OPTIMISATION OF CAR CRASH BOX FINITE ELEMENT MODEL FOR CRASHWORTHINESS ANALYSIS USING MODEL UPDATING AND FACTORIAL DESIGN METHOD

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

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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 or any other institutions.

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ABSTRAK

Pemodelan elemen terhingga dan analisis adalah kaedah yang banyak digunakan untuk mensimulasi perilaku struktur sistem untuk memberikan maklumat tentang struktur di bawah pelbagai keadaan pemuatan. Walau bagaimanapun, model yang dibina tidak selalu tepat disebabkan oleh beberapa faktor seperti penyederhanaan dalam pemodelan, sifat bahan, atau ketidakpastian dalam keadaan sempadan. Kaedah penyemakan model merupakan teknik optimisasi yang bertujuan untuk meningkatkan ketepatan model elemen terhingga dengan menggabungkan data tindak balas dinamik yang diperoleh daripada ujian eksperimental. Dalam bidang keselamatan benturan, kompleksiti pemodelan boleh menyebabkan ketidak tepatan, terutamanya apabila menggabungkan penambahbaikan struktur. Kajian ini menyiasat kebolehpercayaan kaedah penyemakan model dalam mengurangkan ketidak tepatan dalam model elemen terhingga yang digunakan untuk analisis keselamatan benturan. Objektif utama projek penyelidikan ini adalah untuk menilai prestasi model elemen terhingga yang dikemas kini dalam memberikan data benturan yang tepat untuk struktur kotak benturan kenderaan. Model yang dikemaskini dinilai untuk analisis benturan, dan ketepatannya dibandingkan dengan data ujian benturan eksperimental. Sebagai perbandingan, optimasi respons menggunakan rekabentuk faktorial juga dijalankan untuk mendapatkan model yang dioptimumkan dengan kesilapan minimum dalam analisis keselamatan benturan. Keputusan kajian ini menunjukkan bahawa korelasi awal terbaik dengan struktur kotak benturan berpateri dicapai menggunakan elemen bar satu dimensi (CBAR) dengan kesilapan purata 5.3%. Untuk kotak benturan berpalit, korelasi terbaik dicapai menggunakan model bersama yang menggabungkan penggunaan CBAR dan elemen tegar (RBE), dilabel sebagai BOLTED2, dengan kesilapan purata 4.9%. Selepas menjalankan penyemakan model, model SOLID menunjukkan korelasi terbaik untuk spesimen berpateri dengan kesilapan purata 4.5%, manakala model BOLTED2 kekal menjadi yang terbaik untuk spesimen berpalit dengan kesilapan purata yang dikurangkan sebanyak 4.7%. Walau bagaimanapun, kajian prestasi model yang dikemaskini tidak menunjukkan peningkatan yang signifikan untuk analisis keselamatan benturan. Kajian optimasi menghasilkan keputusan yang memuaskan, dengan parameter keluaran benturan yang menunjukkan nilai yang lebih hampir dengan data yang diperoleh secara eksperimental. Hasil projek ini akan menyumbang kepada bidang kejuruteraan automotif dan, khususnya, usaha pengeluar kenderaan untuk menghasilkan kenderaan yang lebih selamat yang memenuhi tuntutan pengguna. Kajian ini menekankan keperluan untuk meningkatkan simulasi komputasi dan kaedah analisis untuk menghasilkan ramalan yang lebih tepat dan mengurangkan masalah ketidakserupaan model yang timbul semasa analisis komputasi. Selain itu, kajian mengenai kaedah penyemakan model untuk analisis keselamatan benturan struktur kotak benturan kenderaan mempunyai beberapa aplikasi yang berpotensi dalam bidang kejuruteraan automotif dan keselamatan.

ABSTRACT

Finite element modeling and analysis are widely used method for simulating the structural behaviour of a system in order to provide information of the structure under various loading conditions. However, the constructed model not always accurate due to several factors such as simplifications in modeling, material properties, or uncertainties in boundary conditions. The model updating method is an optimisation technique that aims to improve the accuracy of finite element models by incorporating dynamic response data obtained from experimental testing. In the field of crashworthiness, the complexity of modelling can lead to inaccuracies, particularly when incorporating structural enhancements. This study investigates the reliability of model updating methods in reducing inaccuracies in finite element models used for crashworthiness analysis. The primary objective of this research project is to assess the performance of updated finite element models in providing accurate crash data for a car crash box structure. The updated model was evaluated for crash analysis, and its accuracy was compared with experimental crash test data. For comparison, response optimisation using factorial design was also conducted to obtain an optimised model with minimal error in crashworthiness analysis. The results of this study show that the best initial correlation with the welded crash box structure was achieved using a one-dimensional bar element (CBAR) with an average error of 5.3%. For the bolted crash box, the best correlation was achieved using a joint model that combined the usage of CBAR and a rigid element (RBE), labeled as BOLTED2, with an average error of 4.9%. After applying model updating, the SOLID model showed the best correlation for the welded specimen with an average error of 4.5%, while the BOLTED2 model remained the best for bolted specimens with a reduced average error of 4.7%. However, the investigation of the updated model's performance did not show a significant improvement for crashworthiness analysis. The optimisation study yielded satisfactory results, with the crash output parameters showing closer values to the experimentally obtained data. The outcomes of this project will contribute to the field of automotive engineering and, in particular, to vehicle manufacturers' efforts to produce safer vehicles that meet consumers' demands. This study emphasizes the need to improve computational simulation and analysis methods to generate more accurate predictions and minimise the problem of model discrepancies that arise during computational analysis. In addition, the study on model updating methods for crashworthiness analysis of car crash box structures has several potential applications in the field of automotive engineering and safety.

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