NUMERICAL BUCKLING ANALYSES OF STIFFENED COMPOSITE PANELS

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SUMMARY

Nowadays the more widespread use of composite structures demands a better understanding of frequently complicated mutual interactions between system parameters like ply-angle directions, stacking sequence on the general response behaviour. It is well known that stiffeners attached to (composite) panels might clearly improve the overall buckling behaviour of the resultant stiffened structure.

In this study, a sampling procedure examines the effects of various influencing factors, such as the position and shape of the stiffener, on the buckling behaviour. Besides the evaluation of stresses, a proof of sufficient stability against buckling is required. Afterwards a meta-model is created based on the results of the sampling procedure. Tailor-made solutions can be provided from the early design stage to their deployment, use and ultimate disposal. It gives us the ability to recommend the best solution from a variety of different realisations.

Virtual prototyping and simulation are key factors in slashing time to market. All computations are carried out in PERMAS.

1: State-of-the-art

The progressive employment of new materials and production methods particularly in lightweight design represents substantial challenges to the structural analysis of load bearing capacity and stability, i.e. buckling. The consideration of uncertainties in rapid design exploration becomes more and more important. These uncertainties can be described by intervals for corresponding system parameters. Finding an optimal stacking sequence is a major concern for laminates. In addition, a variation of ply thicknesses and angles is considered. In most of the cases, the laminates make use of a limited number of ply orientations. Further requirements for the layer build-up, such as symmetry, balanced or unbalanced plies, maximum number of equally oriented plies cut down the number of possible combinations. However, even though there exist some restrictions, the number of possible configurations might increase rapidly. Here, the engineer benefits from the design exploration capabilities of PERMAS by an integrated SAMPLING procedure. Beside the previously mentioned design parameters, such as ply thickness, ply orientation and stacking sequence, the position and shape of the stiffeners can be varied. Different stiffener cross sections like blade, J, T and hat are used in practice does not require a remeshing (in contrast to Mulani 2010) due to sophisticated automatic coupling procedures for incompatible meshes in PERMAS. It is also possible to modify the shape of stiffeners or cut-outs (Hao 2016; Mondal 2015). The following points are to be checked prior to sampling (DOE):

- Selection of variable system parameters including range of values,
- Selection of result quantities (i.e. buckling loads, natural frequencies, displacements, etc.),
- In case of geometric variations (symmetries, continuity at boundaries of design areas),
- Linking of design variables.

Finally, suitable parameter combinations can be extracted from this multidimensional design space.

2: Sampling

The sampling procedure is treated the same way as an optimization. A sampling situation is linked to the actual analysis procedures; in this case, STATIC and BUCKLING ANALYSIS, respectively. Thereby the results of the corresponding analysis are available for further postprocessing. A number of design parameters and their values of interest define the design space. The interesting characteristics are defined by result quantities and their combined evaluation, if needed. The design elements are selected, too. The variation of ply orientations and ply thicknesses in laminates is introduced and coordinate changes are provided. Imperfections can be defined as well.

3: Panel with stiffener example

The first example (see Fig. 1) is carried out in accordance with a publication by Mittelstedt (2008). The composite panel and the stiffener are built as a laminate. Two independent variables are used here; the position of the stiffener is varied translational in the global x-direction (red arrow), plus the height of the rib in z-direction (blue arrow). The stiffener is located in the plane of symmetry for x=0. An in-plane load is applied in the x-y plane along the edges. The finite element model contains 390 elements and 496 nodes.

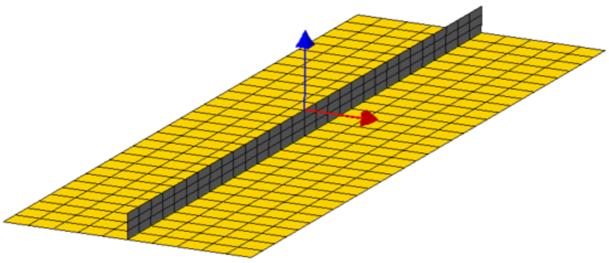

Figure 1: Composite panel with a single rib.

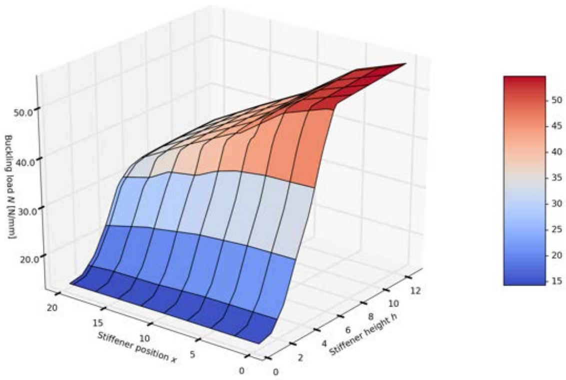

Figure 2: Buckling load as a function of stiffener height and position

The results of the SAMPLING procedure are given in terms of csv files and can be visualized by Python scripts (pyINTES). The buckling load is a function of two independent variables and can be viewed three-dimensionally (see Fig. 2). It is obvious that the buckling load increases with the height of the rib until a plateau is reached. Furthermore, the buckling load decreases when the rib leaves the symmetry plane. In case of multi-dimensional problems (n>2) additional considerations are needed for a proper graphic presentation.

4: Panel with cut-out

Cut-outs are frequently used in the aerospace industry but also in the shipbuilding industry. Stringers as well as vertical structure members may be arranged in intervals to support the skin. The influence of the size and the position of the cut-out is of vital importance (Hao 2016) and is investigated by SAMPLING in this study.

With bigger mesh modifications by mesh morphing it must me internally ensured, that the element quality comply with the requirements. The element quality is a scalar element result and can be requested as additional condition. Alternatively, the shape of curvilinear stiffeners can be taken into account within the SAMPLING procedure (see Fig. 4).

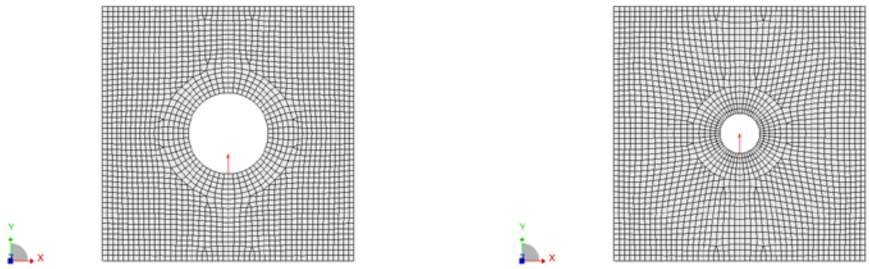

Figure 3: Left: Non-deformed state; Right: Deformed state. Identical number of nodes and elements in both cases.

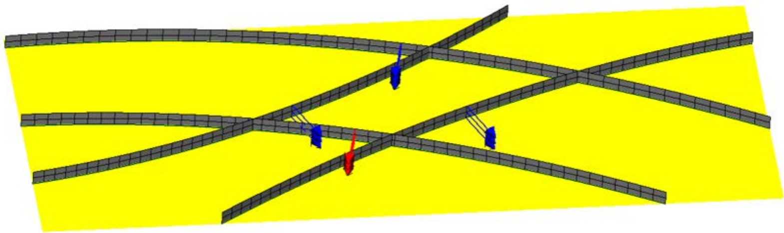

Figure 4: Modification of a panel with curvilinear ribs by shape basis vectors.

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