Interfacial Delamination of SMA Reinforced Composite under Low Velocity Impact

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Abstract Former studies shows that the impact resistance of composite can be significantly enhanced by insterting shape memory alloy (SMA) fibers. The interfacial delamination behavior of SMA reinfored composite plate is numerically studied with the cohesive zone model. Our results indicate that the interfacial damage of SMA reinforced composite plate is apparently decreased compared with traditional composite plates.

Keywords Interfacial delamination, SMA, Composite, Low velocity impact

1. Introduction

As is well known, fiber reinforced compoistes (FRC) are prone to impact damage. The scientific community has sought different ways to improve the impact performance of FRC. Shape memory alloys such as NiTi alloys, have long been known as a class of smart materials, which possess pseuodoelastic behavior and shape memory effect, depending on the temperature of the enviroment. When the SMAs display pseudoelastic behavior, the recovery strain can reach 8%. A large amount of deformation energy can be absorbed in a loading cyclic. This special character of SMAs has importatn potential applications to improve the mechanical performance of FRCs.

The idea of inserting SMA fibers into FRC was initilized by Paine and Rogers in 1994 [1]. They revealed by experiments that the damage of the composites can be largely reduced by inserting SMA fibers. A large amount of the deformation energy was absorbed by the SMAs during the deformation process. Jia et al.[2] further studied the impact behavior of SMA reinforced composites. Their study also shows that the impact behavior of the composites is largely enhanced due to the pesudoelastic behavior of the SMA fibers. Lau [3] and his collabrators studied the interfacial delamination behavior of SMA reinforced composites both experimentally and theoretically. Again, the beneficial effects of the inserting SMA fibers were identified. This paper studies the interfacial delamination of SMA reinforced composites by finite element analysis. The cohesive zone modelling is adopted to simulate the delamination behavior of the composite laminates. The influences of the position of the inserted SMA fibers and the enviroment temperature on the delamination behavior of the composites under low velocity impact are systematically studied.

2. FEM Models and Simulations

Former studies have shown that matrix fracture and interfacial delamination are two main damage modes of fiber reinforced composites. In order to see how the SMA fibers enhance the delamination behavior of the composite laminates, we adopt the FEM model shown in Figure 1.. In Figure 1., eight layers of composite laminates are considered. For the upper four layers, the fibers are along the zero degree direction while for the lower four layers, the fibers are along the 90 degree direction. Inbetween the middle two layers, the cohesive elements are inserted to simulate the interfacial delamination.

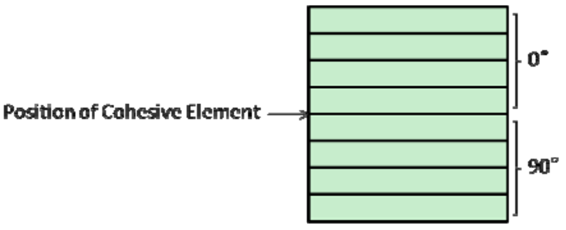

Figure 1. The numerical model to simulate the interfacial delamination.

A cylindrical projectile with a spherical head is adopted to introduce the low velocity impact. The velocity of the projectile is calculated according to the impact energy and the mass of the projectile. We assume the the cross section of the SMA fibers is of rectangular shape. The thickness of of the SMA fiber is the same as that of the laminate. In the simulation, we assume the projectile is rigid. In the impact zone, the mesh of the FE model is refined. The mesh of the FE model is shown in Figure 2.. The simulation was conducted on the finite element software ANSYS/LS-DYNA.

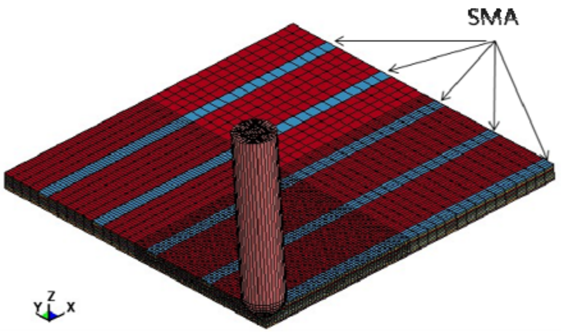

Figure 2. The mesh of the FE model.

In order to simulate the pseudoelastic behavior of NiTi SMA, we adopt the constitutive equation given by Kim et. al. [4]. The constitutive relation of the NiTi SMA is dependent upon the environment temperature. As only limited experimental results are available, only three temperatures are adopted, i.e., 350K, 370K and 390K, as shown in Figure 3..

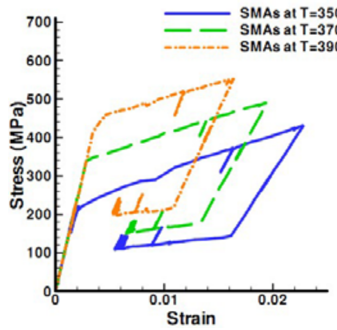

Figure 3.The constituve behavior of SMA under different temperatures [4].

3. Results and Discussions

In order to validate our simulation, we assume there are no SMA fibers inserted in the FE model. The shape of the delaminated zone is then recorded. The simulated results show that the shape of the delaminated zone is consistent with the experimental measurements, which implies that the FE model is reliable to simulate the interfacial delamination of the composite laminates. After that, the influences of the SMA fibers on the delamination behavior is further studied.

Figures 4 and 5. compares the delamination area and maximum deflection of the laminate during the impact process. In these two figures, the SMA fibers are inserted into the third and sixth layers respectively. From these two figures, we can see that the delamination behavior of the composite laminates can be largely enhanced by inserting the SMA fibers.

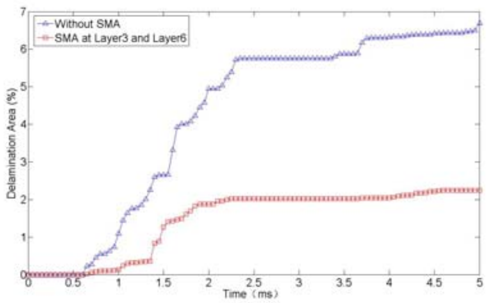

Figure 4. The time history of the delamination ratio. The impact energy is 4J.

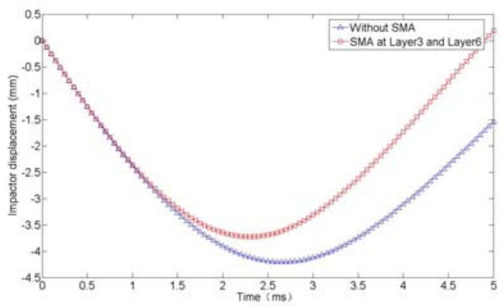

Figure 5. The deflection of the compoiste plate. The impact energy is 4J.

The delamination behavior of the composite laminates under different temperatures are also simulated, as shown in Figure 6.. From Figure 6., we can see that the delamination area under different temperatures doen’t change much. This is due to the fact that the mechanical behavior of the SMA fibers in the temperature range 350K-390K doesn’t change significantly. It is believed that the temperature will influence the delamination behavior more significantly when the temperature changes in a larger range.

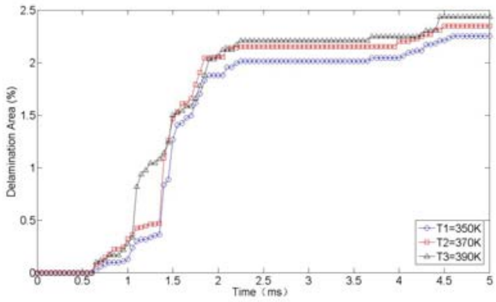

Figure 6. The delamination ratio under different temperatures. The impact energy is 4J.

In Figure 7, the position of the inserted SMA fibers are studied. In Figure 7., the SMA fibers are inserted in the sixth, seventh and eighth layer respectively. We can see that as the position of the SMA fibers is further from the impact point, the beneficial effects of the SMA fibers to prevent delamination become more pronouned.

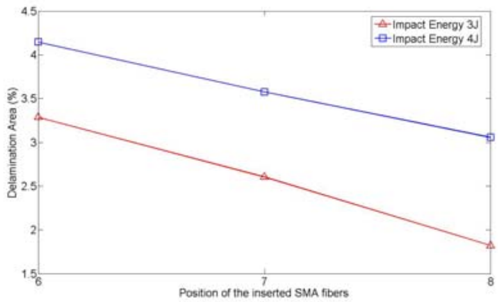

Figure 7. The influence of the position of the SMA fibers on the delamination ratio.

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