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Springback Prediction and Its Influencing Parameters - Review

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ABSTRACT

Most widely operation on the sheet metal is sheet metal Bending process. Occurrence of springback during the manufacturing of the bending products is seen most of the time. The deviation of the component part dimensions from its tool dimension after the forming process is known as the springback phenomenon. This sringback causes deviation of the dimension from the desired dimension causes rejection in the production. To reduce this rejection of the part and to make the part acceptable there is need to know the springback phenomenon for that part. To reduce or investigate the springback phenomenon the trial and error method is widely used in industrial practice. This trial and error is also known as geometrical compensation method & it required many trials causes increase in cost to develop the tool dimensions. Hence there is need to predict the springback effect for the component in tool design process. This paper is based on review of the various researches on the springback phenomenon its influencing parameters. In this paper the review of the previous researches on springback prediction and its influencing parameters is carried out. The research gap is concluded within the reviewed papers.

Keywords: Springback, Bend Angle, Sheet thickness, Regression analysis, FEA

I. INTRODUCTION

The springback is the phenomenon referred with the deviation of the part dimensions after the forming process from the desired or tool dimension. Most of the shapes and parts shows the deviation after the unloading of the blank component from the punch and die assembly. This deviation causes rejection of the part as its dimensions are not acceptable. Hence to reduce this springback phenomenon most of the time in industrial practice geometrical compensation method is widely used. In this geometrical compensation method the trial and error method is used to reduce the springback effect by compensating the dimensions of die and punch. This geometrical compensation method required many trials & it causes increase in cost and delay in the production process. Hence there is need to evaluate the springback effect in the design stage of the press tool. In this paper various researches on the springback of the material in forming process is studied and the conclusion is developed based on The research studies.

II. REVIEW AND DISCUSSION

Various researches had been carried out to evaluate springback by the researchers. In this paper the review of their researches are carried out. **C. C. Weng et.al (1990)** present an experimental investigation of the residual stresses in severely cold bent thick high-strength steel plates is presented. Tension residual stresses on the inside surface of the bend range from 46% to 92% of the yield stress of the material. A zigzag-type residual stress distribution pattern through the plate thickness was observed. The test results were then compared to the values predicted by equations proposed in 1980. The cold-bending behaviors of the thick steel plates were also studied and the results were presented in a companion paper[1] **Nan Song et.al. (2001)** presented study on the prediction of springback angle with focus on the straight flanging operation. The objective of this work was to evaluate the reliability of different methods of prediction. An experiment of straight flanging operation is conducted. Major prediction approaches such as analytical model, numerical simulation using the Finite Element Method (FEM) and the Mesh free Method using the Reproducing Kernel Particle Methods (RKPM) are discussed. The numerical analysis shows that the prediction from the

3D meshes free contact code matches with the data from the FEM 2D solid model. A material property described by the kinematic hardening law provides a better prediction of springback than the isotropic hardening law. This paper gives the conclusion as: Springback angle increases as the gap increases, the FEM with 2D solid elements and mesh free method have better springback predictions than the FEM using shell elements, It is evident that the kinematic hardening law has a better prediction than the isotropic hardening law[2]. **Thaweepat Buranathiti et.al. (2004)** presents an effective analytical model to predict springback for a straight flanging process. The model calculates the final springback angle by conducting bending moment computation, geometry and configuration calculation, and springback calculation. The predicted results are examined against our own experimental data and experimental results from independent papers. Sensitivity and trend analysis of springback are efficiently obtained[3]. **Jenn-Terng Gau et.al. (2005)** presented a new model for springback, based on isotropic and kinematic hardening models, the Mroz multiple surfaces model, and observations from experimental data, is proposed in this paper. In this model, a material parameter (CM), which is significant after reverse yielding, is suggested to handle the Bauschinger effect. A simple, low-cost, multiple bending experiments had been developed to determine CM for aluminum alloys AA6022-T4 and AA6111-T4. By observing the results of Mroz's method, it is also stabilized, but its result (springback prediction) is more accurate than that of the kinematic hardening model. The method proposed in this paper incorporates the capabilities of the isotropic and kinematic hardening models and the Mroz hardening model[4]. **Hyunok Kim et.al. (2007)** presented a new analytical model was developed to predict the bend allowance and springback in air bending. The new analytical model considers the material properties and realistic non-linear curvature of the bent sheet. The bend allowance results from BEND (Version 3.0) were compared to other analytical and experimental results found in literature and were accurate within 2%. The flat sheet length predictions from BEND were compared to experimental results and were accurate within 1.5%[5]. **Z. Cedric Xia et.al.(2007)** presents an in-depth experimental and numerical investigation of a split-ring test, which provides a simple yet effective benchmark for correlating forming and springback predictive capabilities with experimental measurements. The experimental procedure consists of deep drawing a circular 6111-T4 aluminum alloy into a cylindrical cup of 55 mm depth, crosscutting nine rings each of 5 mm wide from the cup, splitting the rings, and measuring their opening displacement. The study explained in paper extends previous investigations by cutting multiple rings from the cup wall. It demonstrates that current simulations are able to predict certain aspects of the forming processes fairly well, such as deformation profile, strain/thickness distributions, and total force required for forming[6]. **Myoung-Gyu Lee et.al. (2007)** presented a simplified numerical procedure to predict springback in a 2D draw bend test based on the hybrid method which superposes bending effects onto membrane solutions. As a semi-analytical method, the new approach was especially useful to analyze the effects of various process and material parameters on springback. The model can accommodate general anisotropic yield functions along with nonlinear isotropic-kinematic hardening under the plane strain condition. Regarding the effect of process parameters, springback decreases as the r / t ratio, constraining back force and friction between sheets and tools increase. As for the effect of material properties, springback increases as the Bauschinger effect decreases from pure isotropic hardening to pure kinematic hardening. The results showed reasonably good agreements with measured results although small deviation existed for large back force.[7] **J. Jeswiet et.al. (2008)** presented that the foregoing had reviewed selected metal forming processes that have been keynote subjects of CIRP STC F since 2000. Included in this review is new information, including updates, that have occurred since those keynotes were given. This paper can be viewed as a continuation of those keynotes. It may be seen that much remains to be done in all areas. Sheet forming at elevated temperatures (warm forming) and manufacturing with light-weight materials now are actively used in production processes. From this paper it can be predicted that environmental effects will become a major consideration, especially increased energy consumption in producing smaller many parts for one product.[8] **M.A. Osman et.al. (2010)** presented a theoretical model for air bending is developed and compared with published models. Experimental work on V-die bending is conducted. The experimental results were used in a correlation analysis to develop a mathematical expression for predicting springback ratio of V-die bending as a correction of the spring back ratio of air bending. These results are verified by comparisons with finite element simulations as well as with other independent sets of experiments. A theoretical model for air bending has been developed using true strain and neutral fiber position that satisfy continuity of the radial stress. This was found to compare it well with the published models. Experimental work on V-die bending of annealed steel has been conducted on specially designed die. The experimental results have been used in a correlation analysis to develop a semi-empirical formula for predicting spring-back ratio in V-die bending process, KV-die, as a correction of the theoretical spring back ratio of air bending, Kair[9]. **Mohammad Ali Farsi et.al.(2011)[10]** presented, the value of the spring-back and bending forces are investigated for a low carbon steel material. Two thicknesses of material (0.95 and 0.75 mm) are applied. Sheet metal components, which are used in the experiments, have oblong holes on their bending surfaces. The influence of the area of the holes, die angles, die widths and punch radius on the value of the spring-back and the bending forces in V-die bending is studied. It is found that all these parameters affect the spring-back and the bending forces, but not in the same way. The results of this study show that the components which have any kind of holes on the bending surfaces behave in a way which is different from the ones without holes. Using the experimental results of the current work, an empirical equation is arrived at. This equation predicts the bending forces with 1.35% average error compared to experimental results. **Tian-xiaZou et.al (2014)[11]** presented paper based on linear combined hardening constitutive model, the bending and springback of the arced thin plate with pre-strain by an analytical method. The tangential strain on the cross section of the arced thin plate during bending was analyzed, and then analytical formulas of material hardening in the circumstance of the positive and reverse loading were deduced. The accuracy of the analytical model was verified by FEM cases. In addition, it can be used to predict the springback of UOE forming processes in welded pipe production.[11] **Zhi Fang et.al (2014)[12]** present that in micro-level, materials cannot be considered as homogeneous owing to the limited quantities grain involved in work piece. The property of each grain will perform its role in the deformation process, especially the grains in deformed region. So it is essential to adopt grained heterogeneity. The V-bending FE simulation result can display the inhomogeneous deformation during micro V-bending process, and it also shows that springback increases with grain size. **Komgrit Lawanwomg et.al.(2014)[13]** presented a new technology to eliminate U-bending springback by applying bottom pushing-up with a counter punch. The reduction of springback in the present process is attributed to the negative bending moment generated at the bent-corner part of the sheet, which is the driving force of 'spring-go'. It was verified from experiments on 980Y HSS sheet and the corresponding numerical simulations. In the process of bottom pushing-up without clamping force, springback angle can be reduced to zero, but the geometrical imperfections will appear at the bottom part and the bent corner, i.e. the bottom is not flat enough and the corner radius is too large. **Min Kuk Choi et.al (2014)[14]** present the effect of punch speed on the springback behavior of SPCC and DP780 steel sheets by conducting U-bending tests and numerical analysis. U-bending tests of SPCC and DP780 steel sheets with various punch speeds were conducted and springback parameters of the blank after U-bending test were measured. The simulation results well predicted the test results. Tangential stress distribution in the blank was investigated to find out different springback behavior of SPCC and DP780 with various punch speeds. For SPCC, negative strain rate sensitivity of springback behavior is because there's smaller difference of tangential stress between top and bottom layer at the sidewall region due to the inertia effect. For DP780, positive strain rate sensitivity of springback behavior is due to strain rate hardening. **Miklós Tisza et.al. (2014)[15]** presented experimental and numerical investigation of large strain cyclic plastic deformation is introduced from the point of view of springback behavior of high strength dual phase steels. On the basis of theoretical considerations of large strain cyclic deformation, it was concluded that the increased springback behavior of the tested high strength steels is strongly affected by the Bauschinger effect. From the numerical simulations it was concluded that the effect of the σ and K parameters is more significant than that of the γ parameter, so it is important to use in industrial simulations the measured χ and K values. **Tianjiao Liu et.al. (2014)[16]** Presented Al-Li alloys extrusions improve the performance of advanced aircraft due to their low density and high stiffness. In order to determine whether 2196-T8511 and 2099-T83 Al-Li alloys extrusions with high ultimate tensile strength/Young's modulus ratios, also exhibit significant elastic recovery, the springback behaviors of the two Al-Li alloys extrusions under displacement controlled cold stretch bending are addressed, using the simple plasticity deformation theory, the explicit/implicit FEM and the physical experiments. The analytical solution and finite element simulation were effective means to assess the impact of material and process parameters on springback in stretch bending. **Oxgusenel et.al.(2014)[17]** presented bending parameters and springback phenomenon of a stainless-steel sheet in air bending process. In most of the applications, springback is determined either by trial and error procedures or by using numerical methods. Artificial Neural Network (ANN) approach had proved to be a helpful tool for the engineers. ANN was used in this study to predict the springback amounts of stainless steel sheets through experiment based networks. Air bending process was first modeled and analyzed by a commercial finite element code. it is seen that Artificial Neural Network algorithm proves to be a useful tool to determine the springback amounts in air bending processes correctly and quickly. Also, different ending operations such as angular bending, hemming, U-bending may be analyzed through FEA and experimentation, and ANNs based on FEA or experimentation may be utilized to analyze more complicated bending operations consisting of several bent-up regions. **Vitalii Vorkov et.al. (2014)[18]** presented the springback analysis of different types of high-strength steels (Weldox 1100 and Weldox 1300) has been studied using finite element modeling. The two standard types of finite elements had been used: shell and solid elements. All calculations have been implemented in commercial finite element software, Abaqus. The model for precise springback prediction has been implemented and the accuracy in function of the number of elements through the thickness - had been analyzed. The isotropic hardening model was suitable for Weldox 1100 and Weldox 1300 for the considered task, but for more advanced bending processes, e.g. with bumping, a more sophisticated hardening mechanism, including kinematic hardening, should be used. **Qiu Zheng et.al. (2014)[19]** Presented the micro bending process, thinner foils may indicate larger springback due to the size effect of strain gradient. Heat-assisted micro bending is an effective process to reduce the springback and improve the accuracy of the products. In order to investigate the mechanism of springback behavior of pure titanium foils under elevated temperature, experimental and numerical analysis were carried out for different thickness foils (0.02, 0.05, and 0.1 mm) with the same hardness. **James A. Polyblank et.al. (2014)[20]** Presented Flexible spinning with three internal support rollers can allow the economic production of very low-volume or one-off prototypes by removing the need for a mandrel. This paper demonstrates the use of a laser scanner to monitor the current work piece, position the internal rollers correctly, and compensate for springback. In addition, the online measurements may be used for failure mode detection and compensation. **Gawade Sharad et.al. (2014)[21]** Presented all the forming processes are more or less prone to the springback depending upon different material properties and process parameters. Bending processes are very widely used in the manufacturing of sheet metal products, particularly in automobile industry. In the present paper the springback is predicted by using finite element analysis, for various die radii, sheet thicknesses, R/t ratios and strength coefficients, for two different materials. Springback predicted by neural network prediction model is found in good agreement with springback obtained by FE simulation. In **N. Schaal et.al (2015)[22]** paper shows that springback is generally referred to as the change of part shape that occurs upon removal of constraints after forming. In cutting this also occurs but on a much smaller level. Experiments done at IWF of ETH Zurich provide results with cutting speeds from Vc =10 to 450 m/min for Aluminum and Titanium. A cutting speed dependency is shown. The data given in paper can help to improve simulation results of cutting processes and to understand the importance of elastic-plastic effects of materials. Furthermore this can help to find cutting conditions for Titanium cutting where flank wear and high passive forces can be reduced to a minimum. **Paul S. Nebosky et.al. (2011)[23]** Presented the elastic recovery (springback) of porous tantalum foam after sheet forming operations. The foam and sheet-like form was applicable to bone in growth surfaces on orthopedic implants and is desirable due to its combination of high strength, low relative density, and excellent osteo conductive properties. The finite element models described in paper were developed for Trabecular Metal, they can be applied to other open-cell metal foams. By altering the material properties and adjusting the aspect ratio to reflect the cell morphology of the foam being studied, these simulations should provide reasonable springback estimations. **Peng Chen et.al. (2008)[24]** Presented study of investigate and gain an understanding of the variation of springback in the forming of HSSs. Two sets of experiments were conducted to analyze the influence of the material property lubrication, and blank holder pressure on the springback variation. The experimental results showed that the variation in the incoming blank material was the most important factor. This paper results shows other factors that might affect the springback and springback variation are related to the tooling such as die clearance, tool surface, etc.; their significance on springback variation should be also quantified to see if they can be used to minimize the springback variation, which will be the future work of this study. **Qiongyao Peng et.al. (2015)[25]** Presented experiments and simulations to analyze the effects of processing and material parameters on springback of a specified LSS for the purpose of process optimization. Various tests including lap-shear, normal tensile, and viscosity analysis were carried out to obtain the mechanical behavior of the polymer layer. From The conclusion of this paper it is seen that, for the 88 deg bending deformation and springback of LSS, based on the given material and processing parameters, galvanized steel sheet with initial yield stress of 270–320 Mpa and with thickness of 1.2 mm, stainless steel sheet with initial yield stress of 313 Mpa, and punch with fillet radius of 0.6mm would be the best combination to control the springback within an acceptable range.[25]

III. DISCUSSION ON RESEARCH WORK

In the above research work the tabulated form of the above research is classified as in terms of parameters on which the work is done, Material Specification, thickness consider to calculate the springback, bending angle, its bending type –forming type, and year of research. The research work is seems varies as the change in the part dimensions, its material and its conclusion. This paper is based on the review of the pre-existing researches based on or containing the parameters affecting springback effect and the various methods to predict the springback angle for that particular component. Table I gives the tabulated form of the comparison of the various researches on the springback phenomenon which includes the springback prediction methodology, blank material specification, component thickness, and its bend type and bend angle.

Table 1. Summary of Research Work On Springback Prediction

Sr. No	Model to calculate Springback for	Material	t mm	Angle (deg.)	Bend Type	Year
1	Residual Stress in thick HSS plate	HY-80, HY-100	25.4, 38.1	90, 120, 150	V Bend	1990
2	Flanging	AA5182-O	1		Flange	2001
3	Straight Flanging Process	HS110, ADQ, SAE980, M.S.	0.79, 2.37, 1.55	90	Flange	2004
4	Aluminium Sheet	AA6022-T4, AA611-T4	1, 0.92	0, 45, 90	Flange	2005
5	Air Bending	AKDQ Steel, HSS	6.37, 12.7	-	Flange	2007
6	Split ring test	6111-T4 Al alloy	0.925	-	Flange	2007
7	2D Draw Bend Test	DP Steel 6022-T4	1	-	Flange	2007
8	Metal Forming Process	-	-	-	U,V	2008
9	V- Bending	Annealed Steel	0.715 , 2.5	-	V	2010
10	Perforated sheet Bending	Low Carbon Steel	0.95, 0.75	90, 120, 135	V	2011
11	Pre-strained arched thin plate	X70	20	-	C, U, O	2014
12	Micro V bend of size 98μm,152μm, 201μm	-	-	-	V	2014
13	Additional bending counter punch	HSS	1.22	-	U	2014
14	Effect of punch speed on springback	SPC, DP780	1	-	U	2014
15	High Strength Duel phase steel	DP600, DP800, DP1000	1	-	Uni axial tens.-comp.	2014
16	Extruded alloy stretch bend in Z &T section	2198-T8511, 2099-T83 Al-Li alloy	-	76	-	2014
17	Artificial neutral network	-	1, 1.5	93.6, 101.4, 121	-	2014
18	HSS for long radius	Weldox 1100& 1300	4.15, 4.1	91	V	2014
19	Temp. Change in Micro bending	Ti	1,0.02, 0.05	-	U	2014
20	Support roller control in flexible spinning	Al grade 1050A-H14	2	-	U	2014

21	U bend & NNA	IS513D, DP600-HDG	1,1.5, 0.8	-	U	2014
22	Metal cutting in High cutting speed	-	-	-	-	2014
23	Porous Tantalum Steel	Porous Tantalum Steel	1.5	-	U	2015
24	Forming of HSS	DP600	1.5, 1.2,1	10	U bend with Flange	2015
25	Laminated sheet	LSS: Galvanized Steel + SS+ Adhesive	0.9, 1.2	90	V	2015

IV. CONCLUSION

From the above mentioned papers it is seen that there is need to evaluate the springback in design process to eliminate the rejection cost. From the above papers it is clear that there is need to develop the springback prediction model for the bending process. Following are some conclusions are made based on the review of the above researches:

- It is seen from the methodology and conclusions from this research paper that no one is produced the analytical model of springback based on the experimental data and the relationship of thickness and bend angle.
- The research gap can be found as need of the model which develops the punch and die angle which compensates the springback angle in the component.
- From the above research papers one can define that thickness of the sheet metal is majorly affects on the springback angle, hence there is need to study the factor affects by change in thickness. On the basis of this conclusion this project is based on the formation of the analytical mythology and DOE Where, the main two parameters are selected and they are namely thickness‘t’, and Bend Angle ‘θ’.

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