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Investigation on Effects of Roll Forming Parameters on Quality of Final Roll Formed Product

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Abstract: Roll forming which is also spelled as roll-forming or roll forming, is a type of rolling that involves the continuous bending of a long strip of sheet of metal (usually coiled steel) into a desired cross-section. The strip is passed through the sets of rolls that are mounted on consecutive stands, each set performing only an incremental part of the bend until the desired cross-section (profile) is obtained. Roll forming process is ideal for producing constant profile parts with long lengths and in large amount. This paper tried to summarize the study of roll forming for different design parameters and its result.

Keywords: Roll Forming, Longitudinal-Residual Strain, Line Velocity, Bow Defect.

I. INTRODUCTION

Roll forming is one of reliable and proven approach for metal shaping that is ideal for modern applications. This process uses a continuous bending operation in which long metal strips, typically coiled steel, are passed through consecutive sets of rolls at room temperature. Every set of rolls performs incremental parts of the bend to produce the desired cross-section profile. Figure 1 showing schematic diagram of 5 stage roll forming process.

Figure 1. Roll forming process

High-volume capacity, Ultra-precise processing to very tight tolerances with excellent part uniformity and superior surface finishes, more flexible and responsive than press braking or extrusion are some advantages of roll forming.

II. METHODS

B. S. Bidabadi, H. M. Naeini, R. A. Tafti, and H. Barghikar [1] studied on bowing defect in pre-notched channel section products in the cold roll forming process. They used 3 steps experimental test in that cut strips from sheet and punched, strips were formed in the roll forming setup and photograph were taken by using 12-megapixel resolution camera to determine the bowing. Six pairs of rollers with seven stands were prepared for the experimental tests. Vision Assistant 8.5 software is used to determine the radius of the tangential arc of the product web. They concluded, longitudinal strain occurs in the flange and web of a channel with greater this difference causes greater bowing. Bowing defects occur more in pre-notched as compared to non-notched products. They concluded different parameters effect on bow defect as shown in below table 1:

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TABLE I. EFFECTS OF ROLL FORMING PARAMETERS [1]

Sr. No.	Roll forming design parameters	Effect on bow defect
1	Web width –Reduce	Increase bowing
2	Hole distance to thickness ratio- Increases	Increase bowing
3	Increasing number of holes would increase the edge buckling	Reduce bowing
4	Strip thickness- Increase	Increase bowing
5	Maximum Longitudinal Strain- Increase	Increase bowing
6	Increasing distance between the holes and strip edge at a given thickness	Decrease bowing
7	A fixed flange width as the hole diameter – Increases	Increase bowing
8	Horizontal distance between forming stands – Increase	Reduce bowing
9	Number of forming stands – Increase	Decrease bowing
10	Effect of uphill and downhill strategies	Downhill case bowing is less than uphill case.
11	Effect of lubrication	It reduces bowing.

B. S. Bidabadi, H. M. Naeini, and R. A. Tafti [2] studied torque in the cold roll forming of symmetrical channel sections by experimental test and numerical method. They used product as a symmetrical channel section with a 60^{0} angle which is made of hot-rolled steel. Three steps experimental tests were performed. In that, first, the required sample size was determined and cut from a sheet with the suitable thickness. Then in the second step, cold roll forming setup was adjusted. Final setup, they conducted and used a dynamic torque sensor (model HX-90D from Hua Hin Electrical Co.) with a capacity of 350 Nm for torque measurement. Setup consists of five-stands with four rollers. They used ABAQUS/Explicit 6.14 finite element software. The Finite Element Method was used. To investigate the effects of transverse strains in the bend zone Micro structural and circle grid analysis were used. To determine how the roll forming process can affect the strain distribution both micro-structurally and micro-structurally in the experimental tests. They concluded different parameters effect on torque as shown in below table 2:

TABLE II. EFFECTS OF ROLL FORMING PARAMETERS [2]

Sr. No.	Roll forming design parameters	Effect on Torque
1	The fold angle increment –Increases	Increase Torque
2	Channel flange width- Increase	Increase Torque
3	Strip Thickness –Increase	Increase Torque
4	Distance between forming stands –Reduced/Decrease	Increase Torque
5	The channel corner radius	Negligible effect on torque (can be Ignored)

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R. Safdarian , H. M. Naeini [3] studied the effect of forming parameters on the cold roll forming of channel section. They selected Steel sheets of St.14 material. In numerical investigation they used the Finite Element Method. Abaqus / Explicit 6.10 software were used. Model consists of two forming stands, a strip and four rolls. For an experimental test, they used one stand of cold roll forming mill. The Coordinate Measuring Machine (CMM) was used to measure bow defect. To calculate coordinates, Solid Works Software was used. They resulted in bow defect increases with bending angle or roll angle increasing. They concluded different parameters effect on longitudinal strain as shown in below table 3:

TABLE III. EFFECTS OF ROLL FORMING PARAMETERS [3]

Sr. No.	Roll forming design parameters	Effect on longitudinal, residual strain
1	Bending angle – Increase	Increase Longitudinal Strain.
2	Flange width – Increase	Decrease Longitudinal Strain
3	Strip Thickness – Increase	Increase Longitudinal Strain.
		Decrease Residual Strain after the roll stand
4	Distance between the roll stand –Increase	Reduce Longitudinal and Residual strain
5	Forming speed	No influence on longitudinal strain
6	Coefficient of friction	No influence on longitudinal strain

W. Wang, Y. Zhao, Z. Wang, M.Hua, and X. Wei [4] studied a variable friction model in sheet metal forming with advanced high strength steels. They selected a DP780 AHSS sheet for tested material and to make the friction tool, a cold-worked DC53 steel tool was used. Electric Discharge Machine (EDM) was used for cutting the rectangular sheet with rounded corners. Friction and Wear tests were performed at room temperature 298K. After testing different pressures were achieved in the interface between the work piece and tool. Friction coefficient was higher and another progression of test resulted in the contacting surfaces becoming smoother, dropping off friction coefficients. In the spring back test, the U-shape BUT test was used. They used Coulomb's law of friction occurring between the contact surfaces. They used two models i.e. Model 1 and Model 2. They used a PIN-ON-DISK test. They concluded the coefficient of friction decreases with normal contact pressure increases. Results of two models differ in distribution of friction shear stress, principal stress and contact pressure. Comparison of model 1 and Model 2 shows a significant improvement of prediction accuracy with the use of pressure-dependent variable friction model 1 and for that U-shape bending test under tension was used. They predicted the spring back angle was incorrect when compared with experimental datum.
S. Ghanei, B. Abeyrathna, B. Rolfe, and M. Weiss [5] studied analysis of material behavior and shape defect compensation in the flexible roll forming of advanced high strength steel. They used Flexible Roll Forming (FRF) trials using Deakin's Flexible Forming Facility (DFFF). They selected material as two dual-phase steels (DP600 and DP1000). They used software as COPRA@ FEA RF 2017 to stimulate the FRF process. They concluded wrinkles can be reduced, implementing a black holder concept. Forming behavior in the conventional FRF is similar to that which observed in DFFF. An accurate Finite Element Model capable of predicting forming strain as well as wrinkling in FRF has been developed.
J. Paralikas, K. Salonitis, and G. Chryssolouris [6] worked on a roll forming process experimental modeling of a symmetrical U-section profile. They used material AHSS DP600-HDG. They studied the major roll forming factors such as line velocity, roll gap, inner distance between roll stations, and diameter of the rolls. They considered optimum values for analysis of major roll forming factors or process parameters. ANOM method was used for analysis. They used ANSYS and LS-DYNA soft wares. They concluded longitudinal strains and shear strains reduced up to 20-35% and 30-50% respectively.
J. Paralikas, K. Salonitis, and G. Chryssolouris [7] studied on the effects of main roll-forming process parameters such as roll forming line velocity, rolls inter-distance, rolls gap and rolls diameter on a quality for a symmetrical V-section profile as final product. They used AHSS material. They used two different element types. For the rigid rolls, SHELL163 elements were used and eight-node brick element SOLID164 was used for the deformable strip. They chose

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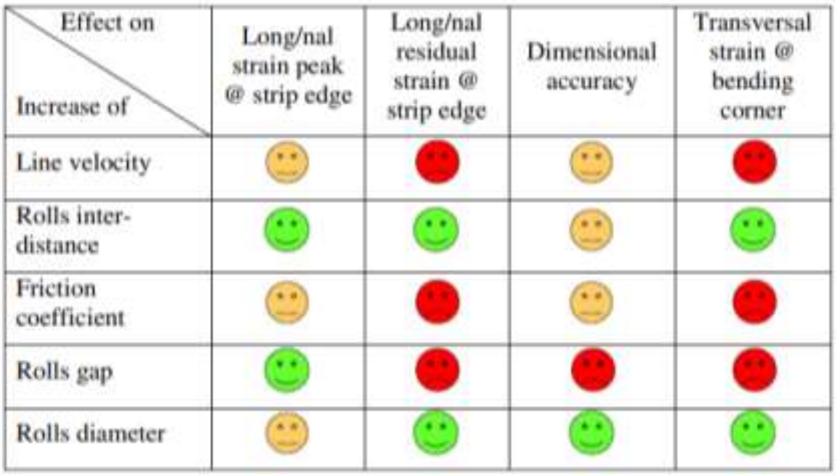
isotropic hardening model for the material model. They used Finite Element (FE) method. They concluded effect of roll forming parameters on longitudinal and residual strain as below 7:

TABLE IV. EFFECTS OF ROLL FORMING PARAMETERS [7]



Effect on / Increase of	Long/nal strain peak @ strip edge	Long/nal residual strain @ strip edge	Dimensional accuracy	Transversal strain @ bending corner
Line velocity	🟡	🔴	🟡	🔴
Rolls inter-distance	🟢	🟢	🟡	🟢
Friction coefficient	🟡	🔴	🟡	🔴
Rolls gap	🟢	🔴	🔴	🔴
Rolls diameter	🟡	🟢	🟢	🟢

E. Billur, M. S. and Dr-Ing T. Altan [8] studied the challenges in roll forming Advanced High Strength Steels (AHSS). They used materials Dual Phase (DP) and Transformation-Induced Plasticity (TRIP). They tested these materials under stretching, bending, deep drawing, stretch bending and flanging. All these are stress and strain states. They summarized to overcome the challenges like press loads, spring back, tribological conditions and determination of formability.

M. Jurkovic, Z. Jurkovic, S. Bulijan, and M. Obad [9] studied an experimental and modeling approach for improving utilization rate of the cold roll forming production line. They used materials such as steel sheet DX 51D (DIN 17162-1, EN 10327), steel sheet DX 53D (DIN 17162-1, EN 10327) and Aluminum sheet Al 99.5 (EN 1050). For measuring rollers load they used measurement device such as force transducer with strain gauges, multi-channel measuring amplifier HBM-Quantum (MX840A), multi-channel measuring amplifier HBM-SPIDER8 (8xSR55) and data acquisition software. For measuring the roll stand deflection measurement device strain gauges were used. They resulted 30% higher productivity achieved, a sheet thickness of 1.40mm was used instead of 0.70% and from 20% to 75% increased utilization of the installed energy.

Abvabi, B. Rolfe, P. D. Hodgson, and M. Weiss [10] studied the effect of residual stress on a roll forming process. The material DP780 steel was used in this study. They performed Standard Tensile Test to obtain the material properties of the stress. They used COPRA-RF software. They used V-section profile. MSC-Marc software was used for numerical set-up. They resulted longitudinal residual stress increase with increase end flare. Thickness reduction rolling process decreases the maximum bow height, spring back angle increases and end flare also increases.

III. CONCLUSIONS

Roll forming process parameters play important roll in roll forming design. Different FEA softwares like ANSYS, ABAQUS, LS-DYNA and COPRA-RF are used for the numerical stimulation of the roll forming process. AHSS offer benefits for roll forming and safety. Distance between the roll stands, thickness, line velocity, longitudinal strain, residual strain, spring back are important factors in roll forming design. Table 5. Shows effect of different roll forming parameters on bow defect, longitudinal strain, residual strain, torque, spring back, end flare.

TABLE V. EFFECT OF DIFFERENT ROLL FORMING PARAMETERS

Sr. No.	Roll forming design parameters	Effect on bow defect, longitudinal strain, torque, residual strain, velocity, end flare, spring back
1	Web width –Reduce	Increase bowing
2	Hole distance to thickness ratio- Increases	Increase bowing
3	Increasing number of holes would increase the edge buckling	Reduce bowing
4	Strip thickness- Increase	Increase bowing
5	Maximum Longitudinal Strain- Increase	Increase bowing

6	Increasing distance between the holes and strip edge at a given thickness	Decrease bowing
7	A fixed flange width as the hole diameter – Increases	Increase bowing
8	Horizontal distance between forming stands – Increase	Reduce bowing
9	Number of forming stands – Increase	Decrease bowing
10	Effect of uphill and downhill strategies	Downhill case bowing is less than uphill case.
11	Effect of lubrication	It reduces bowing.
12	Bending angle – Increase	Increase Longitudinal Strain.
13	Flange width – Increase	Decrease Longitudinal Strain
14	Strip Thickness – Increase	Increase Longitudinal Strain.
		Decrease Residual Strain after the roll stand
15	Distance between the roll stand –Increase	Reduce Longitudinal and Residual strain
16	Forming speed	No influence on longitudinal strain
17	Coefficient of friction	No influence on longitudinal strain
18	The fold angle increment –Increases	Increase Torque
19	Channel flange width- Increase	Increase Torque
20	Strip Thickness –Increase	Increase Torque
21	Distance between forming stands –Reduced/Decrease	Increase Torque
22	The channel corner radius	Negligible effect on torque (can be Ignored)
23	Thickness –Increase	Velocity/Speed –Reduce.
24	Longitudinal residual stress –Increase	Increase End flare
25	Thickness – Reduce	Decrease - maximum bow height
26	Thickness – Reduce	Increase Spring back angle
27	Thickness – Reduce	Increase End flare

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