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SIMULATION OF PARTICLE SIZE EFFECT ON PARTICLE/MATRIX DEBONDING

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The addition of stiff particles in a matrix is a common practice to obtain a reinforced material stiffer and more resistant than the bulk matrix itself. Such a resulting composite material is used in multiple industries such as automotive, aeronautics, aerospace. Various mechanical properties can be obtained using different materials, sizes, shapes, geometries, or surface treatments for the reinforcements. The role of the particles is then preponderant in such a material behaviour. That is the reason why it is important to be able to correctly estimate their influence either in the elastic domain or when damage occurs.

Concerning this important aspect, it must be pointed out that one of the main damage mechanisms for particle reinforced materials is particle debonding. This phenomenon is not simple to observe and describe as it depends upon several parameters (shape of the particles, chemical and mechanical interactions at the particle/matrix interfaces, size of the particles, etc.) For example, in [1], an interesting effect has experimentally been observed: the particle size has a strong influence on the particle/matrix debonding onset. Indeed, the authors observed that, when the debonding phenomenon of particles of several sizes embedded in a matrix occurs, the largest particles tend to debond prior to smaller ones [2]. In Finite Elements simulations, the debonding problem is commonly solved using Cohesive Zone Models (CZM) where a traction-separation law is implemented at the interface. Different types of traction-separation laws are available in the literature (bilinear, trilinear, and exponential) and several parameters are used to correctly describe the interface behaviour: stiffness, strength, fracture energy, maximal displacement. The particle/matrix debonding problem can also be tackled analytically using the Finite Fracture Mechanics (FFM) [3].

According to this framework, a crack develops when a stress criterion and an energy one are simultaneously fulfilled. In the present work, these two methods, i.e. CZM and FFM, are used to analyse the particle size effect [4]. This phenomenon can be described rigorously by studying the debonding of a single spherical particle embedded in a matrix block. To do so, this elementary structure has been replicated in a homothetic manner and both models (CZM and FFM) are applied to predict the stress responsible for the particle debonding onset. Different loadings and particle shapes are also studied. Two asymptotic behaviours are observed for small and large particles. For large particles, the debonding is predominantly governed by the strength of the interface. For small particles, the fracture energy is the governing parameter. However, the asymptotic behaviours described using the CZM or the FFM slightly differ as their dependency on the particle radius is not the same. We might then interrogate the domains of validity of both models as the FFM is only valid in the linear fracture mechanics framework, while a process zone is described with the CZM.

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