EVALUATION OF DAMAGE DEVELOPMENT FOR NCF COMPOSITES WITH A CIRCULAR HOLE BASED ON MULTI-SCALE ANALYSIS

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1 Introduction

Non-crimp fabric (NCF) composite is one of remarkable materials because it has some advantages such as the improvement of out-of-plane strength due to effects of stitching yarns. The stitching technology offers the potential for substantial weight and cost reduction in complex and highly loaded composite structures. Several works have been reported in the literatures regarding FE-based model of NCF composites.

Many applications require a notch for a joining of a NCF composite either to another NCF composite or to metal which is often fastened by bolts. It is very difficult to evaluate the mechanical characterization of notched NCF composite because of not only their heterogeneous characteristics, complex structure but also stress concentration at the hole. For an evaluation of mechanical property of textile composites with several parameters, FEM is one of effective methods in order to reduce the development times and the costs.

We have been developing a simulation procedure for mechanical behaviors for NCF based on Mesh superposition method which is one of the multi-scale analytical methods. The proposed method has applied to stitched laminate composites with/without a circular hole under static tensile loading. The numerical and experimental results are described in the paper.

2 Test Specimens

Test specimens have been prepared as glass fiber / polyester composites. The stitching pattern is a promat type, and the stacking sequence is [(0/90)s]. Two types of stitching pitch are prepared. 2 course means wide pitch, and 6 course means narrow pitch. The geometry of the specimen is based on ASTM D 5766.

3 Numerical Models

Figure 1 shows the scheme of the structure analysis of NCF composites by the proposed method. The geometrical data of NCF is generated by WiseTex software, which has been developed by Lomov S. V. et. al [1]. FE modeling of NCF is implemented by MeshTex, the FE modeling software for fiber reinforced composites developed by Zako, etc [2]. Since geometry of NCF is complex, it is not easy to generate FE models integrally. Therefore, stitching yarn part and laminates part are modeled individually. In order to consider the interaction of each part, the mesh superposition method is applied to the FE analysis. The multi-scale analytical method has applied to stitched laminate composites with a hole under static bending loading in Fig.2.

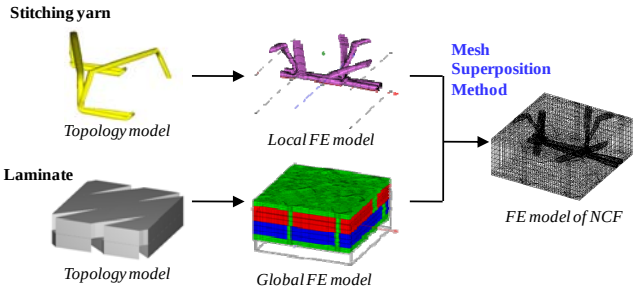


Fig.1 Numerical modeling of a NCF composite

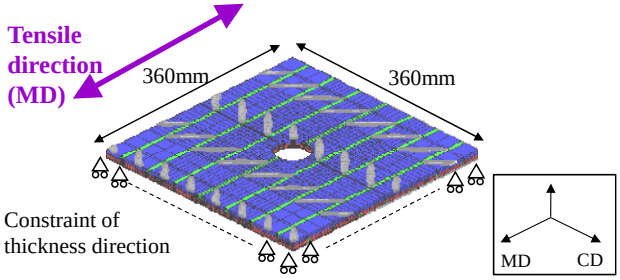


Fig.2 FE mesh of a NCF composite with a hole

4 Numerical and Experimental Results

The stiffness reduction in case of NCF composite (stitching pitch: 2 course) with a hole is shown in Fig.3. The tendency is almost same with the experimental and numerical results. Figure 4 shows the relation between the cumulative numbers of cracks, AE events, and strain. In the figure, 'TC' means transverse cracks, 'SP' is splitting, 'AE' is acoustic emission. The tendency of the increase of transverse cracks and AE signals are almost same. The effects of stitching parameters on mechanical behaviors are not so large compared with the results without a hole, however, the initiation of damage and evolution (splitting) are influenced due the position of a hole and stitching yarns. Figure 5 shows the numerical results of damage development and experimental results with In-situ observation. The colored parts in numerical results mean the damaged elements judged by the criterion of Hoffman. The initial transverse cracks appear around the opening resin region perpendicular to the loading direction. The effects of the position of opening resin region and a hole on the development of damages have to be investigated with the proposed mesh superposition method.

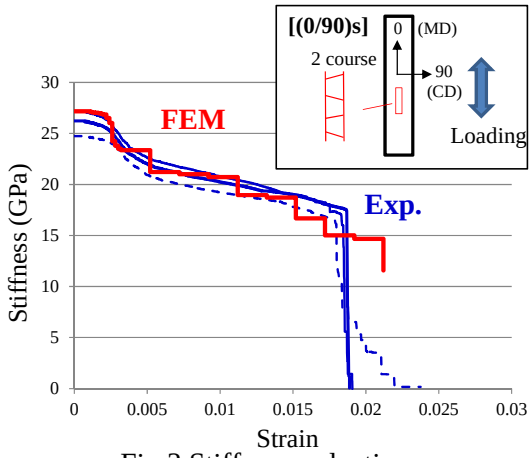


Fig.3 Stiffness reduction

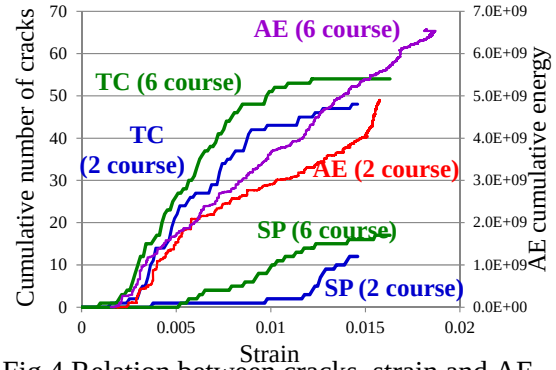
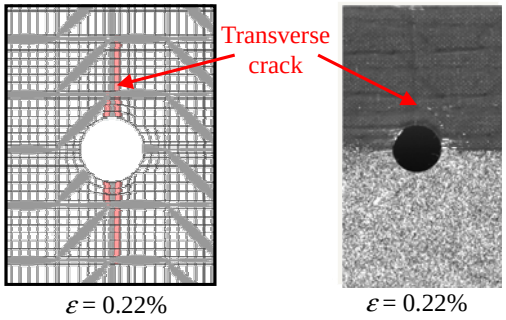
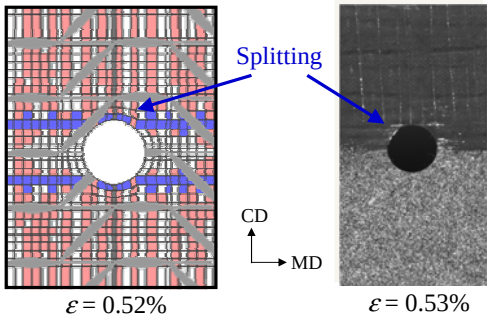


Fig.4 Relation between cracks, strain and AE



(a) Initial failure



(b) Development of damage

Fig.5 Comparison of damage development with FEM and experiment

5 Conclusions

The numerical models of stitching yarn and laminates with a circular hole are generated individually, and the mesh superposition method is applied to the FE analysis. From the numerical results, the mechanical behaviors of NCF composites with a hole can be estimated, and the stiffness reduction under static bending has same tendency with the numerical and experimental results.

Acknowledgement

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