UNIVERSITI PUTRA MALAYSIA

NUMERICAL ANALYSIS OF SHOCK WAVE PROPAGATION AND AL5083 SHEET BULGING IN EXPLOSIVE HYDRO FORMING PROCESS

SAEED JABALAMELIAN

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By

SAEED JABALAMELIAN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirement for the Degree of Master Science

January 2012

DEDICATION

To my beloved parents, that I owe them my entire life

To my supervisor Dr. Aidy Ali who taught me how to be a good researcher

To my compassionate wife, Saeedeh, that without her support I will not be able to complete this dissertation.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

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Chairman : Associate Professor Aidy Ali, PhD

Faculty : Engineering

The present work simulated the explosive forming of a torisperical dished head from the Al-5083 aluminum alloy against a male die. The simulation was used to investigate the strain distribution across the final product as well as to capture the complex nature behind this High Energy Rate Forming (HERF) technique. The study was carried out in the framework of LS-DYNA code, based on the Arbitrary Lagrangian Eulerian (ALE) Multi-Material formulation, which provided a finite element mesh that moved independently from the material flow and allowed each element to contain a mixture of two or more different materials. The underwater explosion phenomenon including the shock wave propagation and the state of detonation products was perfectly simulated using the Jones-Wilkins-Lee (JWL) and Gruneisen equations of state for explosive and water, respectively. The results were validated based on the Cole's experimental and analytical works on underwater explosion of relatively small charge, which showed the average error of 6.4%. The simulation outcomes showed that the primary shock could be modified by accelerating the specimen up to 100 m/s and reflecting back toward the water, which could lead to cavitations. The formation of the cavitations and their effects on the

deformation of the specimen were investigated numerically; same as the other aspects of the desired process. Since many of these phenomena were too difficult to be investigated experimentally, a comprehensive understanding of the Explosive Hydro Forming (EHF) process was achieved through a numerical simulation in this study.

The behavior of the specimen under explosive loading was predicted according to the Johnson-Cook (JC), Modified Zerilling-Armstrong (MZA) and Plastic-Kinematic (PK) constitutive equations, which were used to investigate the strain distribution across the final product. Moreover, three techniques were examined numerically involving increasing the ratio between the thickness and diameter of sheet plate, using the sheet holder and grooving the edge of the workpiece to reduce the wrinkling at the edge of the workpiece.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

ANALISA BERANGKA TERHADAP PENYEBARAN GELOMBANG KEJUTAN DAN PROSES BENJOLAN KEPINGAN AL5083 DALAM PROSES PEMBENTUKAN LETUPAN HIDRO

Oleh

SAEED JABALAMELIAN

Januari 2012

Pengerusi : Profesor Madya Aidy Ali, PhD

Fakulti : Kejuruteraan

Kajian ini melibatkan simulasi pembentukan menggunakan peledak ke atas penutup torisferikal yang diperbuat daripada aloi aluminium AL-5083 menggunakan acuan. Simulasi ini digunakan untuk mengkaji pengagihan tekanan produk akhir serta untuk memahami teknik Pembentukan Kadar Tenaga Tinggi (HERF) yang kompleks. Kajian ini dijalankan dengan menggunakan rangka kerja berkod LS-DYNA, berdasarkan Formulasi bahan rencam “Arbitrary Lagrangian Eulerian (ALE)” yang menyediakan asas unsur terhad yang bergerak secara bebas daripada arus bahan dan membenarkan setiap elemen untuk mempunyai campuran dua atau lebih bahan yang berlainan. Fenomena ledakan dalam air seperti pengagihan gelombang kejut dan ledakan produk telah disimulasi secara tepat menggunakan persamaan-persamaan Jones-Wilkins-Lee (JWL) dan Gruneisen, masing-masing untuk ledakan dalam air. Hasil kajian tersebut telah disahkan oleh ujikaji dan hasil analisa Cole ke atas ledakan bawah air berskala kecil yang menunjukkan ralat maksimum 6.4 %. Hasil-hasil simulasi menunjukkan gelombang kejutan pertama boleh diubahsuai dengan meningkatkan kelajuan spesimen sebanyak 100 m/s dan ditampan oleh air, di mana

peronggaan akan berlaku. Pembentukan peronggaan dan kesan-kesannya ke atas herotan spesimen dikaji secara berangka, sama seperti aspek lain untuk proses tersebut. Memandangkan banyak fenomena agak sukar untuk dikaji melalui eksperimen, satu pemahaman menyeluruh terhadap proses Pembentukan Ledakan Hidro (EHF) telah tercapai melalui simulasi berangka melalui kajian ini.

Perilaku spesimen di bawah muatan bahan ledakan telah diramalkan mengikut persamaan Johnson-Cook (JC), Zerilling-Armstrong (MZA) diubahsuai dan Plastic-Kinematic (PK), yang telah digunakan untuk mengkaji taburan terikan seluruh produk akhir. Selain itu, tiga teknik diperiksa secara berangka yang melibatkan peningkatan nisbah antara ketebalan dan diameter plat kunci, menggunakan pemegang dan alur pada hujung bahan kerja untuk mengurangkan kedutan.

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Finally, I have to express my sincere gratitude to my beloved father, Hossein Jabalamelian, who supports me with his overwhelming efforts.

I certify that a Thesis Examination Committee has met on **10 January 2012** to conduct the final examination of **Saeed Jabalamelian** on his thesis entitled **"Numerical Analysis of Shock Wave Propagation and AL5083 Sheet Bulging in Explosive Hydro Forming Process"** in accordance with the Universities and University College Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of **Master of Science**. The members of the Supervisory Committee were as follows:

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DECLARATION

I declare that the thesis is my original work except for quotations and citation which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or other institutions.

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SAEED JABALAMELIAN

Date: 10 January 2012

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