Simplified models of impact damage in thin-walled composite columns

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Abstract. The paper deals with simplified models of damages as a results of low velocity impact load into thin laminate. The models can be used for reduction of time calculation and simplified the procedure allowing to analyze the behavior of pre-damaged thin-walled laminate structures. The proposed numerical models have been compared with results of experimental tests. A few different models have been proposed and they have been implemented to thin laminate plate and channel section columns subjected to compression. The numerical calculations have been perform using finite element method software.

INTRODUCTION

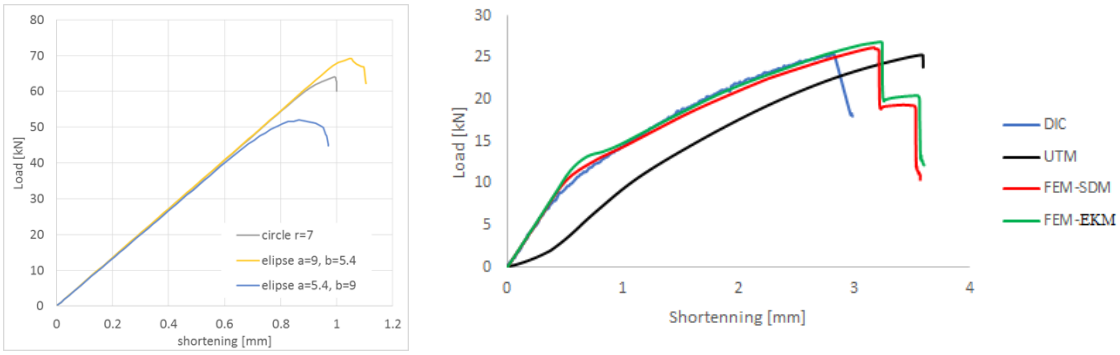
Nowadays the composite materials are very popular and they are used in many branches of industry. Composite materials possess not only many advantages, but also some disadvantages. One of them is impact damages resistance. The problem of damages coming from impacts with low velocities which can be caused by e.g. dropping of tools or collisions during maintenance. Such the damages can be present in different forms: matrix cracks, debonding of fibers from matrix, delamination or even cracking of the fibers. Taking above into account the damage tolerance design of structures made of laminate looks to be very important. To simplified the numerical analysis procedure and to reduce the calculation time it is necessary to introduce to the real structure the simplified model of impact damage.

The one of the very first suggestion of such a model of impact damage have been proposed by Sjogren et. al. [1] who proposed introduce circular delamination and soft inclusion with cylindrical shape. However, in world wise literature there are a lot of paper dealing with modeling of CAI test i.e. impact load and then compression load (e.g. [2]), but there are still lack of the numerical analysis of real or more complicated composite structures then simple rectangular plates. It should be mentioned that in literature there are papers dealing with steel structures loaded by operating load and different kind of impact load. The thin-walled rectangular tube made of steel have been analyzed by Chen et. al. [3], who have investigated the influence lateral impact on the axial bearing capacity. The different impact energy, loading position and width-thickness ratios have been considered to access their influence on the residual axial bearing capacity the failure mode, initial stiffness and ductility of tested specimens. Malachowski et. al. have performed investigation of compressed steel I-section column protected by composite panel and subjected to blast load [4]. The other example is steel pipeline repaired using composite material and subjected to puncture from excavator toot [5].

Taking mentioned above examples and literature overview it can be said that there are still not enough investigation of pre-damage thin-walled laminate structures subjected to operating load.

SIMPLIFIED MODELS AND EXEMPLARY RESULTS OF CALCULATIONS

The represented regions of real damage in the numerical model were defined by a simplified damage model (SDM). The influence of different model parameters and assumptions on the buckling, postbuckling and failure load have been analyzed. The first SDM is based on paper written by Sjogren et. al. [1] - the cylindrical or conical shape with reduced in different way material properties. Additionally, the circular delamination between two layers could be introduced. The next SDM model assume possibility of existing two volumes with different material properties – one softer connected with damages of fibers and matrix and the second one connected with matrix damages or delamination. The next modification of SDM have been introduce the elliptical instead of circular shape of cross-section of damage volume. The other SDM models are based on different reduction of plies thicknesses with assumption the real shape of impact damage [6] or elliptical shape of damage with area corresponding to real impact damage.



(a) (b)

FIGURE 1. Load – shortening curve for plate (a) and channel section column (b) with introduced impact damages

The exemplary results i.e. the influence of shape of soft inclusion on load-shortening curve of compressed plate (Fig. 1a) and the comparison between numerical and experimental results of channel section column subjected to compression with pre-damaged flange (Fig. 1b) are presented in Fig. 1. In case presented in Fig. 1b the pre-damaged model with elliptical shape and thicknesses plies reduction have been assumed. The results (Fig. 1b) denoted as "DIC" and "UTM" have been obtained experimentally based on data collected by digital image correlation system and universal testing machine respectively. The FEM-SDM results have been obtained based on Author's model and for comparison the FEM-EKM results have been obtained using model developed by Esrail and Kassapoglou [7].

Based on obtained results it can be said that there is possible to create simplified numerical model of impact damage allowing to analyze laminate structures with different impact damage and to perform damage tolerance design analysis.

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