EFFECTS OF GROOVE CONFIGURATIONS ON FATIGUE RESISTANCE OF INFUSED SANDWICH PANELS

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ABSTRACT: To draw the connection between manufacturing and performance of the final structure, the resin uptake of different, well established and the latest contour and infusion cut configurations was determined. The fatigue performance of infused sandwich panels was investigated with respect to different groove configurations used for resin transport through the core material (AIREX® T92.100 PET foam) and compared to results obtained on plain foam. No negative effect on the fatigue resistance of grooved and perforated configuration (AIREX® GP) in 100 kg/m^3 PET foam was found. First results on contour cut sandwich beams show the same tendency.

KEYWORDS: Vacuum infusion, contour cut, fatigue properties

INTRODUCTION

High cycle fatigue is present in a wide variety of lightweight sandwich applications, among them are windmill blades, floor panels, ship decks and many more. Lately, such components are designed to meet fatigue requirements over their lifespan although fatigue is usually not the main cause for failure as for example in metallic structures. From manufacturing point of view, grooves and perforations are inherent to most of the infusion processed core materials and are known to reduce static properties in at least some cases.

RESIN UPTAKE OF CONTOUR CUTS

Configurations investigated

Not only properties like resin uptake, wet-out and contourability are the drivers behind the most recent cut configuration, but the new groove configurations should be lean in terms of manufacturing and more cost effective than current options as well. As a reference for the present investigation the current AIREX® ContourKore (CK) and infusion cut AIREX®GP (grooved & perforated) served, figs.1 and 2 [1] respectively.
The AIREX® CK features crosswise through thickness grooves spaced at 30mm distance with scrim cloth on one side. It offers excellent contourability, but at the cost of a high uptake of resin. AIREX® GP features crosswise grooves (width 1.2mm, depth 2.5mm) spaced at distances of 20mm and shifted by 10mm between the sheet sides. Perforations are drilled, diagonally spaced at 50mm to guarantee the resin exchange

between inner and outer skin during an infusion. This cut offers excellent wet-out combined with moderate resin uptake, but limited contourability.

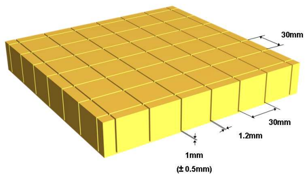

Fig. 1: AIREX CK,

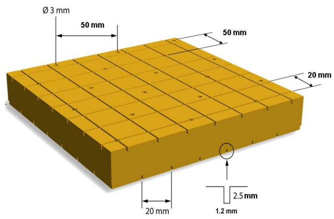

Fig. 2: AIREX GP,

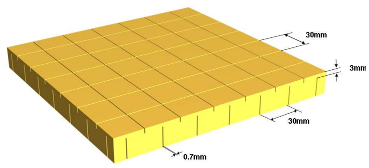

Fig.3: asymmetric double cut

In the latest available cut option, an asymmetric double cut (DC in the latter, see fig.3) perforations are generated in a much more efficient way, by intersection of grooves (double cut principle). Such types of configurations in addition provide a high degree of contourability, especially if the cuts are more than ¾ through thickness. If necessary, the degree of contourability can be adjusted by changing the groove width and the block pattern (distance between the grooves) accordingly.
The latest configurations investigated, was an asymmetric double (DC50 in the latter) cut with a block pattern of 50mm and a groove distance of 25 mm to further reduce the resin uptake.

Resin Uptake

The resin uptake of plain AIREX® T92.100 and different cut configurations was determined according to the procedure described in the following. Of each configuration, 3 specimens with a size of 300x300mm and thicknesses of 20 and 30mm have been manufactured. A peel ply next to the core followed by a single layer of 450g/m^2 continuous filament mat (unifilo), was used to peel off the cured skin (after about 6 hours). Using the above layup, the samples have been infused with an orthophtalic polyester resin, *Crystic 192 LV* from Scott Bader. The areal weight, respectively the density of each sample was determined before and after peeling off the skin. The results are given in figure 4 below (empty symbols).
In parallel, the results on the resin uptake of plain foam were used to calculate the total uptake as the sum of the resin volume in the grooves/penetrations, the uptake of the cut's surface and the surficial uptake of plain foam, all per m^2 (figure 4, solid symbols).

Conclusions

The resin absorption at a thickness of 20mm for GP is about 30% less than for DC. At a thickness of 30mm, DC absorbs even twice as much resin as the GP. If a DC cut sheet is applied with the through thickness grooves away from the mold curvature (towards the center of the radius), the grooves will close because of the curvature, what decreases the uptake by an additional third. Another way is to increase the block to for example 50mm (DC50), what leads to a further decrease (fig.4). An additional advantage, is that the contourability of the foam sheets can be tuned by the groove width, the wider the grooves the smaller the radius, which can be fit. With respect to the calculations, it can be clearly seen, that the calculated uptake for the CK and DC configurations are slightly higher than the measurements. The uptake calculated for the GP configuration reflects the measurement quite nicely.

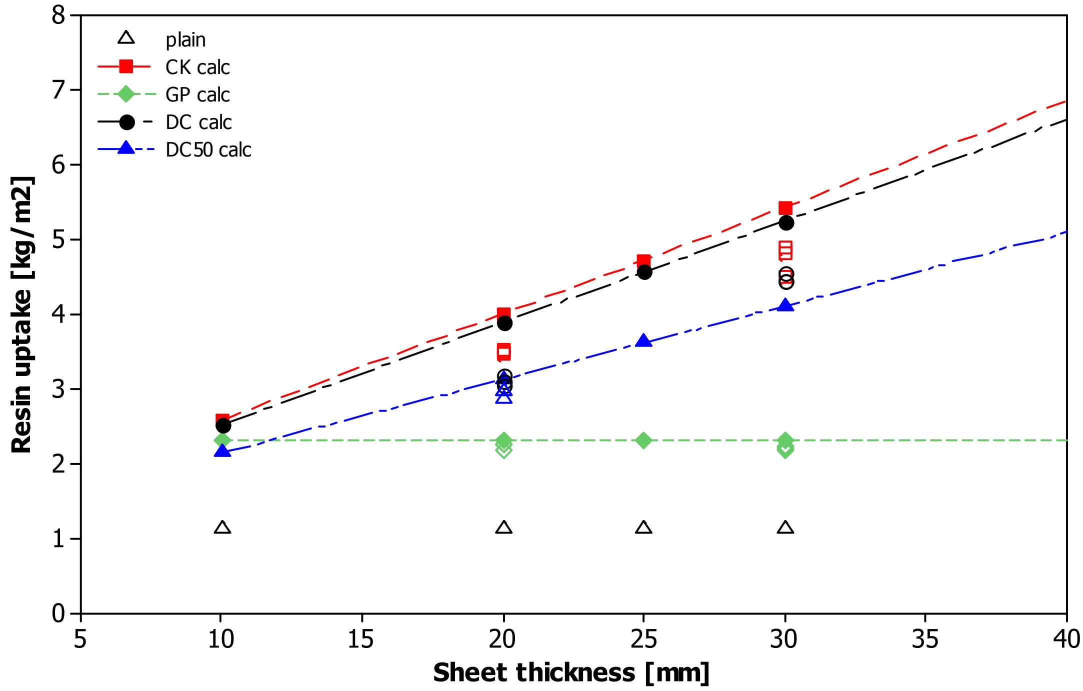

Fig. 4: Calculated resin uptake for the cuts (solid symbols) and the measurements for 20 and 30mm sheet thickness (empty ones)

FATIGUE

All the results in the latter were obtained under shear fatigue loading in a 4-point bending configuration. This setup has the advantage of resulting in a constant shear stress applied between the inner and outer supports. In addition such a configuration is less affected by local effects resulting in stress concentrations.

Sample Preparation

The layup of the skins comprised four layers of CSM 300g/m^2 (chopped strand mat) and 600g/m^2 web roving, each. The samples with plain foam core configuration have been vacuum infused using a flow mesh, all the others (AIREX® GP & DCs) without. Orthophtalic polyester resin, *Crystic 192 LV* from Scott Bader, was used. The core thickness of AIREX® T92, densities 100, 110 and 130 kg/m^3 was 55mm. The specimens tested, had a skin thickness of about 2.5mm, what results in a total laminated sandwich thickness of 60mm, specimen length was 945mm and width 132.5mm.

Testing

The laminates have been tested in 4-point bending setup according to ASTM-C393 with servo-pneumatic and –hydraulic equipment at Alcan Technology and Management in Neuhausen, Switzerland. The tests have been performed load controlled at room temperature (23±2°C) at an R-ratio of 0.1 (ratio between minimum and maximum shear stress). The lower support span was 845mm, the load span of 300mm length. At least two specimens per stress-level have been tested. Samples running at a maximum shear stress and exceeding 10 Mio cycles have been stopped at 10.5 Mio earliest and their remaining static strength was determined (further details in [3]).

Results

Figure 5 shows results for the fatigue tests of all the available T92 densities determined with plain foam configuration, also see reference [3]. Figure 6, compares the different configurations tested to the plain foam results, all for T92.100.

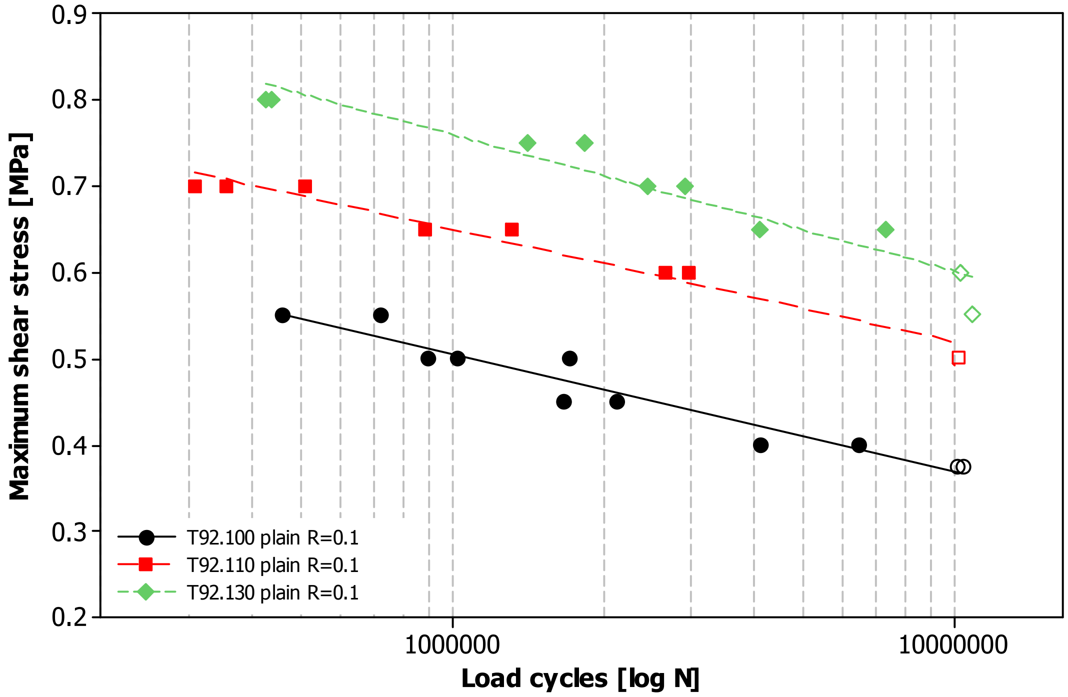

Fig. 5: Test results for AIREX® T92 densities 100, 110 and 130 at R=0.1, solid symbols representing failed samples, empty ones for the runners (> 10^7 cycles)

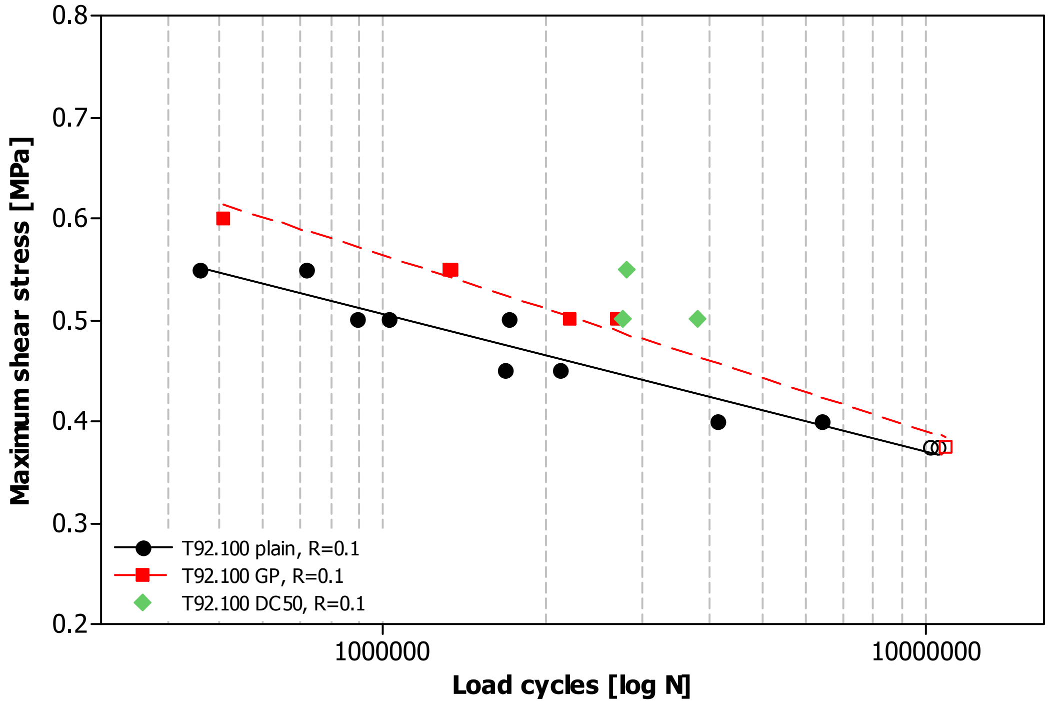

Fig. 6: Test results for AIREX® T92.100 different types of configurations all at R=0.1

CONCLUSIONS

A series of internal static 4-point bending tests according ASTM-C393 [4] showed, that the through thickness foam grooves from the CK configuration result in a higher panel stiffness, but on the other hand reduce the bending strength dramatically. That is a well known fact which applies for other types of core materials as well [5]. With respect to fatigue, no negative effect of the GP configuration was found. Normalizing the shear stress levels of the runners in figs. 5 & 6 by the static shear strength of T92.100, a reduction of the static shear strength in the range of 40% after 10 million loads cycles for plain and GP configuration is found. First results of DC50 (block pattern 50mm) samples show no negative of effect of the through thickness grooves, of course if they are completely resin filled, see also [6].

ACKNOWLEGEMENTS

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