ISSN: 2278 – 7798
International Journal of Science, Engineering and Technology Research (IJSETR)
Volume 2, Issue 10, October 2013

Computation of Minimum Permissible Continuum Volume for a given Level of Accurate Measurements.

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Abstract— **We know for the measurement of various intensive properties we are always concerned with the macroscopic point of view and with volume of the matter which is to be measured since it is very large compared to the molecular dimensions. Even a very small volume is believed to contain very large no of molecules so that the statistical averaging is meaningful and a property value can be assigned to it. Disregarding the behavior of individual molecules matter is here treated as continuous. Materials, such as solids, liquids and gases, are composed of molecules separated by "empty" space. On a macroscopic scale, materials have cracks and discontinuities. However, certain physical phenomena can be modeled assuming the materials exist as a continuum, meaning the matter in the body is continuously distributed and fills the entire region of space it occupies. A continuum is a body that can be continually sub-divided into infinitesimal elements with properties being those of the bulk material. A continuum volume may be regarded as the smallest continuous volume in which measurement of any property has the least accuracy.**

Index Terms— **Continuum, Mechanics, Properties, Volume.**

I. INTRODUCTION

Continuum mechanics deals with deformable bodies, as opposed to rigid bodies. A solid is a deformable body that possesses shear strength, *sc.* a solid can support shear forces (forces parallel to the material surface on which they act). Fluids, on the other hand, do not sustain shear forces. For the study of the mechanical behavior of solids and fluids these are assumed to be a continuous body, which means that the matter fills the entire region of space it occupies, despite the fact that matter is made of atoms, has voids, and is discrete. Therefore, when continuum mechanics refers to a point or particle in a continuous body it does not describe a point in the interatomic space or an atomic particle, rather an idealized part of the body occupying that point or a very small volume of the body is taken into consideration while measurement of any intensive properties

The validity of the continuum assumption may be verified by a theoretical analysis, in which either some clear periodicity is identified or statistical homogeneity and ergodicity of the microstructure exists. More specifically, the continuum hypothesis/assumption hinges on the concepts of a *representative volume element* (RVE) (sometimes called "representative elementary volume") and *separation of scales* based on the Hill–Mandel condition. This condition provides a link between an experimentalist's and a theoretician's viewpoint on constitutive equations (linear and nonlinear elastic/inelastic or coupled fields) as well as a way of spatial and statistical averaging of the microstructure.

When the separation of scales does not hold, or when one wants to establish a continuum of a finer resolution than that of the RVE size, one employs a *statistical volume element* (SVE), which, in turn, leads to random continuum fields. The latter then provide a micromechanics basis for stochastic finite elements (SFE). The levels of SVE and RVE link continuum mechanics to statistical mechanics. The RVE may be assessed only in a limited way via experimental testing: when the constitutive response becomes spatially homogeneous.

Specifically for fluids, the Knudsen number is used to assess to what extent the approximation of continuity can be made

Fluids are composed of molecules that collide with one another and solid objects. The continuum assumption, however, considers fluids to be continuous. That is, properties such as density, pressure, temperature, and velocity are taken to be well-defined at "infinitely" small points, defining a REV (Reference Element of Volume), at the geometric order of the distance between two adjacent molecules of fluid. Properties are assumed to vary continuously from one point to another, and are averaged values in the REV. The fact that the fluid is made up of discrete molecules is ignored.

II.ANALYTICAL ANALYSIS

The measurement of any intensive property (like temperature, density, specific volume, internal energy, specific entropy) is totally based on a sample volume and not the entire one .the result we obtain from the continuum volume and not the entire one. The results we obtain from the continuum volume are approximated and definitely contain error up to a certain level. If the continuum volume is increased then definitely there will be a drop in the maximum possible error in the quantity being measured.

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ISSN: 2278 – 7798
International Journal of Science, Engineering and Technology Research (IJSETR)
Volume 2, Issue 10, October 2013

Modeling an object as a continuum assumes that the substance of the object completely fills the space it occupies. Modeling objects in this way ignores the fact that matter is made of atoms, and so is not continuous; however, on length scales much greater than that of inter-atomic distances, such models are highly accurate. Fundamental physical laws such as the conservation of mass, the conservation of momentum, and the conservation of energy may be applied to such models to derive differential equations describing the behavior of such objects, and some information about the particular material studied is added through a constitutive relation.

Continuum mechanics deals with physical properties of solids and fluids which are independent of any particular coordinate system in which they are observed. These physical properties are then represented by tensors, which are mathematical objects that have the required property of being independent of coordinate system. These tensors can be expressed in coordinate systems for computational convenience.

Continuum mechanics deals with the behavior of materials that can be approximated as continuous for certain length and time scales. The equations that govern the mechanics of such materials include the balance laws for mass, momentum, and energy. Kinematic relations and constitutive equations are needed to complete the system of governing equations. Physical restrictions on the form of the constitutive relations can be applied by requiring that the second law of thermodynamics be satisfied under all conditions. In the continuum mechanics of solids, the second law of thermodynamics is satisfied if the Clausius–Duhem form of the entropy inequality is satisfied.

The balance laws express the idea that the rate of change of a quantity (mass, momentum, energy) in a volume must arise from three causes:

1. the physical quantity itself flows through the surface that bounds the volume,
2. there is a source of the physical quantity on the surface of the volume, or/and,
3. there is a source of the physical quantity inside the volume.

The computation of minimum will be definitely dependent on the quantity being measured, its nature and also on method of the device used for measurement. The material is not thermally homogeneous and in the same manner the properties are also not the same at all points .The heterogeneity present in the medium is in such a desultory manner that might lead us to show virtually such values which are far away from their actual mean. This variability is proliferated at higher temperatures and at higher entropy levels the error might look smaller at first glance but this is true only at steady state (under unsteady condition (with higher rate of energy and mass transfer). The situation becomes worse and we might have an incredible amount of error associated with it.

The first main step is the computation of the relationship between the sample volume through which the measurement is taken and error associated with it. This will definitely be a crucial and challenging task which will require knowledge of mechanics and chemistry of the substance. After getting the relationship we can compute the volume must be undertaken for measurement for a given permissible error.

The continuum hypothesis is basically an approximation, in the same way planets are approximated by point particles when dealing with celestial mechanics, and therefore results in approximate solutions. Consequently, assumption of the continuum hypothesis can lead to results which are not of desired accuracy. That said, under the right circumstances, the continuum hypothesis produces extremely accurate results.

Those problems for which the continuum hypothesis does not allow solutions of desired accuracy are solved using statistical mechanics. To determine whether or not to use conventional fluid dynamics or statistical mechanics, the Knudsen number is evaluated for the problem. The Knudsen number is defined as the ratio of the molecular mean free path length to a certain representative physical length scale. This length scale could be, for example, the radius of a body in a fluid. (More simply, the Knudsen number is how many times its own diameter a particle will travel on average before hitting another particle). Problems with Knudsen numbers at or above unity are best evaluated using statistical mechanics for reliable solutions

The density is a property which requires that liquid is to be continuous. The density can be changed and it is a function of time and space (location) but must have a continuous property. It doesn’t mean that a sharp and abrupt change in the density cannot occur it is referred to the fact that density is independent of the sampling size. Figure 1.1 shows that density as function of the sample size. After certain sample size the density remains constant. Thus density is defined as

$$\rho = \lim_{\Delta V \to \varepsilon} \frac{\Delta m}{\Delta V}$$

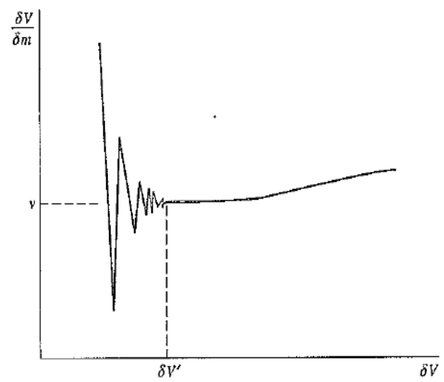

Fig.1.1 shows density as a function of sampling size

ISSN: 2278 – 7798
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It may be noted that is assumed so that the continuous assumption that it is not reduced to the size where the molecular calculations (see fig 1.2 the green lines converge to constant density). Whenever these assumptions are broken, then the principles of statistical mechanics must be utilized.

III.CONCLUSIVE REMARKS

Over study is done based on our wisdom and on the information available concludes that this is an explored area where research and development has still not took place. The sample volume which we take for measurement of any intensive property plays a very important role in the accuracy of the quantity being measured thus deciding the size of the continuum volume is of vital importance.

There are various places where a small error may lead in great failures (Astronomical sector, Nuclear reactor and bomb sector, large scale Industrial applications, Aeronautical applications) in such cases the volume on the basis of which all the measurements are taken should not be measured in haphazard manner. This study might become a new basis for further development in this direction.

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