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Influence of weld stiffness on buckling strength of laser-welded web-core sandwich plates

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ABSTRACT

This paper investigates the influence of weld rotation stiffness on the global bifurcation buckling strength of laser-welded web-core sandwich plates. The study is carried out using two methods, the first is the equivalent single-layer theory approach solved analytically for simply supported plates and numerically for clamped plates. First-order shear deformation theory is used. The second method is the three-dimensional model of a sandwich plate solved with finite element method. Both approaches consider the weld through its rotation stiffness. The weld rotation stiffness affects the transverse shear stiffness. Plates are loaded in the web plate direction. Four different cross-sections are considered. Weld stiffness is taken from experimental results presented in the literature. The results show a maximum of 24% decrease in buckling strength. The strength was affected more in plates with high reduction of transverse shear stiffness and high bending stiffness. Furthermore, clamped plates were influenced more than simply supported. The intersection between buckling modes shifted towards higher aspect ratios, in the maximum case by 24%. The results show the importance of considering the deforming weld in buckling analysis.

1. Introduction

Steel sandwich plates are light-weight structures which can save space and improve safety (see Okazaki et al. [1]). They possess a high stiffness-to-weight and strength-to-weight ratio compared to conventional structures. This study concentrates on sandwich plates which consist of two face plates separated by web plates (see Fig. 1(a)). The connection between the web plates and face plates is achieved by laser stake welding which forms the T-joint. The thickness of the laser weld is typically less than that of the face plates and web plates (see Roland and Reinert [2]). This allows the ideally right angle of the T-joint to change when the sandwich plate is deformed transverse to the web plate direction. Therefore, the connection is not perfectly rigid, which results in the sandwich plate having a lower transverse shear stiffness. This has been found to have a high impact on the bending response, as presented in Romanoff et al. [3] for beams and Romanoff and Varsta [4] for plates.

The bending of a ship hull girder or bridge girder causes compression of its flanges (see Fig. 1(b)). Buckling strength of the sandwich plate used at that location must be known due to in-plane loading. The laser-welded web-core sandwich plate may buckle in a local, global, or combined fashion. Up to now, the local buckling of the face plates has only been studied in a few studies (see Kolsters and Zenkert [5], Kolsters and Zenkert [6], and Kolsters [7]). Global buckling may become important for a slender sandwich plate (see Kozak [8]). However, none of these studies considered the actual laser weld rotation stiffness and its statistical variation. Haj-Ali et al. [9] and Rahman and Abubakr [10] showed for corrugated core plates that the connection between the face and the core has significant influence on buckling strength. Their investigation was based on three-dimensional (3-D) finite element method (FEM). In their work, they did not relate the resulting buckling strength to the transverse shear stiffness, even though Nordstrand [11] has shown that the buckling strength depends on the transverse shear stiffness of the corrugated plate.

The aim of this study is to investigate the influence of weld rotation stiffness on global buckling strength of web-core sandwich plates. Global buckling is in focus since it is dominant for a slender plate, for example when used in a ship or a bridge deck. Bifurcation buckling is studied since it fundamentally describes the buckling phenomenon and is part of structural design rules, e.g. DNV rules for ship classification [12]. Plate global buckling experiments that would validate the findings do not exist and thus the investigation is carried out with two theoretical methods that have different kinematical assumptions. The first is the equivalent single-layer (ESL) theory approach solved analytically for simply supported plates and numerically for clamped plates. First-order shear deformation theory is used. The second method is a 3-D FEM with shell elements for plates and spring elements for welds. Plates are loaded in their main load-carrying direction, i.e. parallel to the web plates. Four cross-sections of different properties are considered.

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