STOCHASTIC FRACTURE PROCESSES IN MECHANICS OF COMPOSITE MATERIALS

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The stochastic failure processes were adopted in micromechanics of fiber reinforced material and probabilistic irreversible damage accumulation from heterogenous structures.This approach implied composite material as connected elements system, every component may be broken or unbroken. Stochastic process of fracture is a break elements events chain and may be described Chapman--Kolmogorov's system of stochastic equations.

INTRODUCTION

The composite material fracture process has considered as discrete stochastic chain of composite filaments destroy events. The sequential failures process has described the stochastic equations system:

$$d\{P\}/ds=[W]\{P\} \qquad (1)$$

The system dimension is high, so as transitional probabilities vector $\{P\}$ and intensity transitions matrix $[W]$ ranges, it's terminate amount of virtual conditions. The reduction range problem was solved for simple line chain processes by Sokolkin et al (1). This work purpose is detail study of the stochastic system structure and reliability methods development for 2D and 3D fiber reinforced composites.

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THEORY

The general set of virtual conditions has to be connected with binary indicator vector. The vector elements locate broken or unbroken conditions of composite components. The virtual conditions amount is terminate a possible combinations of the binary vectors, it's form N-range cube tops set. A composite filaments failure events has direct fracture process from same to other tops of the N-dimensional cube, thus discrete process is based on N-dimension cube oriented graph. Figure 1 shows the five-range cube orgraph (N=5) with numbered tops and ribs direction from smaller to larger top numbers. The cube orgraph is maked by recursive procedure:

$$Q[N+1] = K[2] * Q[N] \quad \text{.....................} (2)$$

$$Q[1] = K[2]\ , N = 1, 2, 3 \ldots$$

Every rib of the orgraph is a virtual step of the composite material fracture process with the intensity transitions matrix corresponding. All inconnected matrix elements is illegal steps of the discrete process, indentically zero elements. A portrait of the intensity transitions matrix is shown on figure 2, black boxes indicate the nonzero elements location. Recursive intensity matrix making procedure can be written as :

$$[Q]_{2n} = \begin{bmatrix} [Q]_n & [I_n] \\ [I]_n & [Q]_n \end{bmatrix} \quad \text{.....................} (3)$$

$$n = 2^N\ , \quad [Q]_1 = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix}$$

RESULTS

Numerical analysis used the sparse matrix technology and finite element method for 2D and 3D composites. The transitional probabilities vector and reliability of carbon-epoxy and carbon-carbon composites for strength and crack resistance are given. Nonzero intensity matrix components were solved at (1).

Figures 3 and 4 show the transition probabilities vector for strength and crack resistance of carbon-epoxy unidirectional composite (carbon fibers: Young's modulus - 276 GPa, average strength - 1.7 GPa, strength scatter - 20%, concentration - 60%, diameter - 7.0 mkm; epoxy resin: Young's modulus - 3.5 GPa. Poisson's ratio - 0.34). The longitudinal strength (fig.3) and the crack across fibers resistance (fig.4) reflected stochastic fracture processes in accordance with unstable and stable failure mechanismes.

Figures 5 and 6 show the strength surfaces of 2D and 3D carbon-carbon composites (pirographite matrix: Young's modulus - 5.0 GPa. Poisson's ratio - 0.27). The strength surfaces were constructed on the spline parametrical functions. The 2D carbon-carbon laminate strength surfaces are shown on figure 5 at warp-weft plane for various reliability levels. The medial 3D carbon-carbon strength surface (fig.6) is acceptable compared with bi-directional loading experimental data obtained by Zhenlong G. et al (2).

SYMBOLS USED

$\{P\}$ = transitional probabilities vector
$[W]$ = intensity transitions matric (1/Pa)
s = loading parameter (Pa)
$Q[N]$ = N-range cube graph
$K[2]$ = second-range complete graph
$*$ = graphs multiply
$[Q]_n$ = intensity transitions matrix portrait
$[I]_n$ = diagonal matrix portrait
n = matrix range
$\langle s \rangle$ = average strength (Pa)
K_c = stress intensity factors ($Pa\sqrt{m}$)

REFERENCES

(1) Sokolkin.Yu.U..Postnikh.A.M. and Chekalkin.A.A.. Mech. of Compos.Mater.J..Vol.28.1992.pp.196-203.

(2) Zhenlong.G..Qunyao.G. and Zhang.W..J. Compos. Mater.. Vol.23. 1989, pp.988-996.

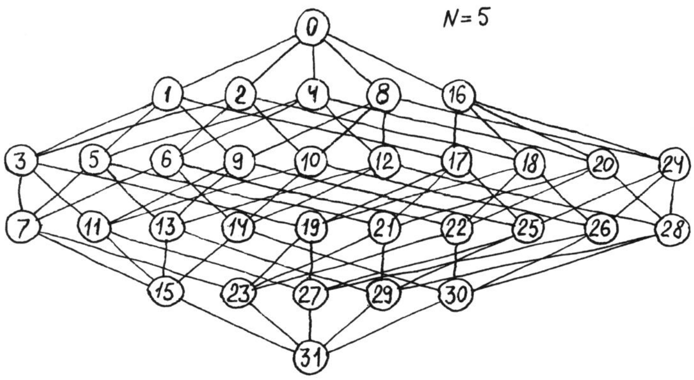

Figure 1 Cube
oriented graph

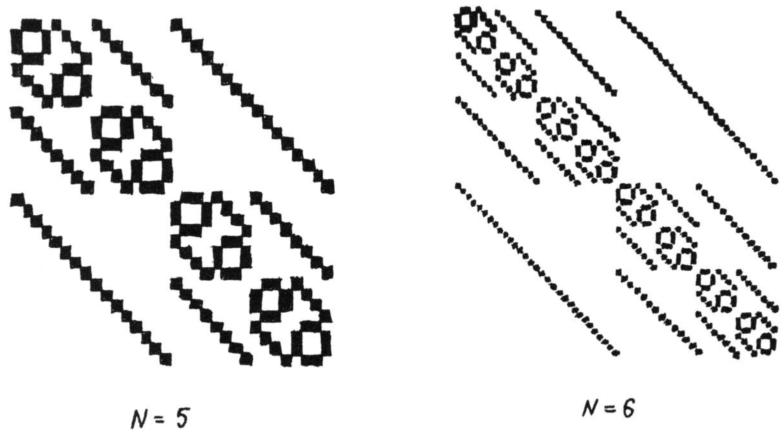

Figure 2 Intensity
transitions matrix portraits

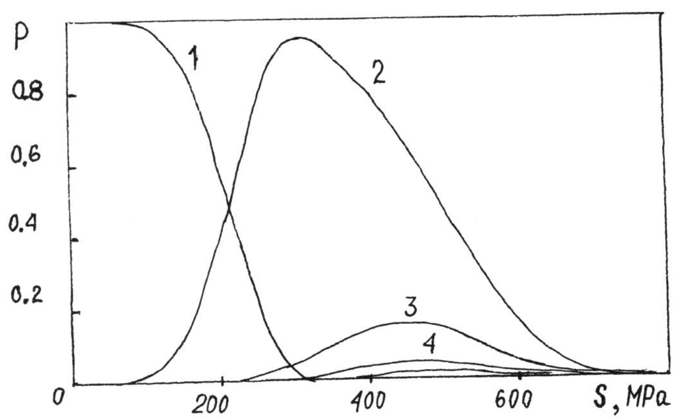

Figure 3 Transitional probabilities of carbon-epoxy lamina strength

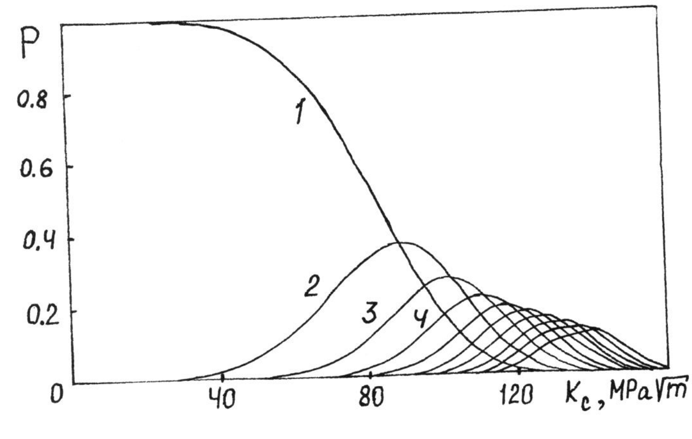

Figure 4 Transitional probabilities of carbon-epoxy lamina crack resistance

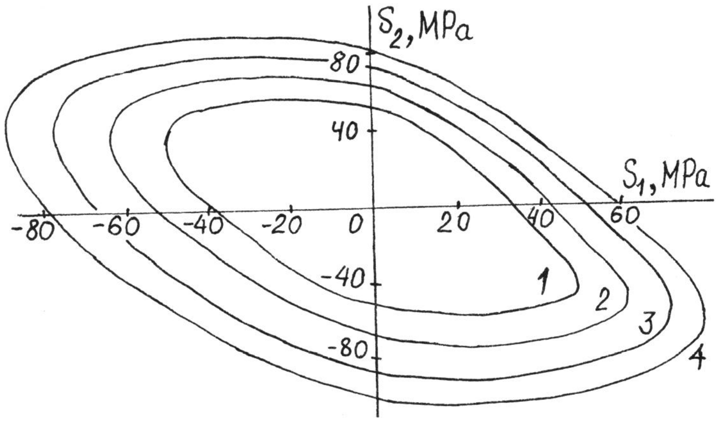

Figure 5 Strength surfaces of 2D carbon-carbon composite. Reliability levels: 1-99%, 2-95%, 3-90%, 4-50%

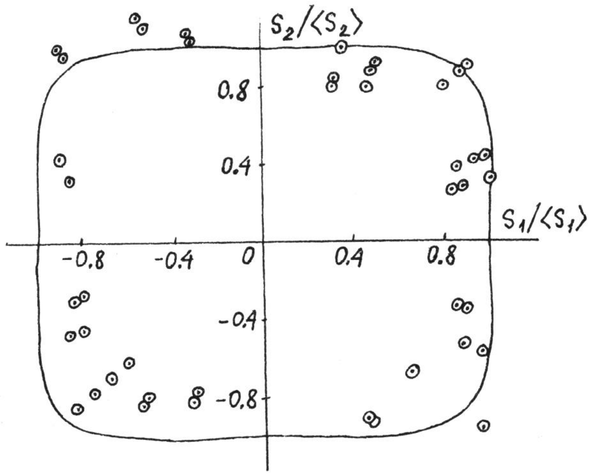

Figure 6 Strength surface of 3D carbon-carbon composite. Experimental data (2) plotted