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Sandwich joints with a gap in the core – A systematic examination of the stress distribution

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ABSTRACT

This paper discusses the applicability of the Finite Element Method (FEM) in conjunction with statistical methods in order to examine local effects in the core of sandwich elements. The sandwich elements under consideration are characterized by a gap in the core which induces high local strains in the core. The load case is 3-point bending. The combination of FEM and the Morris method shall serve the purpose of identifying important factors for the design of a joining technology for sandwich elements at an early stage of the development.

1. Introduction

Sandwich structures have gained importance in some areas of mechanical engineering such as naval or aerospace applications. In other areas however, they are far from being widely used for structural applications. In [1] different reasons for this matter of fact are identified. Amongst others, joining issues and a lack of experience among engineers are identified. These two aspects shall be addressed in this work.

Commercial (i.e. widespread, high-volume) use of sandwich materials is still inhibited by the lack of a consistent joining technology, one which is easy to work with, quantifiable and not dependent on special knowledge about manufacturing processes. In the works of [2–4] a variety of principle solutions for mechanically connecting sandwich materials have been developed and discussed. The focus lies on techniques that require neither adhesives nor inserts and hence facilitate fast joining and repairing of sandwich materials. However, inherent to this concept is the disadvantage of a gap in the core. This in turn leads to local effects in the sandwich due to a disturbed force transmission see Fig. 1. These effects have not yet been investigated entirely in the past. In [5] there is a quite short qualitative discussion concerning this topic. Namely that a non-existent force transmission between two core halves does not necessarily lead to a sandwich failure. However according to the rules of mechanic the value of the lateral force at the free end of the core must decrease to zero. As a result the facings carry the lateral forces in addition to the normal forces which can lead to a severe local bending of the facings (see Fig. 2).

Furthermore Krishnamoorthy discusses this topic in [6]. In this work the shear strain ε_{xy} in the middle of the core of an intact sandwich, a sandwich with a 1 mm gap and a 10 mm gap in the core are compared. The intact sandwich shows an even and continuous distribution between the point of load application and the right support. On the opposite, a gap in the core leads to two peaks on either side of it. It is observed that the wider the gap the more distinct the peaks. Krishnamoorthy therefore advises the use of components that transmit lateral forces similar to small flat springs [6].

A research group around Thomsen examined local effects across core junctions extensively, which is a quite similar problem to that of local effects caused by a gap in the core [7–14]. They found significant stress concentrations in the vicinity of the core junction, which were mostly dependent on the thickness of the facings and the core, the Young's modulus of the facings, the shear modulus of the cores and the Poisson ratio of the weakest core. The intensity of the local effects can be characterized by the maximum face stresses. This is to be found at the face–core-interface close to the junction. The maximum principal core stresses on the other hand help to access the stress state in the adjoined cores. To reduce the stress concentration factor the authors suggest local reinforcement of the facings or structural grading of sandwich substructures.

Summing up it is known that local effects as a result of a gap in the core appear and that they are the more extensive the wider the gap. These stress concentrations are due to shear force transmission by the faces instead of the core. But still a qualitative analysis of the local effects is missing.

This work therefore follows the aim to systematically analyze the stress distribution in a sandwich with a metal face and a gapped foam core. Different factors, their influence and their

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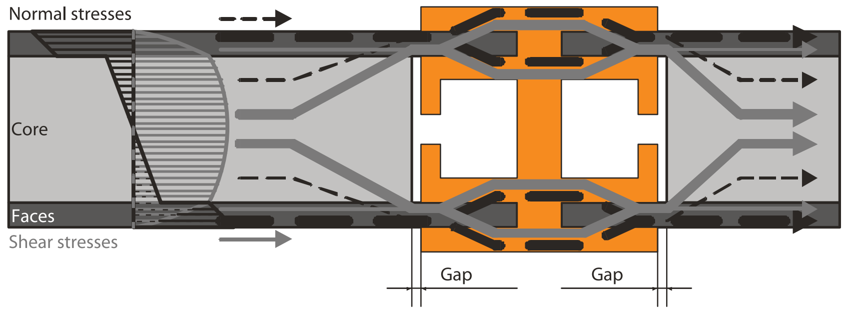

Fig. 1. Disturbed force transmission due to a gap in the sandwich core.

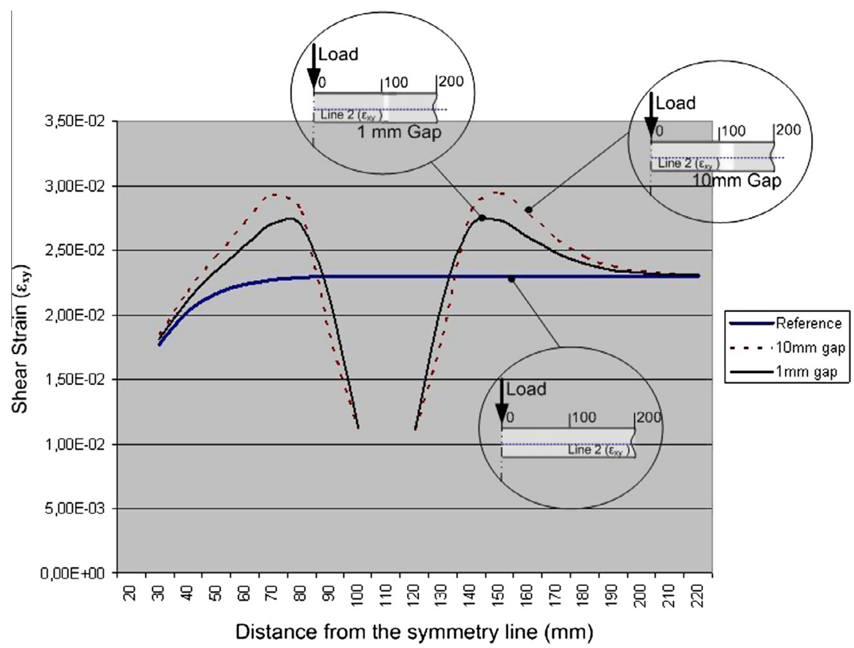

Fig. 2. Influence of an air gap [6].

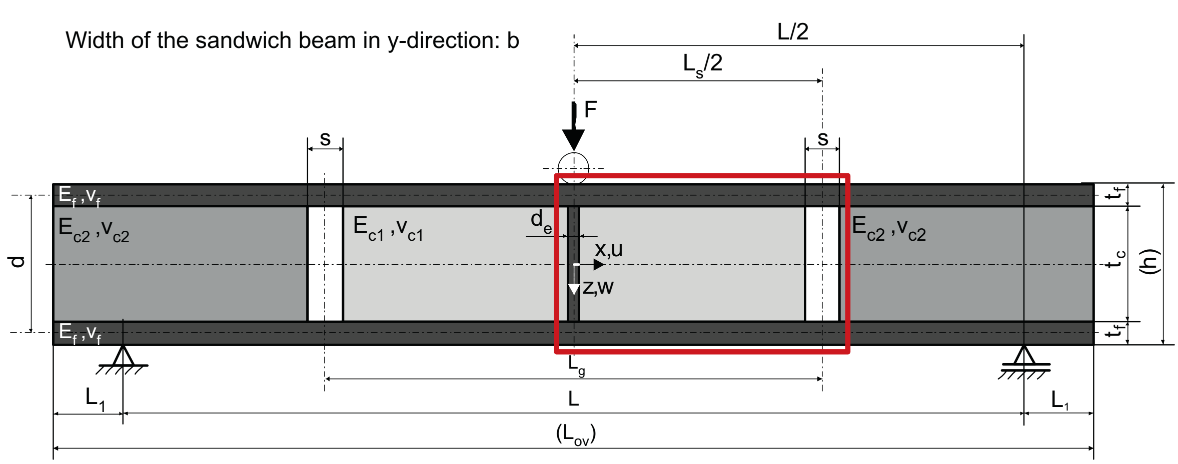

Fig. 3. Examination setup.

interdependencies are considered at different locations in core and face. This is done by using Finite Element Analysis (FEA) in combination with a statistical method for computer experiments. The advantage of the FEA over experiments is the possibility to examine a large number of different sandwich configurations with less time and lower costs than experiments with real specimens. This is especially important for sandwich materials hence there is a nearly infinite number of material and geometrical combinations. Furthermore with statistical means it is possible to examine a great number of influence factors with a manageable number of tests.