MATHEMATICAL MODEL FOR WAVE IMPACT ON VERTICAL WALL WITH MULTIPLE BOTTOM-MOUNTED BAFFLES

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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 Master of Science

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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

Kesan hentaman gelombang air ke atas struktur dianggap penting oleh kebanyakan penyelidik lapangan yang melibatkan masalah kesan hentaman cecair terutamanya dengan keadaan gelombang sangat kuat yang muncul untuk waktu sangat singkat. Masalah hentaman cecair yang umumnya dikaitkan dengan kesan masa sangat singkat, tekanan puncak yang tinggi dan daya hentaman yang besar dapat menterbalikkan kenderaan berisi cecair apabila momen terbalik besar terhasil. Kajian ini mengkaji secara teori berkenaan hentaman cecair dalam bekas berbentuk segi empat berisi sebahagian cecair yang dihentam gelombang pada dinding menegak dengan pelbagai konfigurasi penghadang dipasang pada dasar permukaan. Kajian ini mencadangkan model matematik berkenaan dua penghadang yang dipasang pada dasar permukaan di hadapan dinding menegak yang diubahsuai bagi memperluas hasil kajian pengkaji lepas dalam mengkaji kesan satu penghadang pada dasar permukaan terhadap tekanan impuls pada dinding menegak di belakang penghadang tersebut. Kajian ini mencadangkan teori tekanan impuls (pengamiran masa bagi tekanan) diaplikasi untuk memudahkan persamaan bendalir ideal yang tidak dapat dimampat dan model matematik dua dimensi. Pengembangan fungsi eigen yang diperoleh bagi setiap kawasan segi empat tepat melalui kaedah pemisahan pemboleh ubah memenuhi syarat sempadan kecuali pada kawasan hentaman dan pada garis padanan masing-masing bagi dua kawasan cecair yang kemudiannya dikamirkan secara analitik dengan mengaplikasikan fungsi asas untuk membentuk satu sistem matriks bagi pekali yang tidak diketahui. Masalah formulasi matematik tersebut dikodkan menggunakan perisian MATLAB dan hasilnya dianalisis dengan menukar saiz kawasan hentaman, tinggi penghadang dan jarak penghadang dari dinding. Model matematik yang dicadangkan ini disahkan menggunakan model Cooker bagi mengaplikasikan idea teori tekanan impuls . Kajian ini mendapati tekanan impuls meningkat dengan pemasangan penghadang pada dasar permukaan di hadapan dinding menegak dan bersetuju dengan hasil kajian pengkaji terdahulu walaupun bercanggah dengan fungsi penghadang yang seharusnya mengurangkan hentaman gelombang pada dinding tersebut. Keputusan ini mencadangkan agar beberapa faktor dan parameter lain seperti tekanan impuls yang terperangkap dan lebihan air tersesar diambil kira.

ABSTRACT

Impacts of water wave onto structures have always been considered crucial to most researchers in fields that involve liquid impact problems especially when the wave is extremely brief and violent. Among the problems is liquid sloshing which is generally associated with an extremely brief impact with high peak pressure and large sloshing forces that may capsize any liquid-tanked vehicle when large overturning moments are generated. In this study, liquid sloshing in a partially filled rectangular container with liquid is considered and the wave impact on vertical wall with multiple bottom mounted baffles configurations is theoretically investigated. This study proposes a modified mathematical model of two bottom-mounted baffles in front of a vertical wall problem by extending the work of previous researchers in studying the single bottom-mounted baffle effect on the pressure impulse exerted onto the wall behind the baffle. Pressure impulse theory (time integral of pressure) is applied to simplify the equations of an ideal incompressible fluid notion and a two-dimensional mathematical model is proposed. Eigenfunction expansions obtained for each rectangular region via separation of variables satisfy the boundary conditions except on the impact region and at the matching line of each of the two-liquid regions which are then analytically integrated by applying basis function which creates a matrix system for the unknown coefficients. The formulated problems are coded using MATLAB software and the results are analysed by varying the size of the impact region, height of the baffles and distance of the baffles from the wall. The modified model has been first validated with Cooker's model in order to apply the idea of pressure impulse theory. This study found out that the pressure impulse is increasing with the presence of the baffles in front of a vertical wall which agreed with the theoretical work done by the previous researchers though contradicts with the function of a baffle in reducing the sloshing wave slammed onto the wall. These results suggest that more factors and parameters such as 'trapped' pressure impulse and overtopping might need to be taken into consideration.

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LIST OF SYMBOLS

Hb_1	Height of Baffle 1
Hb_2	Height of Baffle 2
t_1	Time Before the Impact
t_2	Time After the Impact
H	Height of the Wall
U_0	Speed of Impact
ρ	Water Density
μ	Fraction of Impact Zone
g	Gravity Acceleration
p_{peak}	Peak Pressure
Δt	Impact Duration
p	Pressure of the Incident Wave
P	Pressure Impulse
u_1	Wave Velocity before the Impact
u_2	Wave velocity after the Impact
u_{nb}	Normal Component of Incoming Wave Velocity

LIST OF ABBREVIATIONS

LNG	Liquefied Natural Gas
MIROS	Malaysian Institute of Road Safety Research
RANSE	Reynolds Averaged Navier Stroke Equations
SWE	Shallow Water Equations
SPH	Smoothed Particle Hydrodynamics
MAC	Marker and Cell Method
FEM	Finite Difference Method
CIP	Constraint Interpolation Profile
VOF	Volume of Fluid
CG	Center of Rotation
RAO	Response Amplitude Operators
ALE	Arbitrary Lagrangian-Eulerian
CFD	Computational Fluid Dynamic
URANS	Unsteady Averaged Navier-Stokes

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