THE OPTIMISED POST-FITTED FOAM SANDWICH INSERT

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ABSTRACT

One of the biggest difficulties in the sandwich industries today is load introduction. It is very important that the insert has a well-designed load carrying geometry to ensure the strength of the load introduction and the sandwich structure. Well-designed optimised lightweight sandwich structures are often penalised with added weight when the load introductions require higher density core/thicker face sheets or larger inserts. A shape optimisation of core insert geometry was performed by Shipsha, Söderlund and Zenkert and presented at the 4th International Conference on Sandwich Construction. Inserts with this optimised geometry can be both pre- and post-fitted. A disadvantage of pre-fitted load introductions is that it makes it necessary to predetermine the locations of all inserts before the sandwich panel is assembled, which is very time-consuming during design and manufacturing. On the other hand it is also very work intensive to Post-fit this kind of insert, which requires replacing or repairing of the face sheet. To solve those problems, a concept for post-fitted inserts has been developed.

With a special milling tool [SWE pat & int. pat. pending], a cavity, which corresponds to an optimised geometry, is created without damaging the sandwich skin apart from the necessary opening for the load introduction. The cavity is filled with adhesive and if there is a need for stronger fastening an insert with internal threads can be added. This concept can also be applied on a through sandwich load introduction. By using this new non-destructive post-fitted insert system with an optimised geometry for load introductions in sandwich structures you are able to cut manufacturing costs, minimise weight and simplify design.

1. INTRODUCTION

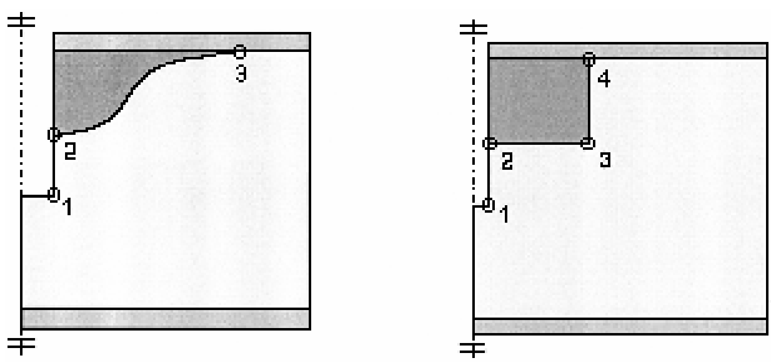
Post-fitted load introductions in sandwich structures usually generate difficulties, especially when it comes to structures with thin face sheets and low-density cores. The most common ways of making load introductions to sandwich structures is joining by adhesive, laminating or using inserts. Joining by adhesives and hand laminating normally gives very strong joints but is also quite labour intensive and bulky. Use of pre-fitted inserts requires more planning and a more precise manufacturing process. Use of post-fitted inserts normally compromise the strength or weight of the fastening and the sandwich structure. When mounting a post-fitted insert you have to cut-out an area of the laminate that corresponds to the size of the insert. To ensure high strength of the fastening the area over/around the insert has to be reassembled with laminate.

More effective production methods and better load introduction solutions are two important issues when developing more economical lightweight sandwich structures, which fully compete with conventional construction techniques. A lot of research has been made to investigate inserts and to find better load introduction solutions in sandwich structures. Both analytical and experimental studies have previously been performed by Söderlund [1], Shipsha A. Söderlund J. Zenkert D [2], Sandström [3], Mortensen [4], Erichsen [5], Bozhevolnaya [6]. Considering the amount of load introductions in structures today, there are much to gain by increasing the performance and lowering the weight of the inserts. By increasing the strength of fasteners the amount of load introductions can be reduced and thereby severe manufacturing costs can be saved.

2. BACKGROUND

When applying high local loads through a fastening in a sandwich structure the loads have to be spread over a large surface, because of the thin face sheets and weak core of the sandwich. Such a fastening should preferably have a decreasing rigidity in order to avoid stress concentrations. Local stress concentrations in bi-material edges often initiate failures. Well-designed optimised lightweight sandwich structures are often penalised with added extra weight when the load introductions require higher density core/thicker face sheets or larger inserts.

Shipsha, Söderlund and Zenkert presented a paper on optimised internal metal doubler (IMD) for load introduction in sandwich panels at the 4th International Conference on Sandwich Construction [2]. They performed Finite Element analyses and shape optimisation of a pre-fitted IMD, which resulted in an optimised insert geometry. The optimisation was performed to obtain a more even stress distribution in the core and to minimise the weight of the IMD for a transverse tension loading. The initial design of the optimisation was a standard axi-symmetric cylindrical IMD. Shipsha, Söderlund and Zenkert showed that by changing the insert geometry a more even distributed stress along the IMD surface can be obtained and by that a higher predicted failure load. Figure 1b shows a standard cylindrical IMD and Figure 1a the optimised IMD geometry with the same weight but with reduced stress concentrations.



(a) *(b)*

Figure 1: Models of sandwich panels containing IMD, Singular points are marked with circles [2]. (a) Optimised design. (b) Cylindrical design.

Shipsha, Söderlund and Zenkert performed analysis for a 60mm PVC foam (Divinycell H100) sandwich panel with 4 mm thick glass fibre reinforced face sheets. The initial and optimised design was also experimentally tested in transverse tension to obtain the fracture loads. The results are summarised in Figure 2.

	Predicted failure load [kN]	*Experimental failure load (average) [kN]*
Cylindrical design	*7.1*	*10.0*
Optimised design	*20.0*	*20.6*

Figure 2: Critical loads from predictions and experiments [2].

The predicted failure load for the optimised IMD was three times higher than for the cylindrically shaped IMD and the experimental failure load was two times higher. The failure initiated at the predicted singular point 3 for the cylindrical IMD (Figure 1b) and at the singular point 2 for the optimised IMD (Figure 1a).

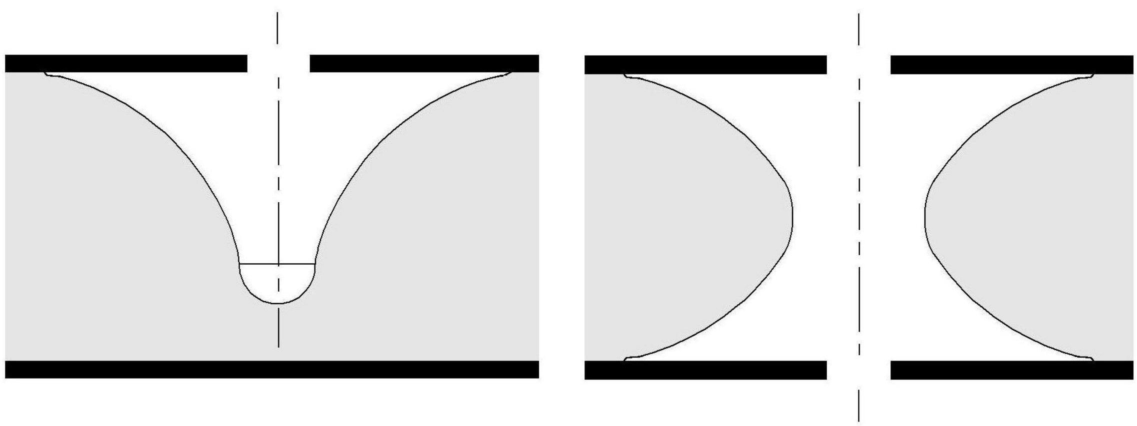
3. DEVELOPMENT

Load introductions shaped like Shipsha, Söderlund and Zenkert´s IMD, normally have to be pre-fitted, i.e. mounted before the face sheet is applied. A disadvantage of pre-fitted load introductions is that it makes it necessary to predetermine the locations of all fastenings before the sandwich panel is assembled, which is very time-consuming during design and manufacturing, nor are the intended locations of fastenings always known before the sandwich structures are used.

A post-fitted insert is implemented in the core after assembling of a sandwich. The core cavity is normally made with an ordinary milling tool. However, such a milling tool cannot create an optimised load-carrying shaped cavity in a sandwich structure with an entry hole in the face sheet, which is smaller than the cavity. A normal milling tool therefore needs to be used before the sandwich structure is assembled. Using such a tool on an assembled sandwich panel requires replacing or repairing of the face sheet. This may result in a weaker sandwich structure and an uneven surface.

In order to simplify manufacturing and making a post-fitted fastener stronger, a development project was started. The objective of the project was to develop an economical non-destructive system to post fit a fastener with an optimised geometry.

Shipsha, Söderlund and Zenkert´s optimised geometry was the starting point for this development of a system for optimised post-fitted inserts. According to Shipsha, Söderlund and Zenkert´s experimental testing of the optimised IMD the failure initiated at point 2 (Figure 1a). This indicates that if the singular point can be eliminated by a smother transition to singular point 1, the failure load will be increased further. This modification can be done with a small weight increase. Figure 3 shows the resulting geometry based on Shipsha, Söderlund and Zenkert´s result with an additional smother transition to point 1.



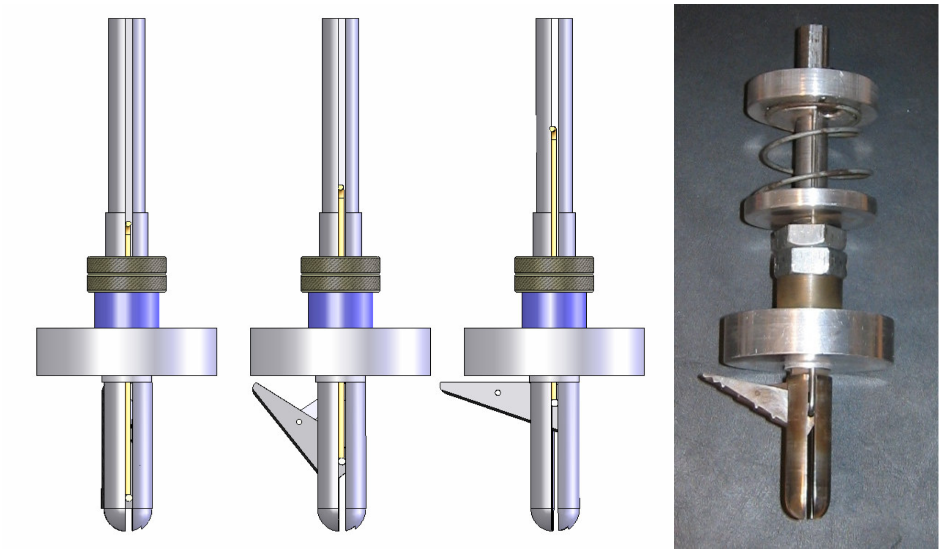
(a) *(b)*

Figure 3: Optimised cavity created by the milling tool. (a) Optimised geometry. (b) Optimised through the sandwich geometry.

Experimental testing of the final geometry is scheduled. This kind of fastening is normally made pre-fitted. This paper presents a system with a newly developed milling tool that creates a cavity with this specific geometry for post-fitted inserts without removing the face sheet. The geometry is also well suited for through the sandwich inserts. This shape of insert can also be assumed to increase fatigue performance.

4. THE MILLING TOOL

This patented [SWE pat & int. pat. pending] milling tool creates an optimised cavity in a foam core sandwich structure used for post-fitted inserts. The milling tool is shown in Figure 4. The resulting cavity is shown in Figure 3.



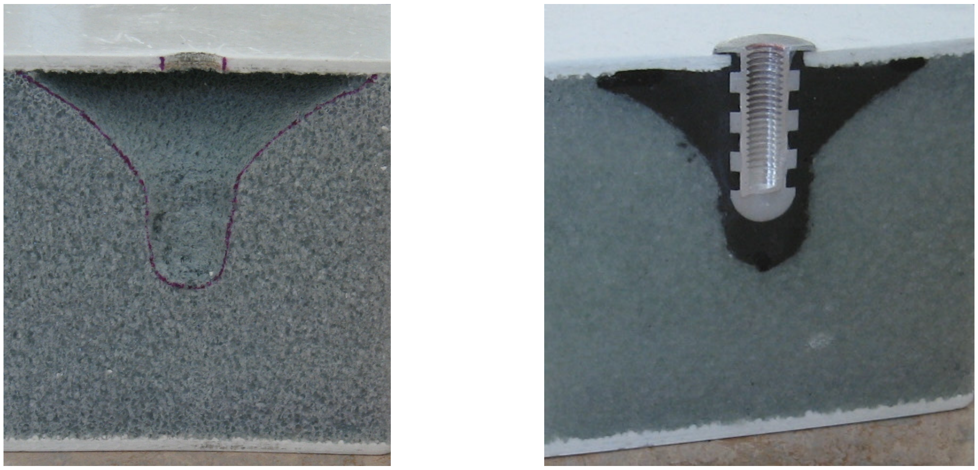
(a) *(b)* *(c)* *(d)*

Figure 4: The patented milling tool. (a) CAD model with closed up cutting sheath. (b) CAD model with partially expanded cutting sheath. (c) CAD model with fully expanded cutting sheath. (d) Photo of a prototype.

The rotating milling tool expands during rotation powered by the centrifugal force and a complementary spring. This spring apply force to the cutting sheet. After a small movement of the sheath, the centrifugal force will help the spring move the sheath. A normal power driller ensures the necessary force, which makes it easy useable. The cutting sheath moves along the face sheet during rotation and simultaneously cuts out the optimised shaped cavity in the core. This is in the end the contour of the fastener. In order to guarantee sufficient adhesion to the face sheet it is of great importance to remove all core material. The fact that the cutting sheath moves tight and parallel to the face sheet ensures that all core material in contact with the face sheet is removed. If the tool was not perfectly adjusted to the laminate thickness prior to milling, it is also possible to pull the milling tool gently outwards during rotation in order to mill the inside of the face sheet after ordinary milling. Before removal from the sandwich the milling tool is reassembled by operating a rod. Figure 5 (a) shows a photo of the cavity created by the milling tool in a cross linked PVC core with a density of 45 kg/m^3 and Figure 5 (b) shows a completed threaded insert. A supporting bearing plate against the face sheet gives support during handling of the tool, which minimise the risk of skew milling. The supporting bearing plate fixates the tool during use in axial and radial direction at an adjustable depth. The milling tool will thereby be usable for different face sheet thickness. It is also possible to use different types of cutting sheaths and springs for different core materials and densities.

The foam decreases in volume when machined due to densification, which makes it unnecessary to remove the cuttings during operation.

This tool makes it possible to mill an optimised cavity in an assembled sandwich structure. The tool only needs an entry hole through the face sheets, which is substantially smaller than the cavity.



(a) *(b)*

Figure 5: (a) Cross section of milled cavity. (b) Cross section of completed insert.

5. THE SYSTEM

The optimised post-fitted insert system consists of the milling tool, adhesive, adhesive dispenser and if needed female/male threaded insert. The adhesive dispenser with an adjustable volume dosage makes sure that the right amount of adhesive is filled in the bottom of the cavity, to ensure solid inserts without air pockets. This will also make the insert repeatable. The adhesive should have a specific viscosity, which ensures that the air flows out of the cavity at the same rate as the adhesive enters during mounting of the insert. It is important to mount the insert slowly and preferable with vibrations. This will minimise the risk of adhesive flowing out of the cavity and air entrapments. Various types of adhesives for different core and insert materials can be used with this system. It is also possible to fill the cavity through a hole in the insert with a special nozzle on the dispenser. Various types of female/male threaded insert can be use in the system i.e. different materials and geometry. For application without very high structural demands it is possible to use only the cured adhesive as an insert. The milling tool [SWE pat & int. pat. pending] creates an optimised insert geometry in an assembled sandwich without damaging the face sheet, utilising an ordinary power driller. The milling tool is adjustable for variable laminate thickness.

This system for mounting an optimised non-destructive post-fitted fastener is very flexible and less labour intense than optimised post-fitted systems used today. The fact that an optimised fastener can be mounted without demounting and reassembling the face sheets with a risk of decreased structural performance as a result makes this system beneficial. The adhesive dispenser with adjustable volume dosage for each insert size makes the mounting repeatable, which guarantee the quality of the assembled inserts.

Figure 6 shows the work description of the system. (1) The system can be used in all foam core sandwich structures. No preparation is needed and the system is applicable on an assembled sandwich structure in use, i.e. post-fitted. No needs for pre manufacturing preparation. (2) The mounting of the insert starts by drilling a normal hole in the sandwich structure with the specific dimension of the insert wanted, through both face sheet and core. (3) The milling tool is adapted to a normal hand holed power driller and the tool is easy adjusted for the specific face sheet thickness. The milling tool is placed in the pre drilled hole. (4) While running the power driller the cutting sheath mills the core and an optimised shaped cavity is created. The cutting sheath moves parallel to the face sheet and the reassembling rod indicates to a scale when the cutting sheath is fully expanded. By gently pulling the tool against the face sheet you ensure that all core material is removed from the face sheet. In order to remove the tool from the sandwich the tool is reassemble by operating the rod. (5) When the optimised shaped cavity is created it should be cleaned from cuttings. This is easy made with pressurised air or a vacuum cleaner. (6) The adhesive dispenser is adjusted for that insert size and the cavity can be filled with the right amount of adhesive. For vertical mounting a special insert with an adhesive injecting hole can be used. (7) The female/male threaded insert can now be placed in the cavity. (8) Time for curing. The insert is ready for use.

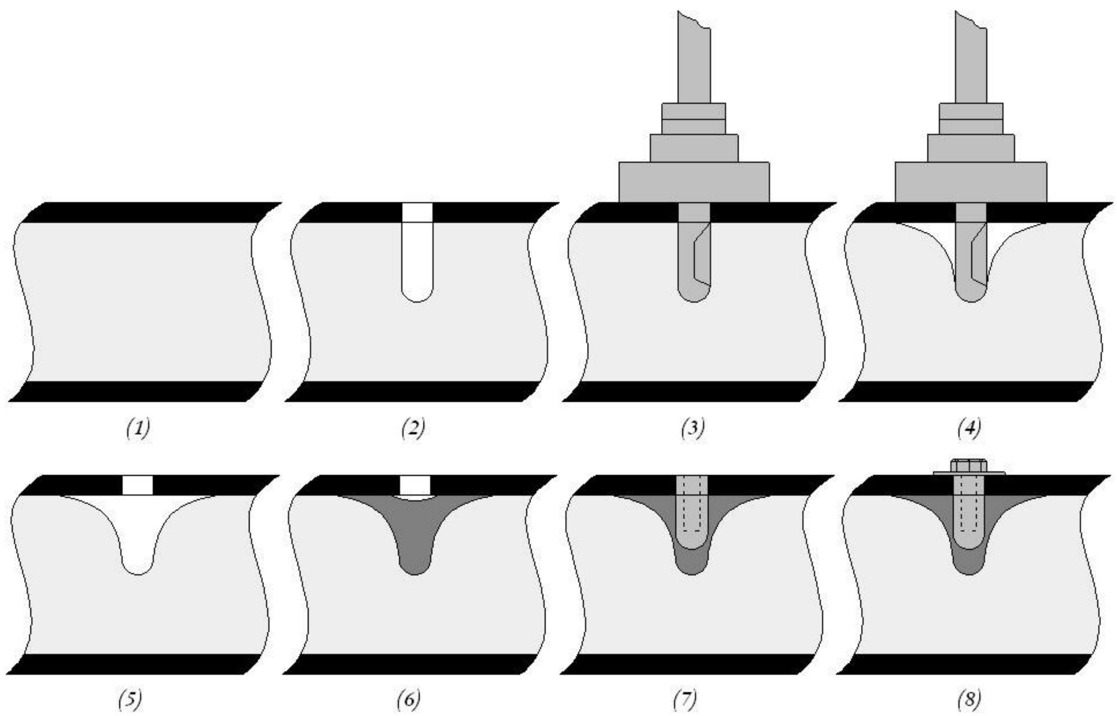


Figure 6: Schematic of the system: (1) Foam core sandwich structure, (2) Drill a hole through the face sheets with the same diameter as the milling tool, (3) Adjust the milling tool for the specific face sheet thickness. Place the milling tool in the drilled hole and attach it to a power driller, (4) Mill the cavity, (5) Clean the cavity with a vacuum cleaner, (6) Use the specific adhesive dispenser to fill the cavity with adhesive, (7) Place the insert in the cavity, (8) Time for curing.

6. CONCLUSION

With this new insert system it is possible to post-fit an optimised fastener without damaging the face sheets. By using this non-destructive post-fitted insert system with an optimised geometry for load introductions in sandwich structures you are able to cut manufacturing costs, minimise weight and increase the freedom of design. The failure load can be increased by a factor 2-3 for a transverse loading by using this optimised fastener instead of cylindrically shaped ones [2].

7. FUTURE WORK

The mechanical behaviour of adhesives with different hardness/strength shall be investigated in terms of: Pull-out strength (out of plane and laterally), Shear strength, Compressive strength and Fatigue. Those tests shall be performed with different core densities and laminate lay-ups. A weight/strength comparison with “normal” cylindrical insert shall be performed.

To be able to work further with this project, there is a need for a partner.

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