Three-Dimensional Modelling of Embedded Coated Spherical Inclusions Through a Regularized XFEM Approach

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We propose a simple and reliable three-dimensional finite element approach for modelling particle reinforced composites where spherical and cylindrical coated inclusions are embedded within a matrix. Particle reinforced composites are employed for instance, in the automotive industry and in electronic products. Mechanical properties strongly depend on interfacial bonding quality. Hence the determination of the maximum radial stress at the particle surface as a function of the applied load and the adhesion parameters is of great interest.

Well established theoretical approaches such as the Eshelby approach for the "dilute" inclusion problem, and (generalized) self-consistent schemes for interacting particles are available [1]. Analytical solutions cannot however be obtained for any general geometry and material behavior. Finite element models appear therefore more feasible. In this context, the coating can be modeled by means of cohesive interface elements either placed along the finite element boundaries or embedded within the finite elements. The latter alternative has the advantage that the geometry of the interfaces is independent of the mesh. Based on the Partition of Unity Property of the finite element shape functions [2], the eXtended Finite Element Model (XFEM) is a broad spectrum technique for dealing with cohesive embedded interfaces. In the last years, the Authors have developed a variant, called Regularized XFEM approach. A two-dimensional application to the delamination problem of a FRP strip glued to a concrete block has shown an excellent comparison with experimental results [3]. Three-dimensional implementation is discussed in [4].

In the present work, imperfect interfaces are studied where discontinuous displacements fields across the interface and continuous traction vector occur. As usual in the XFEM approach, the surface of separation is implicitly defined via a level set function. The main steps are:

1. The assumption of the displacement field as the sum of a constant part and a disturbance part deriving from the coated inclusion.
2. The use of an "equivalent eigenstrain" concept.
3. The assumption of an extended Hill-Mandel work-equivalence principle.

The numerical solution is compared with the analytical results obtained by assuming the Hashin spring-like model [1]. We prove that the proposed approach correctly reproduces the analytical solution. The effect of the coating on the stress concentration is shown to strongly depend on the ratio between the elastic modulus of the matrix and the coating and on the Poisson's ratio of the coating.

References

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