix and $\mathbf{u}$ is the displacement vector of mass points. The force terms describe: S - the springs, D - damping by the dashpot, V - viscous damping by the environment, F - the external loading or constraints. The dependence of force S on the spring length and angles between the ligaments is nonlinear. The corresponding analytical expression is explained in detail elsewhere.(1) The dynamical behaviour of the lattice was studied numerically by the method of Runge-Kutta of fourth order and for initial conditions u(0)=0 and u'(0)=0.

APPLICATION OF THE MODEL

The model enables one to study dynamical transition phenomena caused by external loading as well as internal deformations. Fig.2 shows the numerically and experimentally determined acoustic emission signal corresponding to vertical displacement of the bent beam caused by a sudden crack jump on its surface.

The next example is represented by crack propagation in the symmetrically notched rectangular plate under tension as shown in Fig.3. A bilinear stress-strain relation shown in Fig.4 was applied. A knee of line at σ_q, and a rupture tension at $3\sigma_q$ was assumed. During the numerical experiment the tension on the boundary rose linearly with time: $\sigma = \sigma_q\, t/500\Delta t$. Figures 5a to 5d show the lattice at various values of time. The inelastically deformed cells are drawn darker . The first innelastically deformed cell appears at time $t = 214\,\Delta t$. The plastic zone then spreads and is shown in Fig. 5a at time $t = 432\,\Delta t$. In Fig.5b the the state at $t = 808\,\Delta t$ is shown, corresponding to the rupture of the first cell. In the plastic zone in front of the crack, the

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tension can also fall below the knee value due to waves emanating from the failed calls, as shown at t = 817Δt by Fig. 5c. The field of emanating transient wave exhibits a generally irregular structure expressively shown at t = 847Δt by Fig. 5d. Due to the many degrees of freedom and the nonlinear nature of the phenomenon involved we can argue that observed cracking represents a sort of deterministic chaos. After initiation, the crack propagated approximately linearly with time lapsed, the velocity being approximately one fourth of the velocity of the compressional wave.

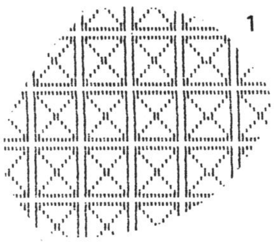
From the experimental point of view the displacement signal from a typical point is interesting. Fig.6 shows the time dependence of calculated displacement in x direction (along the side) at point T marked in Fig.3. Three characteristic intervals are observable in the graph of Fig. 6: (1) the interval of elastic deformations, (2) the interval of development and spreading of the plastic zone, (3) the interval of crack propagation. In the last interval the rapid growth of displacement along the side is caused by the cracking of the sample. Fig. 7 shows the corresponding displacement in y direction. The unloading of the lattice caused by a developing crack propagates as a wave across the sample. When reaching the point of observation T it causes dynamical fluctuations which can be distingushed from the displacements caused by slowly growing tension. To show this the normal displacement in the last tenth of the third interval is represented in Fig. 8 on a finer scale.

Our model is appropriate for the description of acoustic emission signals from small regions as well as for the modelling of distributed sources. Beside crack propagation, the cutting process has been successfully simulated by it. (1)

(1) J.Petrišič, Ph.D.Thesis, 1988, Fac.Mech.Engn., E.Kardelj University, Ljubljana, Yugoslavia

FIGURE CAPTIONS

1. Scheme of the lattice
2. Calculated and experimentally determinened AE signal from the cracking beam
3. Scheme of the notched specimen
4. Strain-stress relation of the ligament spring
5. The development of a crack in the notched specimen
6. Time dependance of the x displacement in the point T
7. Time dependance of the y displacement in the point T
8. Influence of AE signal from the crack on the y displacement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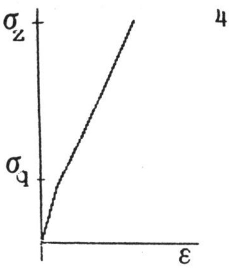
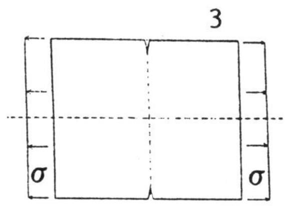

4
σ_z
σ_y
ε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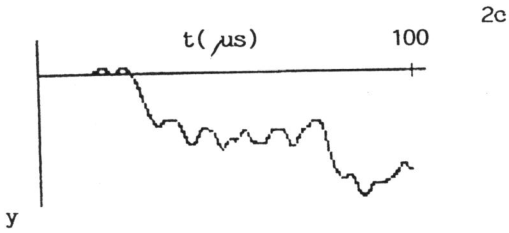
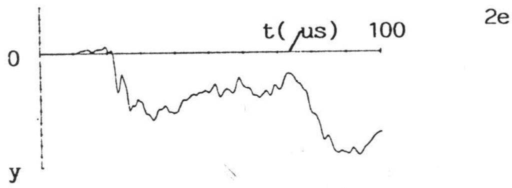
σ
σ


2c
t(μs)
100
y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t(μs)
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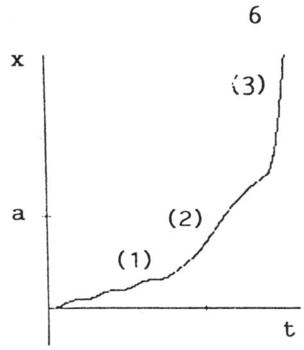
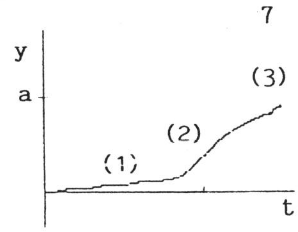
0
y


6
x
(3)
a
(2)
(1)
t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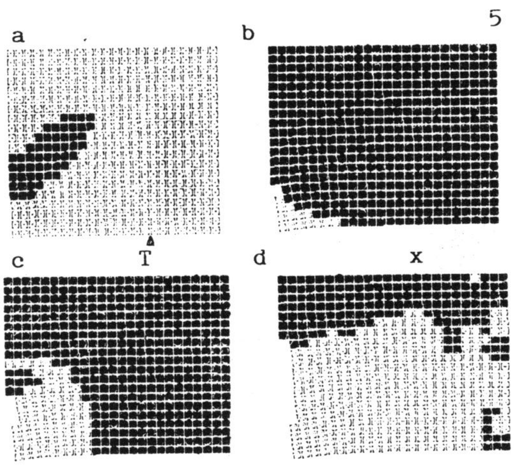
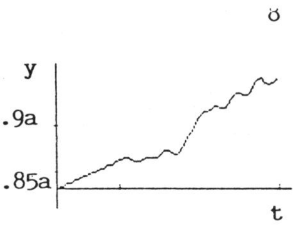
y
a
(3)
(2)
(1)
t


5
a
b
c
T
d
x


y
.9a
.85a
t