DEVELOPMENT OF MALAYSIAN-SIZE HYBRID III ANTHROPOMORPHIC TEST DEVICE'S MODEL FOR FRONTAL IMPACT SAFETY ASSESSMENT

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ABSTRACT

Anthropomorphic test devices (ATDs) are used to assess vehicle occupant injuries during a crash event. In general, the Hybrid III 50th percentile (H350) is used to optimise vehicle restraint systems. However, the H350 is developed based on the United States population's anthropometric sizes. Thus, it can be hypothesised that the vehicle restraint systems are not optimised for the Malaysian population. The hypothesis is supported by studies on the Chinese-size ATD. To explore this issue, it is necessary to develop a Hybrid III 50th percentile Malaysian-size (H350M) ATD. First, a donor H350 finite element was validated against standard biofidelity response corridors. Then, it was scaled using the global scale factor of 0.9437 to meet the 50th percentile Malaysian anthropometric sizes. Validations of the H350M were performed by using a new set of biofidelity response corridors. After the validation process, the H350 and H350M were integrated into a validated vehicle model and restraint systems. Simulations of Full-Width Rigid Barrier at 56 km/h (FRB 56 km/h) and Offset Deformable Barrier at 64 km/h (ODB 64 km/h) were performed to compare the injuries of the H350 and H350M. A total of 12 simulations of frontal crash load cases were conducted at various impact speeds from 30 km/h to 64 km/h. Paired *t*-test indicated that H350M 3ms chest acceleration and chest displacement were higher than those of the H350 for almost every frontal load case with *p*-values less than 0.05. This research also showed that H350M head acceleration and chest displacement can be reduced by 5.3g and 1.6 mm, respectively, with the introduction of a new set of restraint system parameters. Lastly, a Vehicle Pulse Index with new parameters was proposed. It can predict the H350M occupant's peak chest acceleration by using the vehicle acceleration profile as an input, with a root mean square error of 2.86 g. The model will help vehicle manufacturers predict occupant responses at the early stage of vehicle development.

ABSTRAK

Peranti Ujian Antropomorfik (ATD) digunakan untuk menilai kecederaan penumpang semasa kemalangan. Secara umumnya, *Hybrid III 50th percentile* (H350) ATD digunakan untuk mengoptimumkan sistem kekangan kenderaan. Bagaimanapun, H350 dibangunkan berdasarkan saiz antropometrik rakyat Amerika Syarikat. Oleh itu, boleh dihipotesiskan bahawa sistem kekangan kenderaan itu tidak optimum untuk penduduk Malaysia. Hipotesis ini disokong oleh kajian terdahulu yang dilakukan pada ATD bersaiz rakyat China. Untuk meneroka isu ini, model *Hybrid III 50th percentile Malaysian size* (H350M) perlu dibangunkan. Pertama, model elemen terhingga H350 perlu memenuhi piawaian koridor tindak balas *biofidelity*. Kemudian, ia diskalakan menggunakan faktor skala global 0.9437 untuk memenuhi saiz 50-persentil rakyat Malaysia. Pengesahan pada H350M dilakukan dengan menggunakan koridor tindak balas *biofidelity* yang baharu. Kedua-dua H350 dan H350M dimasukkan ke dalam model kenderaan dengan sistem kekangan yang telah disahkan. Simulasi *Full-Width Rigid Barrier* 56 km/j (FRB 56 km/j) dan *Offset Deformable Barrier* 64km/j (ODB 64 km/j) dilakukan untuk membandingkan kecederaan antara H350 dan H350M. Dua belas kes hentaman hadapan telah disimulasikan pada pelbagai kelajuan dari 30 km/j hingga 64 km/j. *Paired t-test* menunjukkan bahawa pecutan dada 3ms, anjakan dada H350M adalah lebih tinggi daripada H350 untuk hampir setiap kes dengan *p* bernilai kurang daripada 0.05. Kajian ini juga membuktikan bahawa pecutan kepala dan anjakan dada H350M boleh dikurangkan masing-masing sebanyak 5.3 g dan 1.6 mm dengan pengenalan sistem kekangan yang baharu. Akhir sekali, *Vehicle Pulse Index* dengan parameter baharu telah dicadangkan. Ianya boleh meramalkan puncak pecutan dada penumpang H350M dengan menggunakan profil pecutan kenderaan sebagai input, dengan ralat purata kuasa dua punca sebanyak 2.86 g. Model berangka ini akan membantu pengeluar kenderaan tempatan untuk meramalkan tindak balas penumpang pada peringkat awal pembangunan kenderaan.

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LIST OF SYMBOLS AND ABBREVIATIONS

a_H	-	peak head acceleration of H350
a_s	-	peak head acceleration of scaled model
C	-	head circumference
D_H	-	chest displacement of H350 dummy
D_s	-	chest displacement of scaled dummy
F_H	-	reaction force of H350 dummy
F_s	-	reaction force of scaled dummy
L	-	head length
M_H	-	neck moment of H350 dummy
m_P	-	mass of pendulum
M_s	-	neck moment of scaled dummy
m_t	-	mass of thorax assembly
R_a	-	ratio between peak head accelerations of scaled dummy and H350 dummy
R_D	-	ratio between chest displacements of scaled dummy and H350 dummy
R_F	-	ratio between reaction forces of scaled dummy and H350 dummy
R_K	-	ratio between thorax stiffness of scaled dummy and H350 dummy
R_M	-	ratio between neck moments of scaled dummy and H350 dummy
R_P	-	ratio between pendulum masses for scaled dummy and H350 dummy
R_θ	-	ratio between rotation angles of scaled dummy and H350 dummy
W	-	head width
θ_H	-	rotational displacement of H350 dummy
θ_S	-	rotational displacement of scaled dummy
λ	-	ratio of size between scaled model and H350 dummy

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PUBLICATION

There are three articles in press that resulted from this research:

a) Samad, M. S. A., Mohd Nor, M. K., Abdul Majid, M. M., & Abu Kassim, K. A. (2021). Investigation on the effect of Malaysian anthropometric size in vehicle crash safety by using finite element method. *Journal of the Society of Automotive Engineers Malaysia*, 5, 176–184.

b) Abdul Samad, M. S., Mohd Nor, M. K., Abdul Majid, M. M., & Abu Kassim, A. K. (2022). Optimization of vehicle pulse index parameters based on validated vehicle-occupant finite element model. *International Journal of Crashworthiness*, 1–7.

c) Abdul Samad, M. S., & Mohd Nor, M. K. (2022). A comparative analysis between a newly Malaysian size ATD and the current Hybrid III ATD in frontal impact. *Cogent Engineering*, 9(1), 2105558.

EXHIBITIONS

There are two exhibitions and awards as resulted from this research:

a) International Research and Innovation (RISE 2021) - Silver Medal Award

b) Malaysia Technology Expo (MTE) 2022 - Silver Medal Award

INTELLECTUAL PROPERTY

There is one intellectual property registered as resulted from this research:

a) Method to Scale a Crash-Test Dummy Finite Element Model or Human Body Finite Element Model to Anthropometrically Fit to a Populace (PI2021007183)

VITA

The author was born on January 17, 1985, in Petaling Jaya, Selangor, Malaysia. He went to Sekolah Menengah Kebangsaan Sri Serdang for his secondary school. He pursued his degree at the Universiti Putra Malaysia and graduated with a B.Eng. in Mechanical Engineering and M.Sc. in Automotive Engineering in 2008 and 2011, respectively. After graduation, he worked as a Mechanical Engineer at Sharp Electronics (M) Sdn. Bhd for about a year and a half. Later, he worked at EDAG Holdings Sdn Bhd. as Computer-Aided Engineering (CAE) engineer. In 2013, he joined PROTON Holdings and worked as CAE Senior Engineer. Later, he is promoted to CAE Lead Engineer. His expertise is in the automotive crashworthiness and occupant safety field. He also has a lot of experience in automotive steel material testing and material characterization for CAE applications. One of his contributions is the SYAZWAN ductile failure surface model, which has been implemented in the open-source explicit finite element solver, OpenRadioss as well as in the commercial solver, Radioss. Another notable contribution is the method to estimate the linear damage calculation based on the strain histories that he has developed. Currently, he has two patents under his name. To date, he has co-authored a total of eleven papers in the field of automotive crashworthiness, occupant safety, and material characterization. In 2022, he joined Western Digital as a Principal Engineer to expand his knowledge in the area of thermal-mechanical simulation.