Sep 17th, 12:00 AM - Sep 19th, 12:00 AM

Fishnet Statistics for Failure Probability of Nacreous Staggered Laminar Materials

Zdeněk Bažant
Northwestern University, z-bazant@northwestern.edu

Wen Luo

IUTAM Symposium Architectured Material Mechanics,
T. Siegmund, F. Barthelat, eds
September 17-19, 2018, Chicago, IL, USA, , Chicago, IL, USA

Fishnet statistics for failure probability of nacreous staggered laminar materials

Zdeněk P. Bažant[1] (presenter) and Wen Luo[2]
(1) Civil and Mechanical Engineering and Materials Science, Northwestern University, 2145 Sheridan Road, CEE/A135, Evanston, IL 60208, z-bazant@northwestern.edu
(2) Theoretical and Applied Mechanics, Northwestern University, 2145 Sheridan Road, CEE/A123, Evanston, IL 60208, wenluo2016@u.northwestern.edu

KEYWORDS:
Nacre, Probability, Failure, Size Effect, Monte Carlo

Similar to nacre (or mother-of-pearl), imbricated lamellar structures are widely found in natural and man-made materials, and are of interest for biomimetics. These staggered imbricated structures are known to be rather insensitive to defects and have a much higher fracture toughness than their constituents. Their deterministic behavior has been intensely studied, while statistical studies have been rare and no theoretical basis for the probability density function (pdf) of strength has yet been formulated. This paper presents a numerical and theoretical study of the pdf of strength and of the corresponding statistical size effect. After reasonable simplifications of the shear bonds, a lamellar axially loaded lamellar shell is statistically modelled as a fishnet pulled diagonally. A FE model is developed and used in many millions of Monte Carlo simulations of strength. An analytical model for failure probability of the fishnet is developed and matched to the computed statistical histograms of strength of fishnet structures of various sizes. Extending fresh results at Northwestern [1,2], post-peak progressive softening of fishnet links is considered and its effect on the strength probability distribution is analyzed. It appears that, with increasing size, the pdf of strength slowly transits from Gaussian to Weilbull distribution but the transition is different from that previously obtained at Northwestern for quasibrittle materials of random heterogeneous mesostructure [3]. An important practical implication is that the staggered lamellar architecture not only enhances the mean strength but also contributes an additional major strength increase at the failure probability level of 10^{-6}, which is what matters for structural safety.

References:

[1] Luo, Wen, and Bažant, Z.P. (2017). “Fishnet model for failure probability tail of nacre-like imbricated lamellar materials.” *Proc. National Academy of Sciences* 114 (49), 12900--12905.

[2] Luo, Wen, and Bažant, Z.P. (2017). “Fishnet statistics for probabilistic strength and scaling of nacreous imbricated lamellar materials.” *J. of the Mechanics and Physics of Solids* 109, 264—287.

[3] Bažant, Z.P., and Le, Jia-Liang (2017). “Probabilistic Mechanics of Quasibrittle Structures: Strength, Lifetime, and Size Effect. *Cambridge University Press*, Cambridge, U.K.