

Analysis and Simulation of Springback for Sheet Metal Hydraulic Forming Processes

羅傑瀛、王正賢

E-mail: 9315361@mail.dyu.edu.tw

ABSTRACT

The main object of this investigation is to derive an efficiently analytical model to predict the springback of sheet metal forming by rubber-pad forming processes. A computer program was developed to predict the springback by the analytical mathematic model and optimization techniques for fitting models of nonlinear material properties of aluminum. This program could offer the manufacturing industry to obtain the fitting function of nonlinear materials and springback angle of bending. The hydraulic forming and rubber-pad press forming methods, which are the most common methods in the manufacturing industry of aviation, were studied in this research. Meanwhile the most common used heat treatment aluminum alloy of aviation field 2024-T3, 7075-T4 and 6061-T4 were adopted in this investigation. Hence, the investigation discussed all the manufacturing parameters of the bending sheet metal parts during the bending procedure, which influence the springback. The relationship between the springback and (1) material properties, (2) material thickness, (3) bending radius, (4) bending angle, (5) length of flange, (6) bending rate and (7) working pressure etc. were already discovered to discuss extensively, and also search the correction factor for the modification of the sheet metal forming die. In the research, the commercial finite element package, ANSYS, was also applied to simulate the forming processes of the sheet metal parts and was compared with experiment data and the analytical model results. To evaluate the results proved the analytical model which is efficient and accurate and also provide the design engineer a good molding tool to design a good sheet metal forming die and shorten manufacturing hours.

Keywords : hydraulic press forming ; rubber-pad forming ; springback ; sheet metal ; finite element method

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REFERENCES

- [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., Das Talukder 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 " . International Journal of Mechanical Sciences, 2002, pp.79~101.
- [8] Dieter, George 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 Physics 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, pp.537-62~760-71.
- [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 multimimima 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, " 鈹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).