ANALYSIS OF THE CRITICAL MOMENT TRIGGERING OFF SNAP-THROUGH OF BISTABLE COMPOSITE WITH INITIAL CURVATURE


1 Mechanical and Aerospace Engineering, Seoul National University, Seoul, Korea

* Corresponding author (mhcho@snu.ac.kr)

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1 Introduction

The unsymmetric cross-ply laminated composite has two stable cylindrical configurations after curing process. One of the two stable configurations can be converted to the other at a specific mechanical load without a permanent deformation [1, 2]. For this reason, bi-stable composite is a promising energy-high-efficiency structure. For the technical application of bi-stable composite, the mechanical load, triggering off snap-through, need to be predicted and controlled well.

However, in the case of the bi-stable composite manufactured on the flat tool-plate, the mechanical load cannot be controlled without an alteration of stacking sequence or fiber volume fraction.

To overcome the design limitation and to expand the field of application with bi-stable composite, we suggest the bi-stable composite manufactured on initially curved tool plate in order to control the mechanical load without a change of stacking sequence or fiber volume fraction.

2 Modeling and Analysis

FEM commercial package, ABAQUS, was used for prediction of critical moment.

The process of snap-through analysis is divided into the curing process and the loading process. At curing process, the evaluated temperature is drop down to the service temperature and the curvature of unsymmetric cross-ply laminated composite changes progressively due to the difference of thermal coefficient between matrix and fiber. After curing process, bi-stable composite has two stable configurations which are defined into mode1 and mode2 for convenience. Mode1 is a stable cylindrical shape with the plus x-dir curvature and mode2 is a stable cylindrical shape with the minus y-dir curvature. At loading process, the shell edge line moment increases linearly, and the strain energy increases progressively. Eventually, snap-through occurs at the maximum strain energy, at which point the shell edge moment is defined as the actual critical moment triggering off snap-through.

Actually, snap-through occur at the maximum strain energy as mentioned above, but local instability occur before snap-through occur, and it occurs when the second derivative of strain energy or bending rigidity instantaneously drop down as shown in the Fig. 1.

Additionally, before instability occurs, bending rigidity is not only almost constant, but also, after local instability occurs, moment increase a little bit. For this reason, the actual critical moment is almost same with the moment inducing instability. If critical moment is defined at this point, we can approach this problem as linear problem, and the second derivative of strain energy can be used as index to select critical curvature and critical moment.

In the analysis, it is also important to distinguish the critical moment with respect to the loading dir. For this reason, forward snap-through and backward snap-through are introduced. Forward snap-through is defined as snapping forth from mode1 to mode2 and backward snap-through is defined as snapping back from mode2 to mode1.

In the result of analysis, the critical moment triggering off forward snap-through increased with respect to the x-dir. initial curvature, as shown in Fig. 2 and 4, because bending rigidity is constant before instability occur and final curvature of mode1 increases linearly with respect to the plus x-dir. initial curvature [3]. But the critical moment triggering off backward snap-through decreased linearly with respect to the x-dir. initial curvature as shown in Fig. 3 and 4, because the residual stress of mode2 increases linearly due to a linear increment of mid-plane strain by the plus x-dir. initial curvature.
3 Conclusions

In order to control the critical moment without a change of stacking sequence or fiber volume fraction, bi-stable composite with initial curvature was suggested.

Critical moment, triggering off the snap-through, has been predicted by FEM.

The following conclusions may be drawn from above analysis:

1. The critical moment, triggering off snap-through, increases or decreases linearly with respect to initial curvature.
2. As a result, we can easily predict the critical moment triggering off back and forth just by two time simulations or experiment with different initial curvature.

![Fig. 1. Variation of second derivative of strain energy with curvature](image1)

![Fig. 2. Variation of moment with curvature in the case of forward snap-through](image2)

![Fig. 3. Variation of moment with curvature in the case of backward snap-through](image3)

![Fig. 4. Critical moment with initial curvature](image4)

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References

