ENHANCING FLANGE LENGTH IN STAMPING OF HIGH STRENGTH STEEL SHEETS SM520B USING STRETCH FLANGING METHOD

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MASTER OF SCIENCE

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SUPERVISOR'S DECLARATION

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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STUDENT'S DECLARATION

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

Pada masa kini, kepingan besi berkekuatan tinggi digunakan secara meluas dalam industri kerana kelebihannya yang berkekuatan tinggi dan beratnya yang ringan. Walau bagaimanapun, disebabkan kekuatan yang tinggi tersebut, proses penghasilan produk perlu dipermajukan bagi mengatasi kecacatan yang terjadi semasa proses penghasilan produk tersebut. Oleh itu, kajian ini menumpukan perhatian pada peningkatan panjang unjuran kepingan besi yang dilentur dengan menggunakan tiga pendekatan yang berbeza; rekabentuk acuan pelentur dengan hadangan sisi, penggunaan kolar iaitu pra-lentur sebelum lenturan dijalankan; dan juga teknik lenturan-secara-regangan bersama haba, untuk meminimumkan kekerapan keretakan yang berlaku dalam proses lenturan kepingan besi berkekuatan tinggi. Penyelidikan dimulakan dengan eksperimen awal untuk menguji had rekabentuk acuan pelentur terdahulu yang berpermukaan rata, dengan mempertimbangkan beberapa parameter seperti panjang maksimum unjuran, bidasan, dan taburan ketebalan. Kemudian, haba digunakan dalam eksperimen dengan memanaskan kepingan besi tersebut sebelum dibentuk untuk meningkatkan kebolehbentukan besi tersebut. pelentur dengan hadangan sisi dihasilkan dan diuji dengan tetapan yang sama yang digunakan dalam ujikaji sebelumnya. Kaedah lain yang digunakan bersama pelentur dengan hadangan sisi adalah penggunaan kolar sebelum proses lenturan-secara-regangan dilakukan. Berdasarkan eksperimen tersebut, didapati bahawa acuan pelentur permukaan rata mencapai panjang unjuran maksimum 12 mm dan tidak mencapai sasaran 18 mm. Proses lenturan-secara-regangan menggunakan haba terbukti meningkatkan kebolehbentukan kerana panjang unjuran maksimum yang dicapai adalah 24 mm dan bidasan dikurangkan hingga maksimum 5 °; dan dalam aspek taburan ketebalan, ketebalan di bahagian tengah unjuran menurun hanya 0.2 mm dan penebalan yang dicatatkan ialah 0.15 mm. Selain itu, dapat disimpulkan bahawa teknik pengunaan kolar adalah berhasil kerana panjang unjuran maksimum meningkat menjadi 24 mm sementara acuan lenturan berpenghadang sisi mencapai panjang unjuran maksimum 16 mm. Bagi penggunaan kolar dalam lenturan-secara-regangan, panjang unjuran meningkat sebanyak 50% berbanding dengan proses lenturan-secara-regangan tanpa kolar. Sudut bidasan berkurangan sementara ketebalan di tengah meningkat juga memperlihatkan produk akhir yang baik dihasilkan daripada kepingan besi berkekuatan tinggi. Sebagai perbandingan, antara ketiga-tiga kaedah ini, lenturan-secara-regangan bersama haba menunjukkan hasil yang paling baik berdasarkan panjang unjuran, sudut bidasan dan juga pengagihan ketebalan yang dicatat. Bagi kaedah lenturan-secara-regangan tanpa haba, penggunaan kolar adalah kaedah terbaik berbanding dengan kaedah konvensional.

ABSTRACT

Nowadays, high strength steel sheets were widely used in the industry due to the advantages in offering high strength with light weight. However, due to the high tensile strength the manufacturing process need to be improved to prevent defects that occurred in the production. Currently, stretch flanging method was used for the manufacturing of steel sheets, however some defects were still observed especially when a long flange length involved. Thus, this research were focusing on minimizing fracture by enhancing the flange length of the stretch flanged steel sheet by using three different approaches namely the side stopper punch shape; application of collar length and pre-heating of the steel sheets before stretch flanging process. The research started with preliminary experiment to test the limit for normal flat-bottom punch with considering a few parameters such as maximum flange length, springback, and thickness distribution. Then, heat was used in the experiment by pre-heating the sheets before being stretch-flanged to improve the formability of the sheets. Side-stopper punch was fabricated and tested with the same setup used in the previous experiment. Another method used with side-stopper punch was the application of collar bending before the stretch flanging take places. From the experiment, it was showed that flat-bottom punch achieved maximum flange length of 12 mm and not achieving the targeted 18 mm. The hot-stretch flanging process was proven to improve the formability as the maximum flange length achieved was 24 mm and the springback was reduced to the maximum of 5° and in aspect of thickness distribution, the thickness at the center of the flanged part were decreased by only 0.2 mm and the thickening recorded were 0.15 mm. Besides, it can be concluded that collar length was a success as the maximum flange length increased to 24 mm while the side stopper punch achieved maximum of 16 mm flange length. For stretch flanging process with collar length, the maximum flanges length of high strength steel sheet increased by 50% compared to stretch flanging process without collar length. The angle of springback was decreased while the thickness at center increased was also show good finished product of high strength steel sheet in stretch flanging process. For comparison, between these three methods, the hot stretch flanging shows the most excellent results due to the flange length, springback and thickness distribution. For cold flanging, the collar bending was the best methods compared to the conventional methods.

TABLE OF CONTENT

REFERENCES

Abbasi, M., Ketabchi, M., Labudde, T., Prahl, U., & Bleck, W. (2012). New attempt to wrinkling behavior analysis of tailor welded blanks during the deep drawing process. Materials and Design, 40, 407–414.

Abe, Y., Fujita, T., Mori, K. I., Osakada, K., Shiba, T., & Daodon, W. (2014). Improvement of formability in ironing of stainless steel drawn cups using low friction cermet dies. Procedia Engineering, 81(October), 1896–1901.

Abe, Y., Mori, K. I., & Norita, K. (2013). Gradually contacting punch for improving stretch flangeability of ultra-high strength steel sheets. CIRP Annals - Manufacturing Technology, 62(1), 263–266.

Ablat, M. A., & Qattawi, A. (2017). Numerical simulation of sheet metal forming: a review. The International Journal of Advanced Manufacturing Technology, 89(1), 1235–1250.

Allwood, J. M., Duncan, S. R., Cao, J., Groche, P., Hirt, G., Kinsey, B., … Tekkaya, A. E. (2016). Closed-loop control of product properties in metal forming. CIRP Annals, 65(2), 573–596.

Altan, T., Groseclose, A., Billur, E., Subramonian, S., & Mao, T. (2013). Advances and challenges in sheet metal forming technology, (June), 1–6.

Amiril, S. A. S., Rahim, E. A., & Syahrullail, S. (2017). A review on ionic liquids as sustainable lubricants in manufacturing and engineering: Recent research, performance, and applications. Journal of Cleaner Production, 168, 1571–1589.

Ayari, F., Lazghab, T., & Bayraktar, E. (2009). Parametric finite element analysis of square cup deep drawing. Archives of Computational Materials Science and Surface Engineering, 1(1), 6.

Baluch, N., Udin, Z., & Abdullah, C. S. (2014). Advanced High Strength Steel in Auto Industry: an Overview. Eng. Technol. Appl. Sci. Res., 4, 686–689.

Bleck, W. (2002). Using the TRIP effect - the dawn of a promising group of cold formable steels. In International Conference on TRIP-Aided High Strength Ferrous Alloys (Vol. 1, p. 13). Ghent.

Bleck, W., & Phiu-On, K. (2005). Grain refinement and mechanical properties in advanced high strength sheet steels. Iron Steel Suppl., (January).

Burt, V. (2018, November 30). Forming of Aluminum Alloys. (K. Anderson FASM, J. Weritz, & J. G. Kaufman FASM, Eds.), Aluminum Science and Technology. ASM International.

Carden, W. D., Geng, L. M., Matlock, D. K., & Wagoner, R. H. (2002). Measurement of springback. International Journal of Mechanical Sciences, 44(1), 79–101.

Cedric Xia, Z., & Cao, J. (2018). Springback. In T. I. A. for Production (Ed.), CIRP Encyclopedia of Production Engineering (pp. 1–6). Berlin, Heidelberg: Springer Berlin Heidelberg.

Cheng, H. S., Cao, J., & Xia, Z. C. (2007). An accelerated springback compensation method. International Journal of Mechanical Sciences, 49(3), 267–279.

Chou, I.-N., & Hung, C. (1999). Finite element analysis and optimization on springback reduction. International Journal of Machine Tools and Manufacture, 39(3), 517–536.

Cora, O. N., Agcayaz, A., Namiki, K., Sofuoglu, H., & Koc, M. (2012). Die wear in stamping of advanced high strength steels - Investigations on the effects of substrate material and hard-coatings. Tribology International, 52, 50–60.

De Cooman, B. C., Estrin, Y., & Kim, S. K. (2018). Twinning-induced plasticity (TWIP) steels. Acta Materialia, 142, 283–362.

Deva, A., Jha, N. K., & Jha, B. K. (2012). Effect of Austenitising Temperature and Cooling Condition on Mechanical Properties of Low Carbon Boron Containing Steel. International Journal of Metallurgical Engineering, 1(1), 1–6.

Dewang, Y., Hora, M. S., & Panthi, S. K. (2015a). Influence of blank holding force on stretch flange forming of aluminum alloy. Materials Today: Proceedings, 2(4–5), 1934–1941.

Dewang, Y., Hora, M. S., & Panthi, S. K. (2015b). Influence of blank holding force on stretch flange forming of aluminum alloy. Materials Today: Proceedings, 2(4–5), 1934–1941.

Gan, W., & Wagoner, R. H. (2004). Die design method for sheet springback. International Journal of Mechanical Sciences, *46*(7), 1097–1113.

Gan, W., Wagoner, R. H., Mao, K., Price, S., & Rasouli, F. (2004). Practical methods for the design of sheet formed components. Journal of Engineering Materials

Ghouati, O., Joannic, D., & Gelin, J. C. (1998). Optimisation of process parameters for the control of springback in deep drawing. In J. Huetink & F. P. T. Baaijens (Eds.), Simulation of Materials Processing: Theory, Methods and Applications: Proceedings of the sixth international conference, NUMIFORM'9*8*. Enschede, Netherlands: Taylor & Francis.

Gupta, M. S., & Reddy, D. R. (2017). Design and analysis of aircraft sheet metal for springback effect. In Materials Today: Proceedings (Vol. 4, pp. 8287–8295).

Hassan, M. A., Saleh, M. A. E., Takakura, N., Ramesh, S., & Purbolaksono, J. (2012a). Effect of bulge shape on wrinkling formation and strength of stainless steel thin sheet. Materials and Design, 42, 37–45.

Hassan, M. A., Saleh, M. A. E., Takakura, N., Ramesh, S., & Purbolaksono, J. (2012b). Effect of bulge shape on wrinkling formation and strength of stainless steel thin sheet. Materials and Design, 42, 37–45.

Henriques, M. P., & Valente, R. A. F. (2009). Numerical simulation of wrinkling deformation in sheet metal forming. In J. Ambrosio et.al. (eds.) (Ed.), 7th EUROMECH Solid Mechanics Conference (pp. 1–12). Lisbon, Portugal.

Hofman, H., Goeklue, S., Gerlach, J., & Bruex, U. (2004). Properties of light steels with induced plasticity (L-IP steels). In Proceedings IDDRG International Deep Drawing 2004 Conference (p. 270). Sindelfingen, Germany.

ichiro Mori, K., Abe, Y., & Suzui, Y. (2010). Improvement of stretch flangeability of ultra high strength steel sheet by smoothing of sheared edge. Journal of Materials Processing Technology, 210(4), 653–659.

Ingarao, G. (2017). Manufacturing strategies for efficiency in energy and resources use: The role of metal shaping processes. Journal of Cleaner Production, 142, 2872–2886.

Ingarao, G., Ambrogio, G., Gagliardi, F., & Di Lorenzo, R. (2012). A sustainability point of view on sheet metal forming operations: Material wasting and energy consumption in incremental forming and stamping processes. Journal of Cleaner Production, 29–30, 255–268.

Ingarao, G., Di Lorenzo, R., & Micari, F. (2011). Sustainability issues in sheet metal forming processes: An overview. Journal of Cleaner Production, 19(4), 337–347.

Irthiea, I., Green, G., Hashim, S., & Kriama, A. (2014). Experimental and numerical investigation on micro deep drawing process of stainless steel 304 foil using flexible tools. International Journal of Machine Tools and Manufacture, 76, 21–33.

Jia, Y., Pu, C., Zhu, F., & Wang, Y. W. (2018). An Analytical Model for Spring-Back Prediction in U-Channel Forming with Advanced High Strength Steel. SAE Technical Papers, 2018–April(July).

Kadarno, P., Mori, K. I., Abe, Y., & Abe, T. (2014). Flanging using step die for improving fatigue strength of punched high strength steel sheet. Procedia Engineering, 81(October), 1133–1138.

Kadkhodayan, M., & Moayyedian, F. (2011). Analytical elastic-plastic study on flange wrinkling in deep drawing process. Scientia Iranica, 18(2 B), 250–260.

Kim, H., Altan, T., & Yan, Q. (2009). Evaluation of stamping lubricants in forming advanced high strength steels (AHSS) using deep drawing and ironing tests. Journal of Materials Processing Technology, 209(8), 4122–4133.

Kim, H., Sung, J. H., Sivakumar, R., & Altan, T. (2007). Evaluation of stamping lubricants using the deep drawing test. International Journal of Machine Tools and Manufacture, 47(14), 2120–2132.

Kim, Y. H. H., & Park, J. J. J. (2002). Effect of process parameters on formability in incremental forming of sheet metal. Journal of Materials Processing Technology, 130–131(3), 42–46.

Krishna, K. M., & Swamy, M. K. (2014). Prediction of draw ratio in deep drawing through software simulations. International Refereed Journal of Engineering and Science (IRJES), 3(12), 24–29.

Kusumi, K. (2013). Formability and FEM simulation of steel sheets in the hot stamping process. Nippon Steel Technical Report, 103(103), 47–55.

Lal, R. K., Choubey, V. K., Dwivedi, J. P., & Kumar, S. (2018). Study of factors affecting Springback in Sheet Metal Forming and Deep Drawing Process. Materials Today: Proceedings, 5(2, Part 1), 4353–4358.

Li, G. Y., Tan, M. J., & Liew, K. M. (1999). Springback analysis for sheet forming processes by explicit finite element method in conjunction with the orthogonal regression analysis. International Journal of Solids and Structures, 36(30), 4653–4668.

Lim, Y., Venugopal, R., & Ulsoy, A. G. (2008). Advances in the Control of Sheet Metal Forming. IFAC Proceedings Volumes, 41(2), 1875–1883.

Lin, B. T., Huang, K. M., Kuo, C. C., & Wang, W. T. (2015). Improvement of deep drawability by using punch surfaces with microridges. Journal of Materials Processing Technology, 225, 275–285.

Liu, J., Ahmetoglu, M., & Altan, T. (2000). Evaluation of sheet metal formability, viscous pressure forming (VPF) dome test. Journal of Materials Processing Technology, 98(1), 1–6.

Liu, X., Zhao, S., Qin, Y., Zhao, J., & Wan-Nawang, W.-A. (2017). A parametric study on the bending accuracy in micro W-bending using Taguchi method. Measurement, 100, 233–242.

Ma, G., & Huang, B. (2014). Optimization of process parameters of stamping forming of the automotive lower floor board. Journal of Applied Mathematics, 2014.

Maier, C. (2013). Failure prediction in sheet metal forming using FEA of Nakazima test. Machines, Technologies, Materials, (7), 9–12.

Malekani, J., Mostafa Pour, A., Eskandarzade, M., & Totonchi, A. (2008). Numerical and experimental investigation on die and blank holder shape in deep drawing process. Journal of Applied Sciences, 8(11), 2153–2157.

Matsuno, T., Nitta, J., Sato, K., Mizumura, M., & Suehiro, M. (2015). Effect of shearing clearance and angle on stretch-flange formability evaluated by saddle-type forming test. Journal of Materials Processing Technology, 223, 98–104.

Mori, K., Abe, Y., Kidoma, Y., & Kadarno, P. (2013). Slight clearance punching of ultra-high strength steel sheets using punch having small round edge. International Journal of Machine Tools and Manufacture, 65, 41–46.

Mori, K. ichiro, Abe, Y., & Suzui, Y. (2010). Improvement of stretch flangeability of ultra high strength steel sheet by smoothing of sheared edge. Journal of Materials Processing Technology, 210(4), 653–659.

Mori, K., Maki, S., & Tanaka, Y. (2005). Warm and hot stamping of ultra high tensile strength steel sheets using resistance heating. Ann. CIRP, *54*(2), 209–212.

Morovvati, M. R., Mollaei-Dariani, B., & Asadian-Ardakani, M. H. (2010). A theoretical, numerical, and experimental investigation of plastic wrinkling of circular two-layer sheet metal in the deep drawing. Journal of Materials Processing Technology, 210(13), 1738–1747.

Nebosky, P. S., Schmid, S. R., & Sellés, M. A. (2011). The springback characteristics of a porous tantalum sheet-metal. Journal of Manufacturing Science and Engineering, Transactions of the ASME, 133(6), 1–9.

Orsato, R. J., & Wells, P. (2007). U-turn: the rise and demise of the automobile industry. Journal of Cleaner Production, 15(11–12), 994–1006.

Peng, L., Hu, P., Lai, X., Mei, D., & Ni, J. (2009). Investigation of micro/meso sheet soft punch stamping process - simulation and experiments. Materials and Design, 30(3), 783–790.

Pietrek, M., & Horst, P. (2018). Determination of the fracture toughness of debonded asymmetric sandwich beams with a thin-walled skin considering plastic deformation. Engineering Fracture Mechanics, 188, 217–231.

Quadfasel, A., Lohmar, J., & Hirt, G. (2017). Investigations on Springback in High Manganese TWIP-Steels using U-Profile Draw Bending. Procedia Engineering, 207, 1582–1587.

Ramulu, P. J., Rao, P. S., & Yimer, W. (2016). Springback analysis on AA 6061 aluminum alloy sheets. AIP Conference Proceedings, 1769.

Reddy, R. V, Reddy, T. A. J., & Reddy, G. C. M. (2012). Effect of various parameters on the wrinkling in deep drawing cylindrical cups. International Journal of Engineering Trends and Technology, 3(1), 53–58.

Rivas, A. (2015). Análisis del efecto de diversos parámetros en el desempeño del proceso de embutido de formas rectangulares.

Sathish, T. (2018). GAC-ANN Technique for Prediction of Spring Back Effect in Wipe Bending Process of Sheet Metal. Materials Today: Proceedings, 5(6, Part 2), 14448–14457.

Schützer, K., Abele, E., & Güth, S. (2015). Simulation-based deburring tool and process development. CIRP Annals, 64(1), 357–360.

Senuma, T. (2001). Physical metallurgy of modern high strength steel sheets. ISIJ International, 41(6), 520–532.

Singh, C. P., & Agnihotri, G. (2015). Study of deep drawing process parameters: A review. International Journal of Scientific and Research Publications, 5(1), 2250–3153.

Singh, S., Ramakrishna, S., & Gupta, M. K. (2017). Towards zero waste manufacturing: A multidisciplinary review. Journal of Cleaner Production, 168, 1230–1243.

Taherizadeh, A., Ghaei, A., Green, D. E., & Altenhof, W. J. (2009). Finite element simulation of springback for a channel draw process with drawbead using different hardening models. International Journal of Mechanical Sciences, 51(4), 314–325.

Takahashi, M. (2015). Sheet steel technology for the last 100 years: Progress in sheet steels in hand with the automotive industry. ISIJ International, 55(1), 79–88.

Tamaoki, K., ichi Manabe, K., Kataoka, S., & Aizawa, T. (2010). Electroconductive ceramic tooling for dry deep drawing. Journal of Materials Processing Technology, 210(1), 48–53.

Viscorova, R., Wendelsrorf, J., Spitzer, K. H., Kross, J., & Flaxa, V. (2004). Forming the future : global trends in sheet metal forming. In Proceedings IDDRG International Deep Drawing 2004 Conference (p. 261). Sindelfingen, Germany: Verl. Stahleisen,.

Xia, Z. C. (2001). Springback compensation technology for aluminium stamping. In NADDRG Spring Meeting. Columbus, Ohio.

Xiong, W., Zhang, W., Lv, Y., Chuan, L., Song, X., & Xia, Y. (2020). The establishment of a newly modified numerical global springback compensation method. IOP Conference Series: Materials Science and Engineering, 729, 12060.

Yang, X., Choi, C., Sever, N. K., & Altan, T. (2016). Prediction of springback in air-bending of Advanced High Strength steel (DP780) considering Young′s modulus variation and with a piecewise hardening function. International Journal of Mechanical Sciences, 105, 266–272.

Zareh-Desari, B., & Davoodi, B. (2016). Assessing the lubrication performance of vegetable oil-based nano-lubricants for environmentally conscious metal forming processes. Journal of Cleaner Production, 135, 1198–1209.

zhi Gao, E., wei Li, H., chao Kou, H., Chang, H., shan Li, J., & Zhou, L. (2009). Influences of material parameters on deep drawing of thin-walled hemispheric surface part. Transactions of Nonferrous Metals Society of China (English Edition), 19(2), 433–437.

Zrník, J., Mamuzic, I., & Dobatkin, S. V. (2006). Recent progress in high strength low carbon steels. Metallurgija, 45(4), 323–331.