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Finite element analysis of tensor skin under water impact

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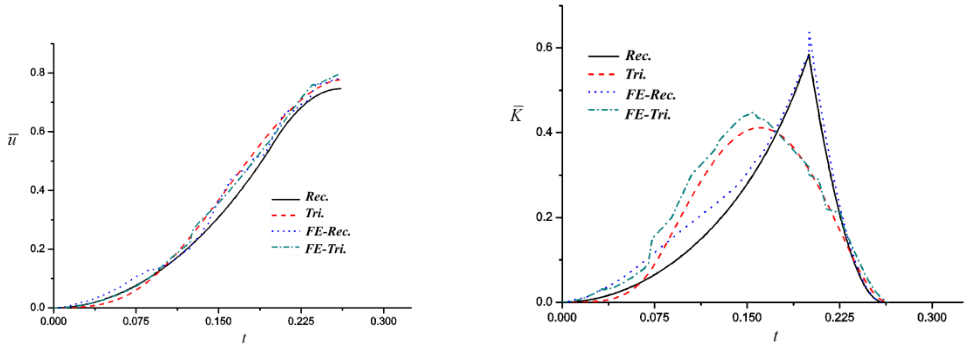
Tensor skin refers to a kind of composite sandwich structure comprised of cover ply, tensor ply and carrying ply, which is developed to improve the helicopter’s crashworthiness in water impacts[1]. From the theoretical model, the static critical pressure of tensor skin has the unstable property, that is the initial pressure to make the structure deform is high, but the structural resistance will decrease with increasing deformation[2]. In this study, the dynamic response of tensor skin under water impact pulse is analysed using both FE simulations and the pulse approximation method[3], which has been proved to be suitable for stable structure and popularly adopted in engineering applications.

A finite element model is prosed using the commercial finite element code PATRAN/DYTRAN. Three-dimensional analysis is applied in our analysis. Two points at boundary are fixed; the displacement in the out-of-plane direction and the rotations in the in-plane directions are constrained. Considering a tensor skin with geometric parameter $k = 0.5$, unit width and length $l = 2$, as shown in Fig. 1. A rectangular pulse and a triangular pulse, that is effective to the rectangular pulse according to the pulse approximation method[3], are applied. It should be emphasized that the triangular pulse is regarded to be most close to the real pulse produced by flat body impacting water[4].

The normalized central deflection $\bar{u} \equiv u/l$ and the kinetic energy curves are given in Fig. 2. Here l is half-length of tensor ply. It found that the central deflection and the kinetic energy of FE simulation are slightly different from theoretical predictions. For the deflection, that is because in the theoretical analysis, the beams are assumed to be rigid segments connected by plastic hinges, while actually, the beams have elastic flexural deformation under pressure loading. For the kinetic energy, there is elastic energy in the FE simulations while it is absent in the theory analysis. However, the difference is quite small; and the theoretical model does capture the major features of the deformation process. The FE results fit well with the theoretical results.

Meanwhile, the final deflections of tensor skin under different effective pressures are recorded in Fig. 3. Here $\bar{u}_t$ is the total deflection of tensor ply under different pulse loadings. It is clear that the final deflection of tensor skin under triangular pulse of FE simulation is larger than the others, but the derivations are within 12%.It is concluded that the FE results have very good agreement with the corresponding theoretical predictions[2]. At the same time, it found that the pulse approximation method[3]is suitable in analysing the unstable structures.

Fig. 1 FE model



(a)Normalized central deflection (b) Normalized kinetic energy

Fig. 2 The dynamic response of tensor skin ($k = 0.5$) under pulses approximate to rectangular pulse （ $\overline{I} = 1.3\overline{q}_s^0$, $\overline{t}_d = 1$ ）

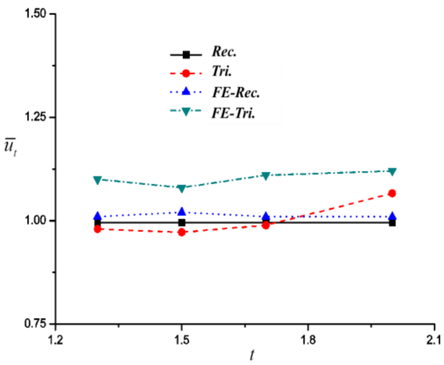


Fig. 3 the normalized final deflection of tensor skin under different effective loads (the reference of final deflection of rectangular pulse is $\overline{u} = 1$)

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