I－16　MICROMECHANICS MODEL OF CREEP CRACKING BEHAVIOR OF ICE

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1.INTRODUCTION: Engineers require the knowledge of the strength of the ice under various conditions of loading and the behavior of ice sheets at failure to evaluate the ice pressure on off-shore structures built in the region of the frozen earth. The literature contains different kinds of phenomenological constitutive equations and some physical models to describe the deformation only under a limited load range. Some researchers have developed physical models for example by considering the mechanism of dislocation pileup, elastic anisotropy (Cole[1]) and grain boundary sliding (Sinha[4]) to relate the size of the grains to the crack nucleation stress. The experimental results by Gold[2] for the constant stress case and Sinha[4] for the constant strain rate reveal that the governing mechanism of the cracking of ice is time-dependent and very complicated. The present study shows the progress in developing a physical model for the cracking behavior of ice under a compressive load.

2.PROPOSED MODEL: The nucleation of first crack generally leads to sudden failure in tension while the damage accumulates by the process of distributed crack nucleation leading to ductile type failure in compression. The arrangement of molecules in an individual crystal of sea ice is hexagonal in structure. The elastic properties of a single crystal are different in different directions, however overall texture of an ice sheet made up of randomly oriented crystal is isotropic. The present model is based on the idea that the local stress due to the mismatch of the grains causes the microcracking.

To start with, consider an individual crystal as a cylindrical inclusion Ω embedded in a homogeneous isotropic matrix D with the same elastic properties as the inclusion (Fig.1). The ice crystal undergoes creep slip along the basal plane. The shear stress due to the applied stress on the basal slip plane is $\sigma'_{12}=\frac{1}{2}(\sigma_2-\sigma_1)\sin 2\theta$. The creep strain inside the inclusion due to the slip is assumed to be $\epsilon^{\Omega'}_{12}=A\sigma'^{3}_{12}t$ based on creep law for uniaxial compression. The uniform stress inside the inclusion is given by Eshelphy's solution for a cylindrical inclusion as $\sigma^{\Omega'}_{12}=-\frac{\mu}{2(1-\nu)}\epsilon^{\Omega'}_{12}$, and the other components are zero. The eigenstrain $\epsilon^{\Omega'}_{12}$ is given inside the inclusion and is zero in the matrix. This causes a stress discontinuity over the boundary,i.e., $[\sigma_{ij}]=\sigma_{ij}(out)-\sigma_{ij}(in)$.; Mura[3]. For a cylindrical inclusion,

$[\bar{\sigma}_{11}]=0,[\bar{\sigma}_{22}]=C\bar{\epsilon}^{\Omega'}_{22}$ and $[\bar{\sigma}_{12}]=0$

in a coordinate system normal to the inclusion boundary (Fig.1) where $C=\frac{4\mu(\lambda+\mu)}{\lambda+2\mu}$. The total stress just outside the inclusion is given by adding the stress jump and the stress inside the inclusion as,

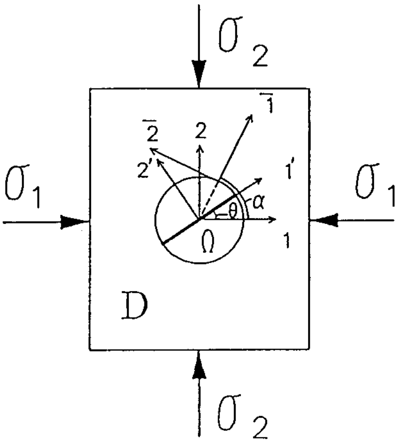

Fig.1 Inclusion Ω inside matrix D and definition of coordinate system.

$$\begin{Bmatrix}\bar{\sigma}^{tot}_{11}\\ \bar{\sigma}^{tot}_{22}\\ \bar{\sigma}^{tot}_{12}\end{Bmatrix}=\begin{Bmatrix}\sigma_1\cos^2\alpha+\sigma_2\sin^2\alpha-\sigma^{\Omega'}_{12}\sin 2(\theta-\alpha)\\ \sigma_1\sin^2\alpha+\sigma_2\cos^2\alpha+\sigma^{\Omega'}_{12}\sin 2(\theta-\alpha)+C\epsilon^{\Omega'}_{12}\sin 2(\theta-\alpha)\\ \frac{1}{2}(\sigma_2-\sigma_1)+\sigma^{\Omega'}_{12}\cos 2(\theta-\alpha)\end{Bmatrix}$$

The maximum tensile stress is obtained as a function of time for different slip plane orientation θ as shown in Fig.2.

The maximum tensile stress criterion is adopted i.e., the crack nucleation occurs when the maximum principal tensile stress is equal to the tensile strength σ_{cr}. Assuming that the distribution of slip plane orientation θ is uniform, the crack density at time t is predicted.

3.RESULTS: The variation of the crack density with increasing time under a compressive stress ranging from 1.0 MPa to 2.0 MPa is shown in Fig.3. The comparison of the time for the first crack nucleation and the crack density dependency on time with the experimental observations of Gold[2] show a good consistency. Fig.4 shows the cracking behavior under the multiaxial stress condition. The proposed model can be extended easily for the case of constant strain rate. The final goal of the present study is the development of constitutive equation of ice and analysis of engineering proplems related to ice deformation and fracture.

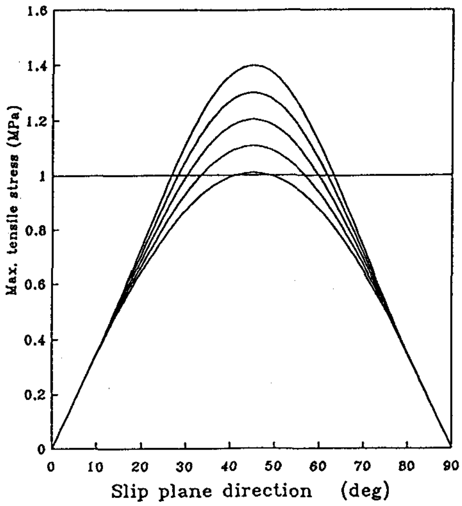

Fig.2 Variation of maximum tensile stress with slip plane direction θ.

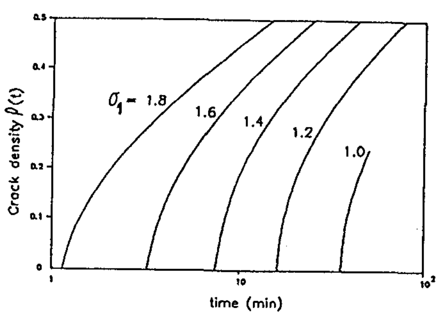

Fig.3 Plot of crack density versus time for different stress conditions.

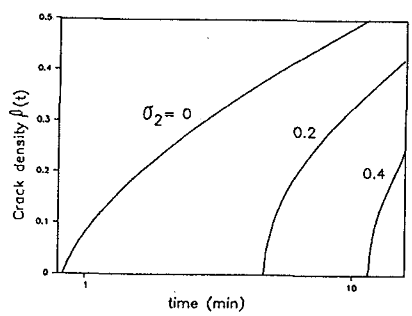

Fig.4 Effect of confining pressure on cracking behavior.

4.REFERENCES:

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