WEIGHT REDUCTIONS FOR THE AIRBUS A380

Postbuckling of the A380 VTP skin panels

The skin panels of the Vertical Tail Plane (VTP) are the largest single piece composite components assembled on the Airbus A380. By allowing postbuckling to these skin panels might result in severe weight reductions for the VTP of the A380. The goal of the study is to give an indication of possible weight reductions by allowing postbuckling to the skin panels of the VTP.

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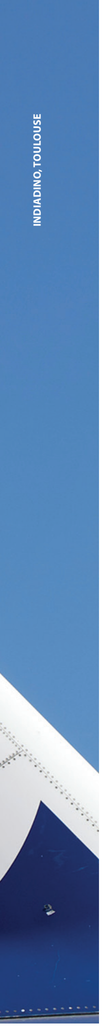
For the present study, a distinction between three different types of buckling has been made; local buckling, global buckling and blade crippling. If local buckling occurs, only local areas of the skin between the stringers buckle (see Figure 1a). This does not result in instability of the panel. In the case of global buckling, the buckles spread over several stringer bays (see Figure 1b). These large deformations result in instability of the panel and the panel will not be able to carry the loads after buckling onset. Blade crippling is local buckling of the stringer blades (see Figure 1c). Due to the crippling of the blades, the stringer is not able to carry the loads after buckling onset and therefore this also leads to instable behavior. Both global buckling and blade crippling are not allowed to occur before Ultimate Load (UL). To set a limit for local buckling onset, the Airbus postbuckling margin policy has been used. This policy gives a limit for local buckling onset depending on the local panel thickness. These limits, ranging from 1.2 Limit Load (LL) up to 1.5LL, are based on empirical data and should make sure that skin-stiffener separation does not occur before UL.

PART A: THEORY

The focus of the first part is on flat rectangular panels. The first goal is to find the correlation between theory and practice and the second goal is to analyze the influence of important parameters on the postbuckling behavior of the panels. Based on the Von Karman equations (Von Karman, 1910) for large displacements of panels and the method presented in the book of Kassapoglou (Kassapoglou, 2010), an analytical model has been created. The boundary conditions are simply supported and the panels are loaded in unidirectional compression. It is assumed that the layup is balanced and symmetric. Abaqus (Dassault Systèmes) has been used for the numerical models since Abaqus is known to be good with non-linear FEA. A good correlation was found between the analytical and numerical models for the out-of-plane and end-displacements.

As part of a parameter study, the influences of the boundary conditions, element types, mesh sizes, layup directions, panel thickness and aspect ratio have been studied. Part of the parameter study has been used to establish the numerical models. The most important conclusion drawn from the parameter study is that the boundary conditions have a major influence on the postbuckling behavior of (unstiffened) panels. It has a large influence on both buckling onset values as well as the deformation behavior of the panel (both out-of-plane and in-plane). Using the parameter study, the influence of every boundary condition component could be analyzed. Finally, the boundary conditions of the numerical model have been adapted to match the boundary conditions of the test panel. Doing so, a good correlation was found between the FE model and the test panel. Finally, design rules for the layup have been formulated which could be used in the final part.



PART B: TEST

The second part has again been split into two parts. First, to validate numerical models using test data and second, validation of a method for skin-stiffener separation prediction. To validate the numerical models, actual test data from the A380 skin panel certification tests were used. This includes the test results of three different 2m panels, which have been tested for pure compression, and three different compression/ shear ratios. An example of an Abaqus model is shown in Figure 2. The complete panel including stringers has been modeled using shell elements and the test rig and support structure was modeled using kinematic couplings and boundary conditions. The strain results from Abaqus have been rotated in the correct direction to determine the membrane and bending strains for all measurement positions in the test area of the panels. A good correlation was found between the test data and the numerical models, especially the sudden steep increase of bending strains after buckling onset was very well predicted by Abaqus.

Since no skin-stiffener separation occurred during the panel tests, test data from another component has been used to validate the skin-stiffener separation method. The skin-stiffener separation prediction method is based on the QFC (quadratic failure criterion), combining the interlaminar normal stress and shear stress. Using a very refined mesh and the ASC (average stress criterion) at the stringer run out where the separation occurred during the tests, the point of separation could be predicted quite well. However, the process of refining the mesh size and finding converging stresses using the ASC is very time consuming. Analyzing a test panel of two meters in length and a width of six stringer bays with the refined mesh needed for accurate predictions took over 48 hours of calculation time.

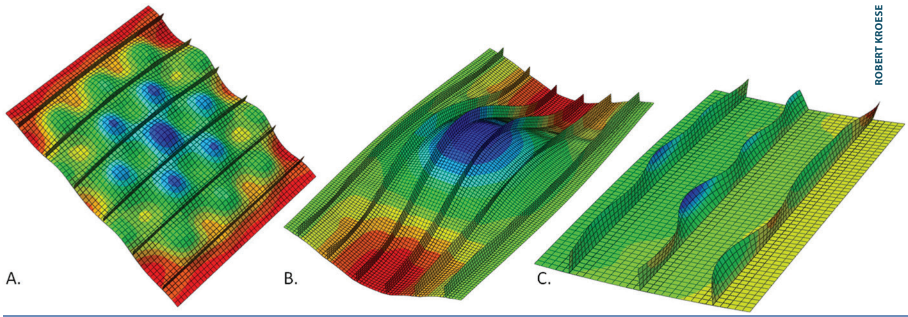


Figure 1. A. Local buckling, B. Global buckling, C. Blade crippling

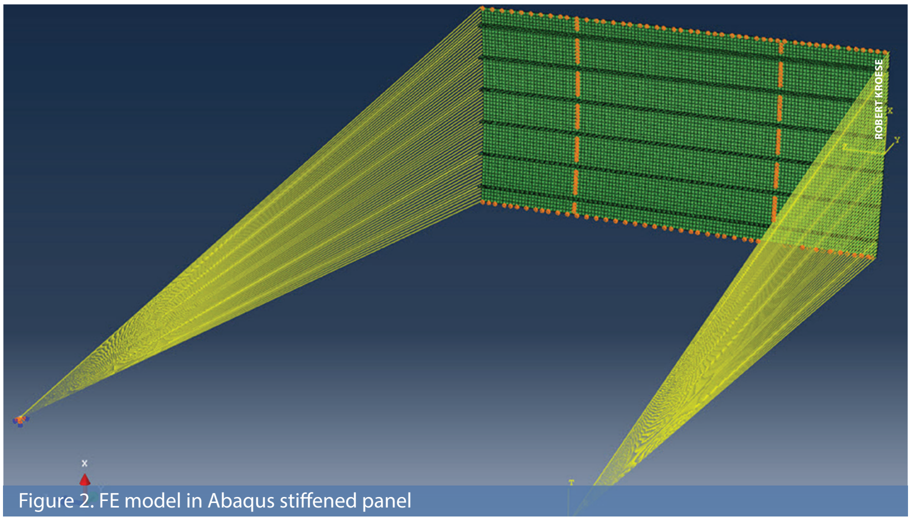


Figure 2. FE model in Abaqus stiffened panel

PART C: A380 VTP SKIN PANELS

To reduce calculation costs, local FE models based on the validated FE models of part B have been used rather than the global VTP model. Three local areas of the actual skin panel have been chosen to be represented by the local models to find weight reductions. A tool has been developed for automatic model generation in which stringer geometry and layup are the parameters, which have been altered during the process. The result files from Abaqus have been analyzed using another automated tool. Using a second order derivative method, the buckling onset values for all three types of buckling have been determined.

With the values of buckling onset known for the original layup, different layups have been analyzed. Different layups were created, by making the original layups thinner with removal of one or more plies. The modified layups have been analyzed for buckling onset. Based on these results, changes have been made to the stringer geometry to increase or decrease buckling onset values. Once the stability criteria had been fulfilled, the results have been checked for strength and skin-stiffener separation. The process of changing the layup and stringer geometry has not been automated on purpose. In this way, the influence of the changes could be studied and analyzed. By changing the stringer foot width, mostly local buckling onset can be influenced while changing the stringer web height has more influence on the global buckling onset. These results can be used in any further optimization process to modify and optimize the complete skin panel. Based on the results of the local areas, up to 20kg can be saved for both skin panels by allowing postbuckling.

FUTURE

Besides weight savings, other advantages are found due to the modified layups. Since the overall panel thickness has been decreased, less time and material is needed to produce the skin panels. Therefore, the skin panels can be produced cheaper and faster. However, this was beyond the scope of this thesis and the economic benefits have not been studied in detail.

Since certification regulations are very strict, numerous tests and numerical simulations have to be performed to demonstrate that a fully modified skin panel is able to carry the same loads as before. Since these tests are expensive and very time consuming, postbuckling will not be applied at this moment. However, it still is a very interesting option to apply postbuckling in the future when it can be combined with other major modifications.

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