

EFFECT OF GEOMETRICAL SIZE AND  
NUMBER OF CORE ON BENDING  
BEHAVIOUR OF WEB-CORE SANDWICH  
STRUCTURE

NUR KHALEEDA BINTI ROMLI

DOCTOR OF PHILOSOPHY

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AL-SULTAN ABDULLAH



اوتنورسيتي مليسيا فهغ السلطان عبد الله  
UNIVERSITI MALAYSIA PAHANG  
AL-SULTAN ABDULLAH

## SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Doctor of Philosophy.

A handwritten signature in black ink, appearing to read 'Ruzaimi', is written over a horizontal line.

(Supervisor's Signature)

Full Name : Associate Professor Ts Dr Mohd Ruzaimi bin Mat Rejab

Position : Associate Professor

Date :

A handwritten signature in black ink, appearing to read 'Mahadzir', is written over a horizontal line.

(Co-supervisor's Signature)

Full Name : Professor Dr Mahadzir bin Ishak @ Mohamed

Position : Professor

Date :



## STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang Al-Sultan Abdullah or any other institutions.

---

(Student's Signature)

Full Name : NUR KHALEEDA BINTI ROMLI

ID Number : PMD 18001

Date :

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NUR KHALEEDA BINTI ROMLI

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## ABSTRAK

Struktur terapit berkimpalan laser mempunyai ciri nisbah kekakuan terhadap berat yang begitu tinggi, di mana secara tipikal diaplikasikan di dalam pembuatan struktur kapal. Masalah lenturan pada struktur terapit semakin meningkat yang disebabkan oleh beban yang berat dan sering dibangkitkan dalam industri kapal. Walau bagaimanapun, daripada perkembangan kajian terhadap struktur terapit dengan perbezaan geometri dan bilangan teras, ia masih belum jelas dan secara menyeluruh. Oleh itu, kajian yang terperinci mengenai struktur terapit bersama teknologi kimpalan, bahan struktur yang ringan dan kuat amat diperlukan. Tujuan utama kajian ini adalah untuk mengkaji kesan saiz geometri dan bilangan teras ke atas beban tiga titik pada struktur terapit teras web berkimpalan laser. Struktur terapit teras web berkimpalan laser telah diperbuat dari kepingan keluli bergalvani dan disambungkan dengan menggunakan mesin kimpal fiber. Tambahan pula, struktur terapit tersebut telah dibina dengan perbezaan dari segi ketebalan kepingan teras, jarak antara dua kepingan teras dan bilangan teras. Selain itu, terdapat dua jenis struktur terapit yang telah dibina, antaranya adalah dengan sokongan busa dan tanpa sokongan busa. busa *polyvinyl chloride* (PVC) telah dipilih untuk digunakan pada struktur terapit. Di samping itu, analisa unsur terhingga dimodelkan dengan berdasarkan kemuluran yang berasaskan terikan untuk meramal kelakuan lenturan ke atas struktur terapit dengan perbezaan geometri dan bilangan teras. Namun begitu, oleh kerana data eksperimen yang terhad, data dari tinjauan literatur telah diambil dan digunakan sebagai input bahan konstitutif pada model di dalam Abaqus/Standard. Ujian tegangan telah dijalankan ke atas sampel tegangan keluli bergalvani dan menghasilkan keputusan tegangan alah bersamaan 324.522 MPa. Berdasarkan pemerhatian, kegagalan pada dua jenis struktur terapit adalah sama, di mana terdapat lenturan pada kedua-dua jenis struktur tersebut. Walaupun, lenturan telah berlaku pada kedua-dua jenis struktur terapit, penjelasan mengenai kelakuan lenturan telah diterangkan pada sudut yang berbeza. Kegagalan struktur terapit teras web tanpa busa berkimpalan laser telah berlaku disebabkan oleh tiada kekangan pada kedua-dua belah hujung struktur untuk sokongan ketika beban tiga titik dijalankan ke atas struktur. Tambahan pula, busa PVC telah digunakan untuk meningkatkan ketegaran and kekuatan lenturan. Penggunaan busa PVC pada struktur terapit berkimpalan laser telah meningkat sebanyak 90% pada kekuatan struktur. Keputusan analisis unsur terhingga-ke taksempurnaan telah disahkan dengan keputusan eksperimen, di mana persetujuan telah dicapai dengan ralat peratusan dalam 5.834%. Berdasarkan perbandingan prestasi lenturan melalui ujian beban tiga titik, kesan saiz geometri dan bilangan teras ke atas struktur terapit teras web berkimpalan laser sangat bermanfaat untuk meningkatkan kekuatan lenturan, dan menyebabkan daya serapan tenaga bertambah juga. Walaubagaimanapun, kekuatan struktur boleh terjejas akibat kegagalan yang biasa berlaku dalam sistem terapit seperti nyah ikatan, masalah ikatan antara dua permukaan dan juga pada sambungan kimpalan. Selain itu, kekuatan struktur terapit telah terkesan dari peningkatan bilangan teras dan menyebabkan ketegaran struktur semakin kukuh and kuat. Di samping itu, kesan jarak antara dua kepingan dan ketebalan teras telah dikaji, di mana jarak yang lebih besar dan kepingan teras yang lebih tebal akan meningkatkan kestabilan dan kekakuan pada struktur terapit tersebut.

## ABSTRACT

Laser-welded sandwich structure is a promising solution due to the high stiffness-to-weight ratio, which is typically applied in the structure of shipbuilding. According to engineering demands, bending of the sandwich structure is frequently raised in the shipbuilding industry due to heavy loads. However, structural improvement with variant geometries and number of cores have not been clearly studied. Therefore, a detailed study of the sandwich structure with the technology of joining, strong and lightweight material is required. The primary aim of this research study is to investigate the effect of geometrical size and core number on the three-point bending performance of a web-core laser-welded sandwich structure. A Web-core laser-welded sandwich structure was manufactured using galvanised steel. In addition, the sandwich structure was fabricated with different web plate thicknesses, spacing distances, and number of cores. Besides that, two types of web-core sandwich structure were fabricated; with foam and without foam. Polyvinyl chloride (PVC) foam was chosen to be installed in the web-core sandwich structure. Furthermore, a finite element analysis was modelled with strain-based ductility to predict the bending behaviour of the web-core sandwich structure by different spacing distances and core numbers. Nevertheless, data from the literature review was extracted due to limited experimental data and applied to formulate the constitutive material in the Abaqus/Standard model. A tensile test was conducted on galvanised steel specimen and found that yield stress was initiated at 324.522 MPa. Based on the observation, failure of the two types of sandwich structures were found to be similar, where bending was initiated due to the bending of the sandwich structure. Although bending was established in both types of sandwich structure, the discussion was stated in different ways. The failure of the web-core laser-welded sandwich structure without foam was due to no constraint acted at the end-sides to support the structure during the three-point bending loading. Moreover, PVC foam was substituted to increase rigidity and bending strength of the web-core laser-welded sandwich structure. The substitution of the PVC foam was increased up to 90% on the structural strength. The FEA-Imperfection result was validated in the experimental result, where good agreement was achieved, in which the percentage error of the comparison was about 5.834%. Owing to the comparison of bending performances in the three-point bending load, the effect of geometrical size and number of cores on the web-core laser welded sandwich structure was beneficial to increase bending strength, where energy absorption would also be higher. However, the strength of bending would reduce because of the common failures in the sandwich structure system, such as debonding due to interface bonding and welding joint problems. Besides that, the strength of the sandwich structure was affected by an increasing number of cores, where rigidity of the sandwich structure was increased and stronger. In addition, the effect of variant spacing distances was also studied, and it was found that the larger space distance and thicker web plate thickness would increase the stability and stiffness of the sandwich structure, respectively.

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