PDF of Strength Values for Nanosized Materials of Lognormal Grain Size Distribution

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INTRODUCTION

All materials are composed of atoms which in turn comprise grains and grain boundaries in crystalline structures. Nanocrystalline materials are the ones having grain sizes on the order of 1-100 nm that exhibit improved material properties like strength and hardness. Regarding the mechanical properties, the most referred-to relationship in investigations of the materials is the empirically established Hall-Petch equation.[1]

$$\sigma = \sigma_0 + k \cdot \frac{1}{\sqrt{d}}$$

However for very small grain sizes, below approximately 10 nm, where the grain boundaries take up a considerable fraction of the material, plastic deformation is mostly carried by the grain boundaries.[2] Thus a relative softening of the materials are observed, with the size-strength relationship expressed as [3];

$$\sigma = \sigma_c - (\frac{\alpha \cdot t}{d}) \cdot (\sigma_c - \sigma_b)$$

$$\sigma_c = 4.2Gpa$$

$$\sigma_b = 1.7Gpa$$

$$\alpha \cdot t = 2nm$$

In this paper, main aim was to express the probability distribution function of strength values for lognormally distributed grain sizes -which is a characteristic of nanosized materials[4]- and thus provide a reliability measure for further studies.

METHODOLOGY

Since this distribution occurs in a random fashion, it is indeed a stochastic process itself and could be approached with stochastic analysis methods. Methods that will be employed in this work has mainly two branches; one following an analytical methodology and the latter following a numeric simulation. In the first approach, transformation of random variables method is used. The set of random variables and their corresponding PDF's (probability density functions) are;

Old Random Variable	:	Grain size (D)
New Random Variable	:	Strength
Old probability density function	:	lognormal grain distribution
New probability density function	:	? (distribution type of strength)

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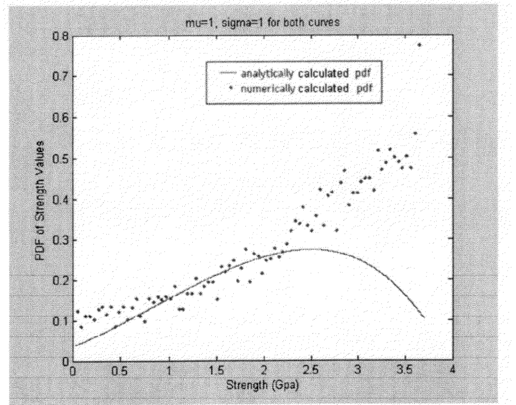
Next approach was based on a numerical iteration process to reach again PDF of strength values. Again a lognormal random grain size generation is used with grain sizes that fall out of 1.2nm-10nm span discarded. Strength values are calculated for each shot using the same relation given above.

RESULTS

Main result of the project could be shown on the PDF plots generated with two methods.



CONCLUSION

When the generated plots are compared with the analytically determined plot, numerically determined curve shows a trend similar to the analytically determined pdf, at lower strength values. The discrepancy between these two curves could be pinned with further analysis. It is seen that the strength values tend to have a peak at the highest values for numeric approach and for analytic approach it's around 2.5 Gpa. Further analysis would provide a measure for reliability issues.

REFERENCES

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