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# REVIEW – METHODS AND MEASUREMENTS OF SPRINGBACK EVALUATION

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## ABSTRACT

*Review of Springback has been given major attention in sheet metal forming past research with numerous studies being conducted to understand and solve the problems. They range from inventing new designs of tooling, such as flexible and warm tooling, Forming to improving the accuracy of springback prediction by empirical and analytical methods and computer simulation. The survey of the springback prediction by analytical and numerical simulation depends on constitutive equations and material parameter identification. Thus, several studies have been performed extensively on the matter. An attempt to review previous works is presented and their advantages and disadvantages are discussed here. Based on the review, a conclusion is drawn regarding a knowledge gap, which motivates the current research.*

**Keyword:** Review, Springback, Survey, Evaluation, analytical, numerical simulation.

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# 1. EMPIRICAL METHODS OF SPRINGBACK EVALUATION

Various experiments have been conducted to obtain empirical data on spring back, which involved various bending processes such as 90-degree wiping, v-bending, air bending and deep drawing as well as actual production processes. Based on the experiments, equations or charts have been developed as a reference for product and tool design in sheet metal forming. Several factors have been considered for the empirical equations such as material properties and geometry, tool geometry and process parameters.(Merklein, Johannes et al. 2014)This paper studied in empirical equations have been compiled in handbooks for industrial use it .(Ablat and Qattawi 2017)studied the influence of material thickness, die gap, anvil radius and prior cold work for high-strength steels subjected to 90-degree wiping bending. Several charts were produced in relation to springback angle.(Zang, Lee et al. 2013) In general, it was concluded that springback increased proportionally to anvil radius, die gap and material strength, but decreased as thickness increased. (Chikalthankar, Belurkar et al. 2014)Besides, it was found that springback can be reduced by increasing the ratio of thickness to radius of the die to a value greater than 0.4. (Choi and Huh 2014)Using air bending and statistical methods, a study of geometric parameter interaction with the material properties was performed. (Singh and Agnihotri 2015)The study concluded that there were interactions among the factors and the design of tools in air bending depended on material properties.(Lunt and Korsunsky 2015)found similar outcomes when performing tests on v-bending. (Abdullah, Salit et al. 2013) in addition also found that springback can be reduced by maintaining the load longer on the materials. (Abdullah, Salit et al. 2013, Ahmed, Ahmed et al. 2014)used a wiping tool with three different inserts, with a radius of 1/2, 3/8 and 3/16 inch, to indicate the relationship of the Bauchinger effect to springback. Figure 1 shows their test tool.

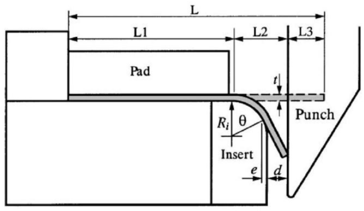


**Figure 1** Wipping tool Effects

## 1.1. CYCLIC LOADING WAS PERFORMED ON THE SHEET METAL BY THE FOLLOWING PROCEDURE:

Bending (B), reverse-bending (RB), bending-reverse-bending (BRB) and bending-reverse-bending-reverse (BRBR). Except for bending (B), the next processes require the sheet metal to be turned over for bending in the opposite direction.(Kitayama and Yoshioka 2014)The experimental materials were aluminium alloy, high strength steel, aluminium killed draw quality steel and bake hard steel.

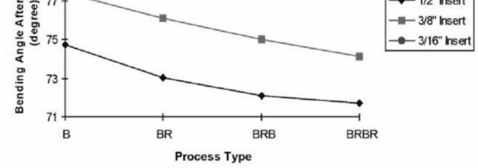


**Figure 2** The effect of cyclic loading on springback

Figure 2 shows the result of springback for aluminium alloy AA6111-T4. The bending angle after springback decreases as the material is subjected to reverse loading. It was concluded that cyclic loading affects springback. In other words, Bauschinger effect should be considered in the analysis of sheet metal springback.

## 2. ANALYTICAL METHODS FOR SPRINGBACK PREDICTION

While providing useful information, empirical data tends to focus more on a limited set of parameters in a specific bending process. Thus, there is a need to consider an alternative more general method applicable to various bending processes with different parameters. An approach based on the mechanics of sheet metal bending and plasticity theory has been considered as an alternative analytical method. Several model assumptions are applied.

(Abdullah, Salit et al. 2013, Khal, Ruszkiewicz et al. 2016)They include pure bending or tool bending of either non-hardening or hardening materials, transverse stress across the sheet, neutral axis shifting, thickness reduction, anisotropy and strain reversal effect. Rigid-perfectly plastic model was used for example by Hill in his analysis of sheet metal deformation based on plane strain bending.(Narayanan and Dixit 2015) He assumed there was shifting of neutral surface with no thickness reduction. (Zang, Lee et al. 2013) The results showed that both formulas underestimate the extent of springback mainly due to the assumption of only elastic stresses through the sheet metal thickness .(Song, Yang et al. 2013) To consider anisotropy, (Leu and Sheen 2013)theory of plastic anisotropy and included normal anisotropy R in his formula.

## 3. FINITE ELEMENT SIMULATIONS FOR SPRINGBACK PREDICTION

Analytical methods of solving bending problems can be applied to simple shapes and idealized process conditions. Nevertheless, for complex shapes of actual products and real bending processes the analytical methods have a limited use. With advances in computing technology, finite element simulation provides an alternative solution.(Barros, Oliveira et al. 2013) reliability and accuracy of the finite element approach is still a challenge. Therefore, further developments of the methods are required. Among them are the improvements in the finite element formulation (new type of elements), the robustness of the numerical methods used and the quality of the constitutive models describing the deformation behavior of the sheet metal. (Ling, Abdullah et al. 2016, Zajkani and Hajbarati 2017)This review papers is only concerned with the last aspect of these improvements and, in particular, the hardening rules used in material models, such as isotropic hardening, linear kinematic hardening, nonlinear kinematic hardening and combination of isotropic and kinematic hardening.(Lajarin and Marcondes 2015)Isotropic hardening for example was used by several researchers to determine geometrical effects of die gap, sheet thickness and die radius on the springback angle and to show that computer simulation can provide a better prediction of the final sheet metal shape.(Noma and Kuwabara 2014)conducted a v-bending test to prove that finite element simulation is a better method of predicting springback. (Khal, Ruszkiewicz et al. 2016)The simulation applied simple elastic plastic isotropic hardening data from a tensile test. Materials tested were aluminium, stainless steel and low carbon steel of various grades and thicknesses. (Ruszkiewicz, Grimm et al. 2017) the simulation results underestimated the springback angle when compared with experimental data, the study concluded that the simulation could be used to predict springback. (Teng, Zhang et al. 2015) performed an experimental and simulation study using v-bend and u-bend on a CK67 steel sheet. The simulation used a similar material model as that used.(Broggiato, Campana et al. 2013, Wagoner, Lim et al. 2013) the simulated springback angles were greater than the experimental ones. UsingHollomon's isotropic hardening model, Samuel focused on understanding the stress strain distribution for sheet deformation due to a draw bead with 5 mm radius. (Singh and Agnihotri 2015, Stoudt, Levine et al. 2017) author claimed that the drawing force and the blank holding force obtained by the simulation were accurately predicted. (Xue, Liao et al. 2015)Finite element simulation using complex hardening models has been considered to improve simulation of sheet metal forming. This, in particular, refers to the case when accounting for a reversal loading in which Bauschinger and the hardening transient effects are present. A study by (Nguyen, Adragna et al. 2013, Chikalthankar, Belurkar et al. 2014) for example, found that including Bauschinger effect can improve springback prediction. Thus, several (Pal and Rao , Yenice, Karşı et al. , Oya and Naoyuki Doke 2013, Seo, Kim et al. 2017)studies were attempted using kinematic hardening or more complex hardening models, to improve the accuracy of the simulation. Some of the studies are presented here for reference.(Gupta and Balasubramaniyan 2016)studied straight flanging and found that using kinematic hardening produced better results in terms of springback prediction compared to isotropic hardening .(Abdullah, Salit et al. 2013, Wang, Lang et al. 2017) a presented Simulations of hemispherical punch stretching, cup drawing and bending drawing tests were performed by Moreira and Ferron to investigate the impact of various types of hardening modelling in sheet metal forming. The isotropic hardening model was found to provide good simulation for the first two tests but not for the bending drawing test.(SOLFRONK, SOBOTKA et al.)They concluded that the kinematic hardening model should be considered to simulate stress reversals in the process of bending-unbending. (Lugnberg and Netz 2016) did a similar study and found that the kinematic hardening model provided fourfold improvement in springback prediction compared to the isotropic hardening model. Isotropic hardening produced up to one hundred percent relative errors while the kinematic hardening model showed seventeen to twenty percent relative error in terms of overall dimensional accuracy.(Hingole)emphasised the importance of including the Bauschinger effect in springback prediction but found that anisotropic effect was quite small, with only 1 degree difference between the experimental results and the simulation results for different material orientations; the(Gupta and Reddy 2017)study was conducted using a draw-bend test for stainless steel 410 . On the other hand, a study on high strength steel performed by (Gautam and Kumar 2017) indicated that orientation has a significant influence on springback. Average simulation errors were 25% for 0 degree, 32% for 45 degree and 23% for 90 degree orientations. However, the study was based on an isotropic hardening model, which meant the Bauschinger effect was neglected. (Paithankar and Varade)It is believed that this could contribute to a bigger discrepancy between simulation and experimental results. The influence of the hardening model has also been investigated in (Chaudhari and Patil , Ab Karim 2013, Esener, Yenice et al. 2015, Toros 2016, Maia, Ferreira et al. 2017)compared the influence of the material model on springback prediction of a u-shape profile. The hardening laws used for the study were the isotropic hardening Swift law and the Voce law, a combination of Swift hardening with nonlinear kinematic hardening and a combination of Voce hardening with nonlinear kinematic hardening. The nonlinear kinematic hardening was represented by the Lemaitre-Chaboche law. The study concluded that each of the constitutive laws provides different results due to different predicted through-thickness stress gradients. The authors further concluded that the strain-path changes identified in the u-shape are very important and should be considered in the springback investigation. For that, the use of a bending-unbending test to characterize material data is required.

## 4. EGGERTSEN AND MATTIASSON STUDIED AND COMPARED 5 HARDENING LAWS

Holloman isotropic hardening law, a combination of Holloman isotropic hardening and Ziegler kinematic hardening law, Armstrong and Frederich hardening law (A-F), Geng and Wagoner hardening law (G-H) and Yoshida and Uemori hardening law (Y-U). Parameters of the hardening laws were determined using the inverse method based on a three-point bending proposed by(Chaudhari and Patil) The quality of hardening rules was evaluated based on two bending processes. The first process was a three-point bending experiment, in which the performance was measured by trying to get the best fit with the experimental force-displacement curve. The findings indicated that the isotropic hardening produced the worst result. The A-F hardening model fitted well the lower part of the curve but was unable to produce a good fit for the upper part, which is the permanent softening region. The Y-U hardening law provided the best results, but due to its mathematical complexity the preferred hardening law was that slightly less perfect one proposed by Geng and Wagoner (G-W). The second process was a Numisheet'93 standard benchmark test as in Figure 3.

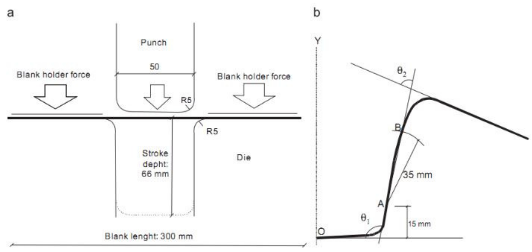


**Figure 3** Numisheet'93 benchmark (a) experimental set -up (b) definition of the angles

Table 1.1 shows the detailed results. Simulations of u-bending showed that all the hardening laws underestimated the springback angle, best prediction of the springback angles was obtained for the A-F hardening law.

**Table 1.1** Comparison between springback angles predicted by using various hardening rules and the experimental angles for material

| Hardening law | $\theta_1$ | $\theta_2$ |
|---|---|---|
| Experiment | $105.15 \pm 0.3$ | $82.6 \pm 0.5$ |
| Isotropic hardening | 100.585 | 81.959 |
| Mixed hardening | 100.00 | 84.60 |
| Armstrong–Frederick | 101.17 | 82.56 |
| Geng–Wagoner | 98.321 | 84.966 |
| Yoshida–Uemori | 97.964 | 85.246 |

Based on these results, we are able to say that the spring predictive ability of multiple-surface based hardening rules (G-W and Y-U) is not as good as in the case of the one-surface based hardening rules.(Zang, Lee et al. 2013, Abvabi, Mendiguren et al. 2014, Leu and Zhuang 2016) and others conducted experimental validations to evaluate springback simulation based on the isotropic hardening law, kinematic hardening law and combination of the two laws. Additionally they used a new non-quadratic anisotropic yield function. Materials tested were aluminium AA5754-O and AA6111-T4 grades and a DP-steel. Material parameters were determined using a cyclic tension and compression test. They used three bending processes, u-bending, unconstrained cylindrical bending and double-s rail bending; the last two processes are shown in Figure 4 For unconstraint cylindrical bending the overall simulation results overestimated springback.

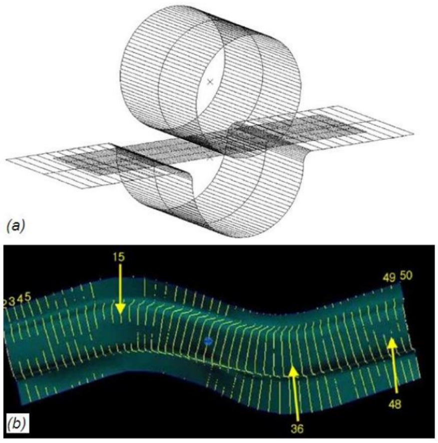


**Figure 4** (a) Unconstrained cylindrical bending (b) double-s rail (Lee et al.2005a)

For u-bending and double-s rail, the joint hardening provided the best results in comparison to isotropic or kinematic hardening (Miyagi, Tanaka et al. 2013, Dinovitzer, Fredj et al. 2014, Khal, Ruszkiewicz et al. 2016, SANDIYAPPAN, GOPALAN et al. 2017)Cyclic Loading Experiments The simple and efficient monotonic tensile test was used extensively in early study on hardening. (Minh 2015, Beulich, Craighero et al. 2017) The need to describe the actual forming procedure, which entails bending-unbending demands the tensile test to execute cyclic or reverse loading, which is very difficult to work for sheet materials. Several unique design specimens and apparatus are developed in an effort to include the reversal effect in tensile tests for sheet metal. The apparatus developed by (Choi, Kulinsky et al. 2014, Qu, Jiang et al. 2015, Behrens, Bouguecha et al. 2017) is shown at Figure 5

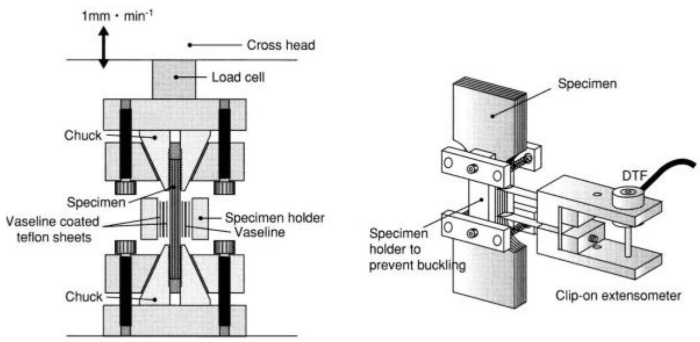


**Figure 5** Yoshida’s specimen holder to prevent buckling in compression

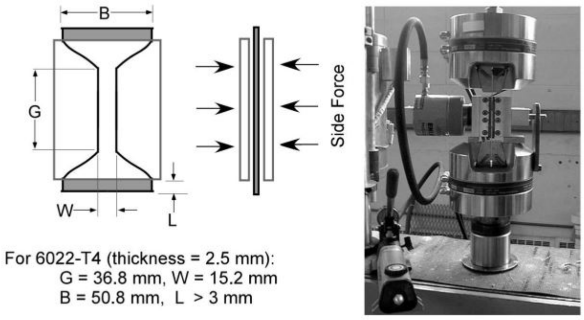


**Figure 6** Boger’s schematic representation of the sheet metal specimen anduniaxial tension/compression tool

(Bashah, Muhamad et al. 2013) apparatus are almost similar. The sheets are packaged together and encouraged by lateral plates to prevent buckling. In accordance with 0.25 and 0.13 compressive strains were listed because of low carbon steel and strength steel . (Rossi, Degee et al. 2013, Maia, Ferreira et al. 2017) on the other hand used two comb-shaped dies to prevent buckling. Using a servo-controlled hydraulic cylinder A, the decrease die-2 moves left and right so that a continuous tensile and compression reverse load can be applied to the sheet metal specimen. Compressive strains of 0.15-0.2 were listed. Due to the requirement to curtail the sample in the depth direction to prevent buckling, all raw stress-strain results need corrections to frictional and biaxial effects arising from this encouraging force. (ul Hassan, Maqbool et al. 2016) asserted that none of the methods were effective at curbing buckling entirely as a result of inevitable exposed area of the specimen. In the first two methods, the exposed regions were identified between the expires and knobs of the electrical system; and in the latter method, between each set of their 'fingers' of the die.To improve the standard support on the entire specimen region during cyclic loading, they created a four-block wedge with pre-loaded spring. (Khadra and El-Morsy 2016) Despite solving the buckling problem, the biaxial influence and the frictional effect between the die and specimen still exist. An additional frictional effect was also acknowledged between wedge spring and plates . (Ma)In conclusion, preparing a tensile test for alteration loading is quite hard. Among the advantages of cyclic torsion is its capacity to extend to large strain deformation.The tool, however, totally deviates from the true sheet forming process and the sheet needs to be welded, which would affect the material properties. (Prakasam and Thangavel2013)he sliding influence on the other hand is the principal problem from the cyclic simple shear test. Furthermore, the measurement of the local strain is quite difficult due to the limited field of the shear zone. The test however is quite simple to setup and utilize it.Using a cyclic bending evaluation was considered as yet another favored alternative, contemplating its capability and flexibility to execute reverse loading to examine the Bauschinger effect and its resemblance to industrial bending processes. (Huang, Fu et al. 2017) Moment and curvature connection in association with all the springback phenomenon found in the procedure can be utilized to derive a fundamental understanding of the stress-strain behaviour during elastic-plastic deformation. Motivated by this connection, substantial experimental research has been conducted to develop and validate stress-strain modelling in terms of moment-curvature relationship. In (Khal, Ruszkiewicz et al. 2016) a comparison analysis of kinematic hardening parameters, derived from the bending-unbending evaluation and by the shear test was conducted on 1mm thick trip steel and aluminum metal. The bending tests along with a specimen used are displayed at Figure 7.

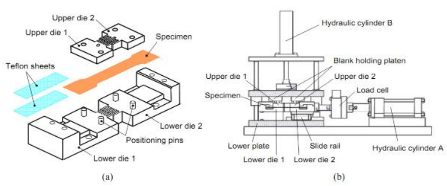


**Figure 7** Kuwabara's comb-shaped device to prevent compression buckling (a) comb shape dies and (b) testing machine (Kuwabara et al. 2009)

The aim was to assess the functioning of the parameters identified in one test in finite element simulation of the results obtained in another test. The material parameters established from the bending-unbending test, when used in the shear test simulation, also provided very good description of the experimental shear data. This outcome is shown in Figure 7 (b) when shear derived material parameters were used, the capability to describe the experimental bending-unbending information was worse. This outcome is shown in Figure 8.

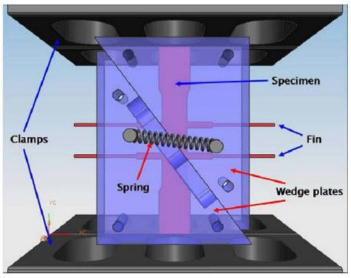


**Figure 8** Cao's tension and compression tool

The study conducted an experiment to capture deformation behavior of steel and aluminium sheet at a forming operation, focused particularly on the attraction beads. authors meant to show the Baushinger effect as a function of strain amplitude, pre-strain and sheet thickness. They discovered that Bauschinger effect decreased as strain amplitude increased and there were no significant changes due to thickness decrease; therefore the moment throughout the sheet thickness has been carried by an individual layer in an identical manner. On the other hand, the end is restricted to thin sheets with 3 mm thickness and less. Pre-strain on the other hand showed a significant influence in the Bauschinger effect and hastened the development of a steady-state hysteresis loop. It was found that pre-strain increased the very first cycle Bauschinger effect factor. The apparatus is shown in Figure 9

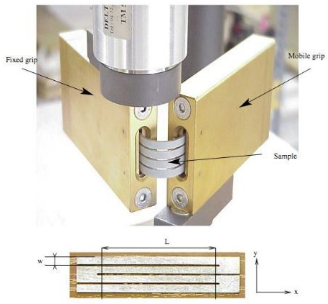


**Figure 9** The bending device and a four-piece specimen (Carbonniere et al. 2009)

Utilized the three-point bending and the results of Zhao and Lee to discover material parameters for their proposed hardening equation according to a modification of the Chaboche constitutive equation. The modification accounted for a permanent offset in the flow stress. It was discovered that the parameters describing bending were similar to parameters derived from tension-compression and fitted well the permanent offset of the experimental curve. Generally, they reasoned that both the three-point bending and tension-compression may be used to identify material parameters to your suggested. The authors used an optimization procedure based on iterative multipoint approximation to identify material parameters for isotropic and nonlinear kinematic hardening which would provide satisfactory agreement between the experimental and analytical moment-curvature outcomes for several cycles. Verification was performed by comparing the stress-strain curves derived from the cyclic tests with all the experimental curves obtained by tensile testing. They found that a good match supplied the material parameters for bending-unbending were based on experimental outcomes for over 1 cycle. In (Minh 2015) the authors used a four-point bending test to study cyclic loading and the least-square optimization to identify parameters for isotropic-nonlinear kinematic hardening of the Lemaitre-Chaboche equation. Materials used were 0.8 mm thick of aluminium alloy and low carbon steel. They indicated that it was enough to consider the very first cycle and monotonic loading to the material parameters of the constitutive equation to be established. Verification has been conducted. Figure 10 reveals the three-point bending evaluation utilized by (Ruszkiewicz, Grimm et al. 2017, Zajkani and Hajbarati 2017). Instead of using the moment-curvature connection, the tool provided a force-displacement chart for its cyclic study. 83 used the instrument to compare hardening legislation for cyclic loading together with the one derived from tension-compression test. Materials for the study were aluminium alloy 6022-T4, high-strength low-alloy steel (HSLA) and drawing-quality silicon-killed steel (DQSK). They discovered that the constitutive models obtained by fitting the reverse-bend evaluation and tension-compression test reveal substantial differences when evaluated in regard to their stress-strain responses after a pressure reversal and the nonlinear kinematic hardening law which has been unable to match the Bauschinger effect at strains larger than 0.02. (Stoudt, Levine et al. 2017) conducted finite element analysis of this cyclic bending with isotropic, nonlinear kinematic and joint corrosion for low carbon steel (SPCEN) and higher strength steel (SPRC). Combined hardening can demonstrate the predictable Bauschinger effect accurately. They utilized a genetic algorithm to identify parameters to the joint hardening. Continued with that work using a redesigned three-point bending instrument for high strength steels ZSte340 and DP600 and aluminium metal AA5182. Two parameters for each of the isotropic hardening and nonlinear kinematic hardening were identified by reducing the amount of square differences between experimental and finite element results using the response surface method of an advertising code.

## 5. CONCLUSIONS

Despite various attempts to boost sheet metal forming true spring back prediction and substance modelling, there remains works for advancement of understanding in this area was reasoned within this inspection functions. More precise constitutive laws describing substance behavior have to enhance the quality of the analytic and finite element simulation results in order they can better reflect the actual deformation procedure. Property information obtained in the uniaxial tensile-compression evaluation is no longer adequate. An effort to paper reviewed for the Baushinger result in experimental testing of sheet confronts a buckling problem and suffers from friction because of the side most aid. Cyclic bending test was able to create far better outcomes but they frequently refer to an perfect three-point bending instead of actual industrial bending procedures. This gap in the wisdom of plastic deformation demands further functions. Experimental identification of material parameters utilizing reverse method demands an efficient optimization strategy. To tackle the above-mentioned issues from the present study, a plain-strain pure bending instrument was created to do experiments on a choice of substances, with a view to identifying substance parameters such as constitutive equations for a variety of thicknesses. It's anticipated that this study will enhance the predictive capacity of sheet-metal forming professionals, so the throughput times can be lowered.

## REFERENCE

[1] Ab Karim, F. (2013). Experimental and Finite Element Evaluation of Bending for Galvanized Iron, UMP.

[2] Abdullah, A. B., M. S. Salit, Z. Samad, K. H. MTandoor and N. A. Aziz (2013). "Twist springback measurement of autonomous underwater vehicle propeller blade based on profile deviation." American Journal of Applied Sciences 10(5): 515.

[3] Ablat, M. A. and A. Qattawi (2017). "Numerical simulation of sheet metal forming: a review." The International Journal of Advanced Manufacturing Technology 89(1-4): 1235-1250.

[4] Abvabi, A., J. Mendiguren, B. F. Rolfe and M. Weiss (2014). "Springback investigation in roll forming of a V-section." Applied mechanics and materials 553: 643.

[5] Ahmed, G. S., H. Ahmed, M. V. Mohiuddin and S. M. S. Sajid (2014). "Experimental evaluation of springback in mild steel and its validation using LS-DYNA." Procedia Materials Science 6: 1376-1385.

[6] Barros, P. D., M. Oliveira, J. Alves and L. Menezes (2013). "Pre-strain effect on springback of 2D draw bending." International Journal of Materials Engineering Innovation 4(2): 187-211.

[7] Broggiato, G. B., F. Campana and E. Mancini (2013). "Computer-aided engineering for sheet metal forming: definition of a springback quality function." Engineering with Computers 29(3): 319-327.

[8] Chaudhari, S. S. and N. K. Patil "SPRING BACK PREDICTION OF SHEET METAL IN DEEP DRAWING PROCESS."

[9] [9] Chikalthankar, S., G. Belurkar and V. Nandedkar (2014). "Factors affecting on springback in sheet metal bending: a review." International Journal of Engineering and Advanced Technology (IJEAT) 3.

[10] Choi, M. K. and H. Huh (2014). "Effect of punch speed on amount of springback in U-bending process of auto-body steel sheets." Procedia Engineering 81: 963-968.

[11] Esener, E., M. Yenice and M. Firat (2015). A Stamping Die Design Procedure for Part Springback and Compensation. 8th International Conference and Exhibition on Design and Production of MACHINES and DIES/MOLDS, Pine Bay Holiday Resort, Kusadasi, Aydin, TURKEY.

[12] Gautam, V. and D. R. Kumar (2017). "Experimental and numerical investigations on springback in V-bending of tailor-welded blanks of interstitial free steel." Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture: 0954405416687146.

[13] Gupta, G. and V. Balasubramaniyan (2016). Estimation of Spring-Back of Single Torus Inner Vessel Sector by Finite Element Analysis. Applied Mechanics and Materials, Trans Tech Publ.

[14] Gupta, M. S. and D. R. Reddy (2017). "Design and analysis of aircraft sheet metal for spring back effect." Materials Today: Proceedings 4(8): 8287-8295.

[15] Hingole, R. S. "A Review Paper on FEA Application for Sheet Metal forming analysis."

[16] Khal, A., B. J. Ruszkiewicz and L. Mears (2016). Springback Evaluation of 304 Stainless Steel in an Electrically Assisted Air Bending Operation. ASME 2016 11th International Manufacturing Science and Engineering Conference, American Society of Mechanical Engineers.

[17] Kitayama, S. and H. Yoshioka (2014). "Springback reduction with control of punch speed and blank holder force via sequential approximate optimization with radial basis function network." International Journal of Mechanics and Materials in Design 10(2): 109-119.

[18] Lajarin, S. F. and P. V. Marcondes (2015). "Influence of process and tool parameters on springback of high-strength steels." Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture 229(2): 295-305.

[19] Leu, D.-K. and S.-H. Sheen (2013). "Roughening of free surface during sheet metal forming." Journal of Manufacturing Science and Engineering 135(2): 024502.

[20] Leu, D.-K. and Z.-W. Zhuang (2016). "Springback prediction of the vee bending process for high-strength steel sheets." Journal of Mechanical Science and Technology 30(3): 1077-1084.

[21] Ling, J., A. Abdullah and Z. Samad (2016). "Application of Taguchi method for predicting Springback in V-bending of aluminum alloy AA5052 strip."

[22] Lugnberg, M. and T. Netz (2016). Investigation of thermal spring back of a hot formed 22MnB5 A-pillar with tailored properties.

[23] Lunt, A. J. and A. M. Korsunsky (2015). "A review of micro-scale focused ion beam milling and digital image correlation analysis for residual stress evaluation and error estimation." Surface and Coatings Technology 283: 373-388.

[24] Maia, A., E. Ferreira, M. Oliveira, L. Menezes and A. Andrade-Campos (2017). Numerical optimization strategies for springback compensation in sheet metal forming. Computational Methods and Production Engineering, Elsevier: 51-82.

[25] Merklein, M., M. Johannes, M. Lechner and A. Kuppert (2014). "A review on tailored blanks—Production, applications and evaluation." Journal of Materials Processing Technology 214(2): 151-164.

[26] Narayanan, R. and U. Dixit (2015). Advances in Material Forming and Joining, Springer.

[27] Nguyen, V. D., P.-A. Adragna and P. Lafon (2013). Assessment of sensitivity of numerical simulation in sheet metal forming process applied for robust design. Smart Product Engineering, Springer: 493-503.

[28] Noma, N. and T. Kuwabara (2014). Material Modeling and Springback Analysis Considering Tension/Compression Asymmetry of Flow Stresses. Key Engineering Materials, Trans Tech Publ.

[29] Oya, T. and N. Naoyuki Doke (2013). Framework for springback compensation based on mechanical factor evaluation. AIP Conference Proceedings, AIP.

[30] Paithankar, S. A. and B. Varade "International Journal of Modern Trends in Engineering and Research."

[31] Pal, B. P. and D. R. Rao "ANALYTICAL AND EXPERIMENTAL EVALUATION OF SPRING BACK EFFECTS IN A TYPICAL COLD ROLLED SHEET."

[32] Ruszkiewicz, B. J., T. Grimm, I. Ragai, L. Mears and J. T. Roth (2017). "A Review of Electrically-Assisted Manufacturing with Emphasis on Modeling and Understanding of the Electroplastic Effect." Journal of Manufacturing Science and Engineering 139(11): 110801.

[33] Seo, K.-Y., J.-H. Kim, H.-S. Lee, J. H. Kim and B.-M. Kim (2017). "Effect of Constitutive Equations on Prediction Accuracy for Springback in Cold Stamping of TRIP1180."

[34] Singh, C. P. and G. Agnihotri (2015). "Study of deep drawing process parameters: a review." International Journal of Scientific and Research Publications 5(2): 1-15.

[35] SOLFRONK, P., J. SOBOTKA, M. KOLNEROVA and L. ZUZANEK "SPRING-BACK PREDICTION FOR STAMPINGS FROM THE THIN STAINLESS SHEETS."

[36] Song, F., H. Yang, H. Li, M. Zhan and G. Li (2013). "Springback prediction of thick-walled high-strength titanium tube bending." Chinese Journal of Aeronautics 26(5): 1336-1345.

[37] Stoudt, M. R., L. E. Levine and L. Ma (2017). "Designing a Uniaxial Tension/Compression Test for Springback Analysis in High-Strength Steel Sheets." Experimental mechanics 57(1): 155-163.

[38] Teng, F., W. Zhang, J. Liang and S. Gao (2015). "Springback prediction and optimization of variable stretch force trajectory in three-dimensional stretch bending process." Chinese Journal of Mechanical Engineering 28(6): 1132-1140.

[39] Toros, S. (2016). "Parameters Determination of Yoshida Uemori Model Through Optimization Process of Cyclic Tension-Compression Test and V-Bending Springback." Latin American Journal of Solids and Structures 13(10): 1893-1911.

[40] Wagoner, R. H., H. Lim and M.-G. Lee (2013). "Advanced issues in springback." International Journal of Plasticity 45: 3-20.

[41] Wang, Y., L.-h. Lang, S. Lauridsen and P. Kan (2017). "Springback analysis and strategy for multi-stage thin-walled parts with complex geometries." Journal of Central South University 24(7): 1582-1593.

[42] Xue, X., J. Liao, G. Vincze and J. Gracio (2015). "Modelling of mandrel rotary draw bending for accurate twist springback prediction of an asymmetric thin-walled tube." Journal of Materials Processing Technology 216: 405-417.

[43] Yenice, M., A. Karşı, E. Esener and M. Firat "An all in-computer engineered stamping tooling and process design procedure."

[44] Zajkani, A. and H. Hajbarati (2017). "Investigation of the variable elastic unloading modulus coupled with nonlinear kinematic hardening in springback measuring of advanced high-strength steel in U-shaped process." Journal of Manufacturing Processes 25: 391-401.

[45] Zang, S.-l., M.-g. Lee and J. H. Kim (2013). "Evaluating the significance of hardening behavior and unloading modulus under strain reversal in sheet springback prediction." International Journal of Mechanical Sciences 77: 194-204.