Preface

The testing and evaluation of nuclear graphite components pose such an uncertainty of scattered damage accumulation patterns leading to catastrophic brittle fracture. So, that the probabilistic methods have been developed to study their operational and functional transients. The low-impurity graphite is the most sought structural material for the core design of Next Generation Nuclear Reactor (NGNR). The quantitative and qualitative accuracy, reproducibility, and reliability of test proceedings and results when correlated with the actual real life problem of reactor components become dubious when a nuclear graphite specimen becomes excessively smaller or larger when compared to the standardized dimensions suggested by the ASTM standard Such mitigating factors give an uncertainty of proper design postulations reflecting the low level of confidence among the research community within the spectrum of nuclear graphite applications. Such mitigating factors give an uncertainty of proper design postulations reflecting the low level of confidence among the research community within the spectrum of nuclear graphite applications. In most cases the material selections based on outstanding physical properties such as high temperature strength, erosion-corrosion, thermal shock resistance, low density and well established refractory properties for the sustainability of structural integrity of critical components leads to ceramic based materials like graphite. However, the uncertainty of stochastic fracture behavior of even near identical components, the susceptibility to sustain tensile stresses, low strain and fracture toughness arising out of the general problem of scattered flaws and brittleness results in compromising structures from the designer's perspective rather than tackling the problem efficiently. Many a cases, the different stress strain behaviour in tension and compression for such materials are rather avoided in design than solved by efficient analytical, numerical or experimental procedures.The acumen of such hypothesis is reasoned to be simplifying the strength design, though we understand the fallacy of such assumptions shall only be magnified as we build up real structures of significantly large size than lab scale models. As the size and so the volume and/or surface area of the structure is scaled up, the probability of encountering severe flaws and their numbers are only increased and hence if the material is inherently brittle, catastrophic failure of such components are very intriguing to explain with existing classical unimodular assumptions. Therefore, there is a need for reassessment of such assumptions leading to closed form and semi-analytic solutions for an improved design. The endeavor of the present work has been to conduct a detailed analytical, numerical and experimental analysis of strength scaling of bimodular specimens with different geometry to eliminate the deficiencies associated with the existing model. Probabilistic approach based on the weakest link theory (WLT) model of Weibull distribution functions has been employed for evaluating effective volume and area by developing a semi-analytic three-dimensional numerical model. Weibull functional parameters such as Weibull modulus and characteristics strength has been evaluated from tension and compression testing of C-ring graphite specimens. The numerically the unimodular model and bimodular model have been compared with existing literatures.

Bimodularity has been recognized as an uncertainty in the design and development of high risk ceramic and graphite structures leading to catastrophic failure. This results in an asymmetric shifting of elastic axis and elastic surface from an otherwise neutral axis and neutral surface respectively, when the structure is mechanically loaded. Classical elasticity theory has limited application for these kinds of structural materials in its original form as it not only considers the elastic properties to be same in tension and compression, but also it does not take into account the material non-linearity. Early works by Saint Venant and Timoshenko has postulated the concept of variation of elastic modulus for beams under flexural loading exhibiting bimodular characteristics even under simple bending. Structural integrity assessment of structures comprising of bimodular materials necessitates the evaluation of state of stress as an integral factor of tension and compression modulus following a rigorous iterative procedure, where numerical computations are very much involved even running into hundreds of thousands of steps for an acceptable convergence limit. In this regard, evaluation of only effective modulus are erroneous leading to a design handicap at the prototype stage, though it might give some initial estimate of bending and shear deformation with a unimodular constitutive relationship . Consequently, the influence of variation of structure behavior from test specimen geometry to actual structural shape becomes highly exaggerated forcing the designer to take shelter under either over designed/under-designed hypothetical safety factor. This might lead to huge material and volume loss, not to mention that the cost and reliability of the structure has been compromised. The redundancy observed in the existing literature to address those issues concentrating only on unimodular based reliability evaluation of effective volume and surface area parameters for test specimens has been the motivation of the present study. Expectedly, this has been a cause of worry in correlating the experimental observations with postulated design parameters for a bimodular based material structure. Though present endeavor to evaluate reliability parameters for analytical and numerical modeling of such real life structural behavior might be uncannily computationally exhaustive, still we feel it will be worthy to get rid of such uncertainty of scaling of size and shape from laboratory specimen to actual prototype in high risk design parts exhibiting stress dependent elasticity. The conversion of design data from one specimen configuration to another without concern of bimodularity effect and prior knowledge of flaw distribution leads to unexpected failure rendering the existing design principles very much conservative for such ceramic and graphite cladded structures in contrast to metals.