MEASURING STRENGTH PROPERTIES OF BRITTLE MATERIALS BASED ON FAILURE LOCATION

S. Givli* E. Altus**

* Faculty of Mechanical Engineering
Technion – Israel Institute of Technology
Technion city, Haifa 32000, Israel
mesefi@tx.technion.ac.il

** Faculty of Mechanical Engineering
Technion – Israel Institute of Technology
Technion city, Haifa 32000, Israel

The probabilistic nature of strength in brittle materials has been studied extensively. Large dispersions of strength coupled with size effects were observed in ceramics, concrete, rocks, and other materials. In most cases the strength probability was found to follow the Weibull distribution, and size effects were attributed to the weakest link concept. Similar characteristics have been also observed in micro/nano structures, focusing on silicon/polysilicon and nano-tubes, which are the prime materials used in MEMS and NEMS. The probabilistic nature of strength dramatically affects the device reliability and should be considered in the design of micro/nano structures. To obtain the statistical properties of strength, a large number of experiments must be performed, involving the measurement of strains and stresses. This task becomes extremely complex on the micro/nano scale.

In this work, it is shown that the statistical properties of the failure location can be used to obtain important information regarding the strength distribution. The analysis is based on the fact that due to the inherent probabilistic nature of strength, the failure location does not necessarily take place at the highest stress level. Nevertheless, failure is more probable to occur at locations of higher stress.

One dimensional tension and bending of a beam under arbitrary distributed loads are studied as examples. Analysis is based on the weakest link approach, and is not confined to specific strength distributions (such as Weibull, Gaussian etc.). It is found that the statistical moments of the failure location (average, variance etc.) are directly related to the area moments (centroid, inertia etc.) of a simple function of the stress field. For example, the average and variance of an ensemble of cantilever beams loaded by a concentrated load at the free end (up to failure) is

$$< x >= \frac{\beta+1}{\beta+2} \quad , \quad < x'^2 >= \frac{\beta+1}{(\beta+3)(\beta+2)^2} \, . \tag{1}$$

where x is the non-dimensional (normalized by the length of the specimen) location of failure, and β is associated with the statistical dispersion of strength; For example, in the particular case of a Weibull strength distribution, β corresponds to the Weibull shape parameter.

Based on the analysis, important information related to material strength can be experimentally obtained by means of measuring failure locations. Such experiments do not require the measurement of stresses, strains or displacements, and are very attractive for MEMS/NEMS applications. Moreover, this approach can be used to detect process anomalies during mass-manufacturing.

Keywords*: strength, failure location.*

References:

[1] Givli S., Altus E., "Relation between Stochastic Failure Location and Strength in Brittle Materials", *J. Applied Mechanics*, in press, 2006.