鈑金液壓製程回彈分析與模擬

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摘 要

本研究主要目的是推導一有效率的數學模型，以預測鈑金橡皮墊成型法製程之回談角，並結合最佳化演算法開發一電腦應用程式，提供業界找尋最佳化之鋁合金非線性材料擬合方程式、快速計算鈑金回彈角和回彈模修模角度等，以利鈑金製造業開發回彈模。探討的加工方法為目前航空航空鈑金製造業最常使用橡皮墊成型法(Rubber-Pad Forming)，其中包括液壓油囊(Hydraulic Forming)和橡皮墊加壓(Rubber-Pad Press Forming)成形法，此類加工設備為目前航空製造市場中最常使用在板金折彎製造的機器，液壓油囊成形法與橡膠墊加壓成形，可依零件種類不同及折彎型態利用橡皮墊取代不同的上模，節省上模開發的成本，並可多模同步加工，以滿足複雜之彈性製造需求。本研究並將利用開發之電腦程式，討論鈑金製程中的⑴材料種類，⑵材料厚度，⑶折彎半徑，⑷折彎角度，⑸鈑金件大小，⑹折彎角度變化率和⑺工作壓力等因子與回彈角之關係，並利用得到之回彈角結果，作為模具設計和修正模具的重要設計依據，以利零件之設計及製造模具之開發，提昇產品品質。本研究中亦採用有限元素法(Finite Element Method)之商業軟體ANSYS為模擬分析之應用軟體，並進行真實加工實驗，結合實驗的數據與模擬分析的結果，與數學預測的模型比較，驗證此數學預測模型確實能達到快速並準確的期望效果，藉由此研究期望能提供模具設計人員快速找尋出最佳之回彈量及模具回彈修正，降低鈑金手工之修整比例，並進一步縮短設計時間與製造時程，以提昇航太鈑金零件之設計製造能力。

關鍵詞 : 液壓成形 ; 擬合方程式 ; 橡膠墊加壓成形 ; 回彈現象 ; 鈑金 ; 有限元素法

目錄

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參考文獻

[1] Volkan E., Haluk D., Mustafa I.G.“ Finite element analysis of springback in bending of aluminium sheets ”. Materials and Design, 2002, vol. 23, pp.223~229.

[2] Lia K.P., Cardenb WP., Wagonera RH.“ Simulation of springback ”. International Journal of Mechanical Sciences, 2002, vol. 44, pp.103~122.

[3] Gau J.T., Gary LK.,“ An experimental investigation of the influence of the Bauschinger effect on springback prediction ”. Journal of Materials Processing Technology, 2001, vol. 108, pp.369~375.

[4] Zhang L. C., Lin Z.,“ An analytical solution to springback of sheet metals stamped by a rigid punch and an elastic die ”. Journal of Materials Processing Technology, 1997, vol.63, pp.49~54.

[5] Xue P., Yu T.X., Chu E.,“ Theoretical prediction of the springback of metal sheets after a double-curvature forming operation ”. Journal of Materials Processing Technology, 1999, vol. 89:90, pp. 65~71.

[6] Dwivedi J.P., Shah S.K., Upadhyay P.C., DasTalukder N.K.,“ Springback analysis of thin rectangular bars of non-linear work-hardening materials under torsional loading ”. International Journal of Mechanical Sciences, 2002, vol. 44, pp.1505~1519.
[7] Carden W.D., Geng L.M., Matlock D.K., Wagoner R.H.,“ Measurement of springback ”. Internationl Journal of Mechanical Sciences, 2002, pp.79~101.
[8] Dieter, Geoge E. 著, 陳伯宜編譯, Mechanism metallurgy. 全華出版社,1991.
[9] Hollomon J.H.“ Tensile deformation ”, AIME Transactions, 1945, pp.162~268.
[10] Swift H.W.“ Plastic instability under plane stress ”, Journal of Mechanics and Phsics of Solids, 1952, vol. 1:1.
[11] Voce E.“ The relationship between stress and strain for homogeneous deformation ”. Journal of the Institute of Metals, 1948, vol. 74, pp537-62~760-71.
[12] Jasbir S.A., Introduction to Optimum Design. McGraw-Hill international Editions, 1989.
[13] Reklaitis G.V., Ravindran A., ragsdell K.M., Engineering Optimization-Methods and Applications, Vol. 1, 2, 國立編譯館, 1995.
[14] Makinouchi, A.,“ Sheet Metal Forming Simulation in Industry ”. Journal of Materials Processing Technology, 1996, pp.19~26.
[15] Hsu T.C., Shien I.R.,“ Finite Element Modeling of Sheet Forming Process with Bending Effects ”. Journal of Materials Processing Technology, 1997, pp.733~737.
[16] Keum, Y.T., and Lee, K.B.,“ Sectional Finite Element Analysis of Forming Processes for Aluminum-ally Sheet Metals ”. International Journal of Mechanical Sciences, 2000, pp.1911~1933.
[17] Chou, I.N., and Hung C.,“ Finite Element Analysis and Optimization on Springback Reduction ”. International Journal of Machine Tools & Manufacture, 1999, pp.517~537.
[18] Xue, P., Yu, T.X., and Chu, E.,“ An energy approach for predicting springback of metal sheets after double-curvature forming Part II: Unequal double-curvature forming ”. International Journal of Mechanical Sciences, 1999.
[19] Hongzhi D., Zhongqin L.,“ Investigation of Sheet Metal Forming by Numerical Simulation and Experiment ”. Journal of Materials Processing Technology, 2000, pp.404~410.
[20] Datsko J.,“ Material properties and Manufacturing Processes ”. John Wiley & Sons, Inc., New York, 1966, pp.18-20.
[21] Adams AutoForm User ’ s Manual.
[22] Nelder J., Mead R.“ A simplex method for function minimization ”. Computer Journal, 1965, vol. 7, pp.308~313.
[23] Rachid C., Patrick S.“ Genetic and Nelder—Mead algorithms hybridized for a more accurate global optimization of continuous multiminima functions ”. European Journal of Operational Research, 2003, vol. 148, pp. 335—348.
[24] Jeffery C.L., James A.R., Margaret H.W., Paul E.W.“ Convergence properties of the Nelder-Mead simplex method in low dimensions ”. SIAM J. OPTIM, 1998, vol. 9(1), pp.112~147.
[25] 王正賢、蕭尊賀、陳奕安、陳正忠、施義舜,” 板金件液壓加工回彈之預測與分析 ”, 90年度中華民國力學學會年會暨第二十五屆全國力學會議, 台灣 台中, 2001, Dec. pp.15~16.
[26] 王正賢、蕭尊賀、陳正忠、施義舜,” ANSYS於板金件加工回彈模擬之應用 ”, ANSYS Taiwan User's Conference,台北 台灣, 2001, 11, pp.26~27.
[27] 王正賢、鄭彩華, ”鈑金液壓加工回彈模擬與補償角之計算,” 91年度中華民國力學學會年會暨第二十六屆全國力學會議, 台灣 虎, 尾2002, Dec. (NSC 90-2212-E-212-009).